A HANDBOOK ON

OCCUPATIONAL HEALTH PRACTICE
IN THE SOUTH AFRICAN MINING INDUSTRY

Editors
R. Guild, R.I. Ehrlich, J.R. Johnston, M.H. Ross

The Safety in Mines Research Advisory Committee (SIMRAC)
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FOREWORD

The publication of this book could not have been more appropriately timed. Within the last month, the Mine Health and Safety Council approved a raft of occupational hygiene regulations and guidelines that will shortly be presented to the Minister of Minerals and Energy for promulgation. These regulations and guidelines concern occupational hygiene practice, reporting of workplace exposures, respiratory protective equipment, airborne pollutants, thermal stress and noise. They are the mining equivalents of the hazardous chemical substances and other occupational hygiene related regulations under the Occupational Health and Safety Act of 1993 (OHSA), and they complete the regulatory framework for safeguarding the health of workers employed in South African mines.

The road leading to this point has been long and arduous, fraught with tension and struggle, and the deaths and disability of too many miners. Although the link between exposure in mines and occupational disease has been well documented for over a century, until recently little was done to appropriately quantify and control such exposures. Average dust levels have inappropriately served as a proxy for personal exposure. Airborne substances, other than silica and asbestos, have received scant attention and have been erroneously dismissed as “nuisance dust”. Legislative changes, starting with the OHSA and Compensation for Occupational and Injury Diseases Act of 1993, marked the start of a new era in which occupational health and the work environment are explicitly addressed in law. The Commission of Enquiry into Occupational Health and Safety in the Mining Industry, which sat in 1994, and the promulgation of the Mine Health and Safety Act of 1996 achieved the same for the mining sector.

Today, the owners and operators of many factories and mines recognise that productive work environments are safe and free from health hazards. South African chemical and mining companies that compete in the global market have recognised that high standards of health and safety are vital for staying in business. Nonetheless, available occupational injury and disease data illustrate that South African workplaces are far from ideal. Much more must be done to protect the health and safety of workers as well as communities exposed to hazards emanating from workplaces. In the mining sector, despite gaps in data, it is widely accepted that the burden of occupational diseases on workers and their communities is now greater than occupational injuries. This assessment is astounding given that the rate and severity of injuries in our mines are unacceptably high.

I have no doubt that this book responds to a need for guidance on breaking with the past. While our historic preoccupations with the recognition of occupational disease and the compensation of workers have value in their own right, we must focus on prevention.

Fine minds, engaged at the cutting edges of the legal, occupational medicine and occupational hygiene professions, have edited and written the various chapters of this book. All have applied themselves to setting out, in a practical format, fundamental and best practice. The book cuts a broad swathe through governance, management and auditing, hazard identification and risk assessment, to specific topics such as air pollutants, lung disease, noise, vibration and heat. It exemplifies what the Safety in Mines Research Advisory Committee has to offer to the industry. It is my hope that the wealth of experience captured here will serve as an up-to-date resource for managers and practitioners charged with giving effect to our legislation.

May Hermanus
Chief Inspector of Mines

October 2001
THE EDITORS

Dr R Guild
Occupational Health and Safety Consultant
Haggis Guild is Managing Director of Advantage Consulting in Johannesburg. The company provides occupational health services to mining and chemical organisations that encompass corporate governance, strategic planning, policy development, health risk assessment and management, information systems and data analysis, quality improvement and related areas. Dr Guild originally qualified as a medical practitioner and then earned postgraduate degrees in occupational health (DOH) and business (M.B.A.) from the University of Witwatersrand. He has 20 years experience of health, safety and environmental management within the mining and minerals industry of which 15 years have been in senior management positions, including 10 years in the corporate environment.

Prof. R.I. Ehrlich
Specialist in Public Health Medicine and Occupational Health
Rodney Ehrlich is currently Associate Professor in the Department of Public Health and Primary Health Care, University of Cape Town. He is also Adjunct Associate Professor in the Department of Community and Preventive Medicine, Mount Sinai School of Medicine, New York. He has training in economics, medicine, epidemiology and occupational health. He has extensive experience in treating occupational disease, including occupational lung disease in ex-miners, and in conducting medical surveillance of workers exposed to workplace hazards. He has served as advisor to the Ministers of Health and Labour on occupational health and has contributed to policy and legislation in the areas of hazardous substances and occupational health services. His recent research activities have covered lung function testing in the mining industry, pneumoconiosis in gold miners, the compensation system for occupational disease and the impact of tuberculosis on HIV/AIDS.

Dr. J.R. Johnston
Physicist and Occupational Hygienist
John Johnston is a physicist by profession and received his doctorate while working at the Institute of Occupational Medicine and Royal Infirmary in Edinburgh, Scotland. He has spent 26 years in South Africa in a variety of management, safety, occupational hygiene and environmental roles and was privileged to become the first Fellow of the Southern African Institute of Occupational Hygiene. He is currently employed by Anglo American Platinum Corporation Ltd. as the Group Safety, Health and Environmental Manager.

Prof. M.H. Ross
Specialist in Public Health Medicine and Occupational Health
Mary Ross is currently Occupational Health Programme Manager for SIMRAC and Honorary Associate Professor in the School of Public Health, University of the Witwatersrand. She is also Deputy Regional Advisor for the Faculty of Occupational Medicine, UK. She has postgraduate training in health service management, epidemiology, tropical diseases and occupational health. She has extensive practical and research experience in community and occupational health at a central, provincial and local government level plus independent consultancy. This has included establishing and managing occupational health services; providing occupational health advisory services for expatriate miners; research on silicosis in the refractory industry; audit of tuberculosis services in the mining industry; and developing a training manual on the COID Act for medical practitioners.
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This handbook springs from a renewed concern with occupational disease in the South African mining industry. Although the heavy burden of occupational disease, particularly lung disease in gold mining, has been known and described by medical observers, researchers and government commissions since the late 19th century, the lack of progress in reducing this burden has required fresh political attention at the beginning of the 21st century.

While sudden injury or death remains the most feared consequence of mining operations in general, it is sobering to note that annual certifications for pneumoconiosis plus new cases of tuberculosis in gold miners exceed the annual number of injuries reported in this population. It has long been understood that silica inhalation and silicosis greatly increase the risk of tuberculosis in miners. The HIV epidemic has added a deadly ingredient by further increasing the risk of tuberculosis in HIV positive miners. Death while on treatment for tuberculosis, from the disease itself or from other HIV related infection, is now the most common cause of mortality among active gold miners and exceeds the death rate from accidents.

The mining industry, which includes underground and surface ore extraction, smelting and refining, remains a pillar of the South African economy. Although the numbers employed in the South African mining industry have shrunk over the past twenty years, the industry is still a major employer, with just under 400 000 people in service in the year 2000. Owing to the chronic and irreversible nature of the major mining related diseases, particularly lung disease and hearing loss, the burden of past practices is carried for life by large numbers of miners and ex-miners throughout the subcontinent.

The re-engagement with occupational disease in the mining industry has been marked by two major events. The first was the publication in 1995 of the Report of the Commission of Enquiry into Occupational Health and Safety in the Mining Industry, known as the Leon Commission. After hearing evidence from representatives of employers, employees and the state, the Commissioners concluded that self-regulation of occupational health and safety in the mining industry had failed. Further, there was no reason to believe that the environment in the mines had improved since the 1950s.

The second event was the promulgation in 1996 of the Mine Health and Safety Act (Act 29 of 1996). This legislation sought to modernise occupational health and safety practice in the mining industry, and introduced a number of notable innovations. Among these is the duty of employers to produce a health and safety policy and to undertake a risk assessment of all hazards in their operations. Employers are required to produce an annual medical report as a public statement of the state of health of the mine’s employees. Employees have to be informed of the hazards of their work and, through the mechanism of health and safety representatives and committees, consulted on all aspects of the implementation of health and safety policy. Employees also have the right to refuse to work in conditions they consider dangerous.

This new legislative framework has placed extra demands on mining managers responsible for health and safety, and on the professionals, including environmental engineers, occupational hygienists, medical practitioners and nurses, who carry out the tasks of measuring the environment, controlling health hazards and examining and counselling employees. There is also a climate of heightened expectation among employees and their representatives that the new legislation will lead to a demonstrable improvement in mining health and safety and a decline in the toll of work-related disability and disease.

This handbook has been produced in an effort to assist the parties responsible for occupational health in the South African mining industry to meet these challenges. The book seeks to lay out best practice in the control and mitigation of the main health hazards faced in the industry. The handbook is published, under the guidance of independent editors, by the Safety in Mines Research Advisory Committee (SIMRAC), a statutory body charged with improving health and safety in the mining industry through research.
As editors of this handbook we have pursued an ambitious undertaking. Our aim is to reach a wider audience than the typical discipline based occupational health textbook. Our intended readers include not only medical and nursing practitioners and occupational hygienists, but also managers, engineers, union representatives and government officials. Trainees and students will also find the book of value in preparing them for the above roles.

Another ambitious aim of the handbook is to try to encourage the shifts in thinking and practice that are needed if we are to make progress in lessening the burden of occupational disease in the industry. An example of such a shift is a move from a reactive management system based on incident investigation to one based on exposure measurement and control and the prevention of occupational disease. Such a development has to be reflected in the policies that are written, the risk assessments that are performed, the information that is reported and ultimately in the investments that are made in control measures. This preventive approach needs to supersede reliance on the compensation of workers once they have developed disease. New attitudes are required, within a potentially volatile industrial relations arena, to be able to manage employee participation as required by the Mine Health and Safety Act. Operational managers and health and safety representatives need to know how occupational diseases occur and what can be done to prevent them. Finally, all parties have to recognize the ethical requirements of occupational health practice, particularly as they pertain to medical and nursing practitioners in their relationships with employers and employees.

The first three chapters of this handbook provide a framework for the management of occupational health in mining and related operations. Chapter 1 summarises the legal setting for the practice of occupational health in the mining industry. The emphasis is on the Mine Health and Safety Act, but the additional important subjects of ethical medical practice and HIV testing are addressed. Chapter 2 describes the elements of a management system needed to give effect to the legislation and to meet the needs of various stakeholders. Chapter 3 is a guide to the performance of risk assessment directed at disease control rather than traditional safety objectives.

The major mining related hazards of airborne pollutants and lung disease, noise and vibration and heat are accorded primary attention in chapters 4 through 8. Ionising radiation, a neglected and poorly understood hazard in mining as noted by the Leon Commission, is dealt with in chapter 10. Chapters 9, 11 and 13 cover subjects which have received little attention in mining in South Africa, namely chemical hazards (other than mineral dusts and underground gases), musculoskeletal disorders caused by ergonomic stresses, and skin disorders. Although mining in South Africa is dominated by gold, platinum and coal, the diving hazards of offshore diamond mining are sufficiently important to warrant a chapter of their own (chapter 12).

Return to work following illness, disability and compensation are thorny industrial relations issues, and their management requires an understanding of the medical, policy and legal dimensions of the subject. The situation in the South African mining industry is complicated by a dual compensation system, one for lung disease and a separate one for all other occupational diseases (and injuries), and by an historical lack of access of black ex-miners to the compensation system. This subject is dealt with in chapter 14.

The primary prevention of occupational disease requires control of hazards at source. However, the particular difficulties of source reduction measures in mining make choice of appropriate personal protective equipment an important subject, covered in chapter 15.

Although the handbook has adopted a hazard-based approach to mining related occupational disease, the contribution of the migrant labour system and of mine housing to ill health among miners cannot be underestimated. The Leon Commission identified crowded and unhygienic housing conditions on the mines as a factor in the spread of disease and in unhealthy behaviour among miners, and called for upgrading of mine housing including increased provision of family quarters.

The handbook appears in the shadow of the HIV epidemic. At the time of publication, it is estimated that up to 30 percent of mineworkers in certain mines may be HIV positive. Migrant labour and single sex hostels cannot have failed to contribute to the spread of sexually-transmitted infections, including the virus that causes AIDS, both in neighbouring residential communities and in remote rural areas.
In this handbook, only HIV testing and the impact of HIV on TB are dealt with in detail. The manifold clinical and public health dimensions of AIDS must be left to other texts. However, the whole mining community, including but not limited to those with responsibility for occupational health, will have to grapple with this interaction between work, mine housing and the social and family life of miners outside the mines, if the impact of the HIV/AIDS epidemic on the mineworkers is to be in any way mitigated.

Being the first edition, this handbook no doubt suffers from the shortfalls of an initial attempt to direct nineteen different authors in a common project. With the exception of one person, the authors are all based in South Africa, making it a distinctly home-grown product. They are experts in their disciplines but had access to differing amounts of information and experience directly applicable to the South African mining industry. Where information was plentiful, the authors have distilled best practice from historical experience and more modern thinking on the subject. Where information was scarce, as in the newer subjects of ergonomics, chemical hazards and skin disease, the authors were asked to lay out general principles, with mining examples where possible, to be adapted by the readers to their specific purpose.

The usefulness of the handbook will be tested by whether it assists readers in doing their jobs more effectively and ultimately in making mining a healthier industry. Criticisms and suggestions are welcome and will strengthen future editions. The legislative and policy environment will continue to evolve, with new regulations and guidelines requiring incorporation into such future editions.

R. Guild
R. I. Ehrlich
J. R. Johnston
M. H. Ross
CHAPTER 1

The legal, policy and ethical framework of occupational health practice in the South African mining industry

This chapter sets out the legal, policy and ethical framework within which the practice of occupational health occurs in the South African mining industry.

The Mine Health and Safety Act 29 of 1996 (MHSA) is the principal law regulating occupational health practice in South Africa’s mining industry. This chapter summarises the policy considerations that led to the enactment of the Act and discusses those provisions that are relevant to the conduct of occupational health practice. The chapter also covers the ethical considerations relevant to occupational health practice.

A number of other statutes regulate the practice of occupational health, particularly the management of disability. These statutes include the Labour Relations Act 66 of 1995 (LRA), the Basic Conditions of Employment Act 75 of 1997 (BCEA) and the Employment Equity Act (EEA). The BCEA and EEA both regulate the employment of disabled persons. The EEA also has far reaching provisions dealing with medical testing of employees and the provisions dealing with HIV testing, which have attracted considerable attention, are discussed in some detail. The BCEA also imposes obligations in respect of night workers and pregnant workers.

P Benjamin
Lawyer

Paul Benjamin is a practising attorney and a director of Cheadle Thompson and Haysom. His involvement in health and safety dates back to 1983 when he represented the National Union of Mineworkers (NUM) at the inquest into the Hlobane Colliery disaster. He represented NUM at the Leon Commission of Inquiry and played a central role in drafting the Mine Health and Safety Act. He is also the author of a commentary on the Occupational Health and Safety Act published by Juta.
GLOSSARY

BCEA: Basic Conditions of Employment Act
COIDA: Compensation for Occupational Injuries and Disease Act
EEA: Employment Equity Act
LRA: Labour Relations Act
MHSA: Mine Health and Safety Act
MOHAC: Mine Occupational Health Advisory Committee
MRAC: Mine Regulation Advisory Committee
ODMWA: Occupational Diseases in Mines and Works Act
OHSA: Occupational Health and Safety Act
OMP: Occupational medical practitioner — a medical practitioner who has undertaken post graduate studies in occupational health
SIMRAC: Safety and Mines Research Advisory Committee
1.1 Legislative history

The Mine Health and Safety Act (MHSA) came into effect on 15 January 1997 replacing the Minerals Act 50 of 1991 as the legal basis for regulating occupational health and safety in the South African mines. It has been said, “the MHSA will substantially alter the culture and politics of health and safety in the mining industry. It can be regarded as a new Constitution for the mining industry. As such it is a major achievement in legislative terms.” MHSA replaces those sections of the Occupational Diseases and Mines and Works Act 78 of 1973 (ODMWA), which regulated the control of occupational health hazards in the mines thereby consolidating the provisions dealing with the control of occupational health into a single statute.

MHSA was enacted after an extensive policy review undertaken by the Commission of Enquiry into Health and Safety in the Mines (“the Leon Commission”) which published its report and recommendations in 1995. The Act, as well as the subsequent Mine Health and Safety Amendment Act of 1997, was developed through a tri-partite consultation process involving representatives of government, employers and trade unions. As a result of the high level of participation in its drafting, the Act enjoys substantial legitimacy among employers and workers in the industry.

The Leon Commission concluded that the mining industry had taken inadequate steps to protect mine workers from work-related health conditions. There was no evidence indicating a decline in the prevalence or severity of the major occupational diseases in the mining industry during the past 20 years. Legislation had been inadequately enforced and the State’s enforcement agencies had not been able to control occupational health problems. This led the Commission to recommend a major legislative restructuring coupled with the devotion of greater resources to enforcing of mine health and safety standards. Other recommendations include —

- mine managements must establish health and safety management systems incorporating the principles of risk assessment
- urgent action must be taken to upgrade the standards of practice for measuring workplace exposures and conducting medical surveillance so that workplaces giving rise to disease could be identified and targeted
- all mines should implement an expert occupational health programme as part of their risk assessment system
- the law should entrench basic worker’s rights, promote active worker participation in health and safety and create institutions for tri-partite consultation on health and safety law and policy

MHSA draws upon and modernises the approach in the Occupational Health and Safety Act 85 of 1993, which regulates health and safety in other sectors of the South African economy. The International Labour Organisation’s Mine Health and Safety Convention 177 of 1995, adopted during the process of developing the new Act, also significantly influenced the legislation. The Act is also influenced by the Labour Relations Act 66 of 1995, particularly in its approach to worker participation on health and safety and the resolution of disputes over the disclosure of information.

1.2 Overview of MHSA

The principal features of MHSA are —

- the primary responsibility for ensuring a healthy and safe working environment in mines is placed on the mine owner (employer). The Act sets out in detail the steps that employers must take to identify, assess records and control health and safety hazards in the mine
- the Act entrenches basic worker rights, most notably, the right of workers to participate in health and safety, the right to receive health and safety information, the right to training and the right to withdraw from the workplace in the face of danger
- the Act establishes representative tri-partite institutions to promote a culture of health and safety and develop policy, legislation and regulations
- the responsibility for enforcing MHSA lies with the Mine Health and Safety Inspectorate. The Inspectorate’s powers are recast and include the power to impose administrative fines upon
employers who contravene MHSA. The Act also contains innovative approaches to the investigation of accidents, diseases and other occurrences that threaten health and safety.

1.2.1 The legal hierarchy

The Act provides for the use of a range of legal and policy instruments in regulating health and safety —

- Mine Health and Safety Act
- Regulations (including regulations previously in force under the Minerals Act). The Minister may make regulations after consulting the Mine Health and Safety Council
- Codes of Practice — Mines must prepare codes of practice as required by the Chief Inspector. Codes of Practice must comply with any guidelines issued by the Chief Inspector

1.2.2 Employer’s duties

1.2.2.1 Overview

The owner of a mine must ensure that it is operated in a healthy and safe manner. MHSA regards the owners as the employer of all persons working on the mine. The owner of a mine is required to fulfil the obligations of an employer in terms of the Act. These duties are set out most generally in section 5(1) which requires employers to provide and maintain a working environment that is safe and without risk to the health of employees. The remainder of Chapter II (MHSA) delineates specific steps that employers must take to comply with this general duty.

1.2.2.2 Employer’s principal duties

An employer must —

- operate the mine in a healthy and safe manner
- implement a health and safety management system based on the principles of risk assessment. This is discussed in detail in the following section of the chapter
- supply free of charge the necessary health and safety equipment and facilities to employees and maintain that equipment in a serviceable and hygienic condition
- ensure that employees, including supervisors, know and understand the hazards attached to any work they may perform
- appoint persons to manage the mine and supply the managers with the resources to enable them to perform their functions
- establish a health and safety policy
- prepare and implement Codes of Practice as required by the Chief Inspector of Mines
- provide every employee with information, instruction, training and supervision to enable them to work safely and without risk to health

1.2.3 Risk assessment and hazard control

1.2.3.1 Identifying and assessing risks

MHSA requires employers to implement systems to create and maintain a healthy and safe working environment. While OHSA has a similar approach, MHSA’s obligations in regard to identifying, assessing and controlling risks and hazards are considerably more detailed and rigorous than the equivalent provisions in OHSA.

Employers must identify health and safety hazards involved in mining activities. This obligation covers both hazards to employees as well as hazards that may affect the health and safety of a person who may be directly affected by activities at the mine. A range of mechanisms should be used to identify hazards. These include workplace inspections, health and safety audits conducted by management and employers or by independent consultants, job safety analysis and the collection and
analyses of accident and occupational disease statistics. The hazard identification must examine what actually happens in the workplace — it cannot merely be assumed that all work will take place in terms of the mine’s procedures.

All identified hazards must be assessed. The likely consequences of a hazard must be evaluated in order to determine what measures should be taken to control the hazard. The assessment must include an evaluation of the severity of the potential harm and the number of persons who are potentially at risk as well as the methods that are available to control the risk. In general terms, the greater the seriousness of the potential harm or the greater the probability of its occurrence, the greater will be the need for taking safety precautions. An employer must undertake risk management systematically and on an ongoing basis. Risks must be monitored and there must be a periodic review of the hazards identified and the risks assessed.

The primary mechanisms used to identify and assess occupational health risks are occupational hygiene measurements and medical surveillance. (These are discussed below).

1.2.3.2 Who is an employee?

In terms of MHSA every person who is employed at or who works at a mine is an employee.

The definition of an employee in MHSA differs from the definition in other labour statutes such as the LRA, BCEA or COIDA. The distinction between an employee and an independent contractor, which arises under other labour legislation, is not relevant to MHSA. The employer must ensure the health and safety of everyone working at a mine, regardless of whether they would be classified as independent contractors or even the employees of sub-contractors. Therefore, the employees of a construction company working on a mine are classified as employees of the mine for the purposes of applying MHSA even though the construction company would be regarded as their employer in terms of the LRA or BCEA. In the light of the extensive use of contractors in the mining industry, the extension of the extended definition of an employee is of particular importance.

1.2.3.3 The hierarchy of control

MHSA sets a hierarchy of measures that must be taken to prevent exposure to risks. Wherever, possible risks must be eliminated. However, many of the perennial hazards of mining cannot be avoided in this manner and therefore the primary obligation is to seek to control the risk at source. This requires that the employer implement engineering or other collective measures to control or minimise the risk. Only if this is not reasonably practicable can the employer rely on the issue of personal protective equipment to protect employees. Even where personal protective equipment is issued, the employer remains under a continuing obligation to take collective measures as and when they become reasonably practicable. Where employees are exposed to risks, employers must institute a programme to monitor the risk. This monitoring may take the form, in the case of occupational health hazards, of conducting occupational hygiene measurements or establishing systems of medical surveillance.

1.2.3.4 Investigations

Investigations into accidents and other health threatening occurrences play a key role in risk identification and assessment. All reportable accidents, serious illnesses and health-threatening occurrences must be investigated. The employer is responsible for conducting the investigation. The investigation must be conducted in conjunction with the health and safety representative concerned and the employer must consult with the Health and Safety Committee about the investigation. A report must be prepared identifying the causes. This report must state whether any unsafe conditions, acts or procedures contributed to the incident and must also contain recommendations to prevent recurrences. The conduct of investigations form part of the employer’s general duty to identify, assess
and control hazards. Failing to investigate or inadequately investigating an occurrence would be a significant indication of employer negligence if there were a reoccurrence of the particular accident or occurrence.

1.2.3.5 Training

The supply of appropriate training is an integral part of risk assessment and management. Employers must ensure that employees are properly trained and familiar with work-related measures and the measures that must be taken to manage these hazards. Workers must be trained in all procedures that form part of work including emergency procedures. The effective implementation of a training plan will require an employer to monitor whether the training that has been supplied enables workers to perform their work safely and without risk to health. The obligation to train continues throughout an employee’s employment. Training must be supplied before an employee starts work, at appropriate intervals during employment and if there is any significant change made to any aspect of the mining operation or to an employee’s occupation or work.

1.2.3.6 Employee participation in risk assessment

MHSA stresses the need for intensive employee participation in risk assessment processes. Health and safety representatives have the right to participate in the identification of risks and hazards as well as in health and safety investigations. The record of hazards that is maintained by the employer must be open for inspection by the employees and the employer must consult with the Health and Safety Committee on health and safety measures it proposes to take.

1.2.4 Occupational Hygiene

*Occupational hygiene — the anticipation, recognition, evaluation and control of conditions at a mine that may cause illness or adverse effects to persons.*

Mines must use occupational hygiene techniques to measure levels of exposure to the hazards at the mine. A mine must engage a qualified occupational hygienist, either on a part-time or full-time basis, to conduct the measurements. The measurements must be appropriate to the hazards to which employees are exposed. The system of measurements must be designed to provide information that would allow the employer to decide what measures to take to control or minimise the hazards concerned. All occupational hygiene measurements must be recorded. The method of recording should allow information, where practicable, to be linked to each employee’s record of medical surveillance.

1.2.5 Medical surveillance

*Medical surveillance — a planned programme of periodic examination, which may include clinical examinations, biological monitoring, or medical testing of employees by an occupational health practitioner or an occupational medical practitioner.*

Biological monitoring is a planned programme of periodic collection and analyses of body fluid, tissues, excreta or exhaled air in order to detect and quantify the exposure to or absorption of any substance or organism.

Every mine must have a system of medical surveillance for employees exposed to health hazards. The system of medical surveillance must be appropriate to the health hazards to which employees may be exposed. It must be designed so as to provide relevant information to the employer for the purpose of controlling the health risk and for preventing, detecting and treating occupational diseases. Employees must undergo an initial medical examination (base-line examination) when starting work at the mine. Thereafter, employees must be examined at appropriate intervals.
A mine must engage the services of an occupational medical practitioner to conduct its medical surveillance programme.

The OMP may be engaged on a part-time or full-time basis, depending on the extent of medical surveillance that the mine is required to provide. If required, a mine must also engage additional persons with appropriate qualifications in occupational medicine to assist the occupational medicine practitioner conduct the medical surveillance programme.

### Duties of OMP

*Occupational medical practitioners must take every measure that is reasonably practicable —
  * to promote the health and safety of employees at the mine
  * to assist employees in matters related to occupational medicine*

### Employee or independent contractor?

Mines are not required to hire the OMP as an employee. In cases where the mine requires the services of a full-time OMP, it will usually be appropriate for the mine to engage him or her as an employee. A smaller mine that engages an OMP part-time to conduct medical surveillance could hire the OMP as an employee or an independent contractor. If the OMP is hired as an independent contractor, the contract should specify in detail the services the OMP is to perform. If the OMP is engaged as an employee, the mine will have to comply with applicable labour legislation (such as the Labour Relations Act and the Basic Conditions of Employment Act). The employee will be obliged to comply with reasonable and lawful instructions made by the employer. The significance of this is explored in the following paragraph. The following table summarises the principle difference between an employee and an independent contractor.

**Table 1.1. Categorisation differences between an employee and independent contractor**

<table>
<thead>
<tr>
<th>EMPLOYEE</th>
<th>INDEPENDENT CONTRACTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Object of the contract is to render personal services as defined in the contract.</td>
<td>Object of the contract is to perform specified tasks or produce a specified result.</td>
</tr>
<tr>
<td>2. Employee obliged to perform lawful and reasonable instructions of the employer.</td>
<td>Independent contractor must provide services in terms of the contract, not under supervision or control of employer.</td>
</tr>
<tr>
<td>3. Employer liable for negligence of employee.</td>
<td>Employer not liable for negligence of contractor.</td>
</tr>
<tr>
<td>4. Employee cannot be unfairly dismissed.</td>
<td>Contract terminates on completion of work or production of result as specified in the contract.</td>
</tr>
<tr>
<td>5. Employee may not be unfairly dismissed.</td>
<td>Contract can be terminated in accordance with the contract. Contractor may claim damages for unlawful termination.</td>
</tr>
</tbody>
</table>

### The twin duties of an OMP: professional and employee

MHSA places significant duties on occupational medical practitioners. These legal duties are consistent with their professional and ethical obligations as medical practitioners. At the same time, many OMPs will be employees of a mine. As an employee, they are obliged to obey lawful and reasonable instructions issued by the employer. The dual obligations placed on an OMP as an employee and a medical professional creates the potential for difficult situations to emerge.

The starting-point of this discussion is to emphasise that an employee is only obliged to comply with instructions that are lawful and reasonable. An OMP is not obliged to comply with an instruction that
would require him or her to breach the legal or ethical requirement of medical practice, including the duties in MHSA. In fact, the OMP is obliged to disobey an instruction that would, for example, require the OMP to breach the patient’s rights to confidentiality. In practice, the broad wording of the OMP’s duties in MHSA may give rise to situations in which the employer and the OMP differ over the content of these duties. An employer and an OMP may differ on what measures it is reasonably practicable for an OMP to take to promote the health and safety of employees. This could occur if a mine and an OMP were to differ over the level of resources that the mine was required to provide the OMP in order to promote the health and safety of the employees. A mine is not entitled to take any disciplinary action against the doctor for refusing to comply with an instruction that would require the OMP to breach a legal or ethical obligation. MHSA does not contain any procedure for resolving any differences between a mine and an OMP concerning the OMP’s duties.

A mine is liable for any negligent conduct by an OMP employed by it while performing his other duties. Equally, the failures of an OMP to take due care in performing his or her duties may render an OMP liable for claims based on malpractice. This issue is discussed in greater detail in the following section.

1.2.5.2 The doctor-patient relationship

Does the relationship between an OMP and an employee, who the OMP examines during a pre-employment or as part of a medical screening programme, differ from a normal doctor-patient relationship?

A patient who consults a medical practitioner in private practice has a contractual relationship with the doctor. There is no equivalent contractual relationship between an OMP and the employees he or she examines. The employee is undergoing the examination because of his or her contract of employment with the employer. Nevertheless, it is suggested that the doctor owes the normal professional duties to an employee he or she examines in his or her capacity as an OMP. These include the normal ethical and legal obligations of the requirement for informed consent to any examination or procedure and the patient’s right to confidentiality.

The OMP’s duties include the duty to inform a patient, who he examines, of any condition that may require treatment and to advise the employee or she to consult his or her personal doctor. In general, OMPs do not have a duty to treat employees outside of the work setting. The OMP’s duties may be more extensive at mines at which the employee is unable to access other medical personnel.

The occupational medical practitioner is required to investigate the circumstances under which any employee is declared to be unfit to perform work as a result of an occupational disease. If the employee who is examined is temporarily unfit and may reasonably be able to return to work, the occupational medical practitioner must record this fact and notify both the employer and the employee.

1.2.5.3 Confidentiality

A patient, who is examined by an OMP, has the usual rights of a patient to confidentiality. This right is grounded in the ethical, legal and constitutional entrenchment of the right to privacy. However, in many situations undergoing a medical examination amounts an implied consent for the results to be disclosed to the employer. This is true of a pre-employment medical to establish whether an employee has the physical capacity to perform a particular task. However, the doctor may only release information that is relevant to assessing the employee’s physical capacity to perform that particular task.

The patient’s right to confidentiality is not absolute. There are circumstances where, for instance, the law requires all doctors to notify the relevant authorities that the employee has a notifiable condition. Section 25 of OHSA requires medical practitioners who believe that an employee they have examined
or treated has contracted a work-related illness to advise the employee as well as his or her employer and the chief inspector. There is no equivalent provision in MHSA.

1.2.5.4 Records and reports

The employer at a mine where medical surveillance is conducted must keep a surveillance record of every employee, at the mine, who performs work in respect of which medical surveillance is conducted. The record must be delivered to the medical inspector when the employee ceases to be employed at the mine or if required by the Chief Inspector of Mines.

A mine must maintain a record of the medical surveillance for each employee who is exposed to a health hazard. This record must be kept confidential and may only be made available in accordance with the ethics of medical practice, if required by law or court order or if the employee has consented in writing to release that information. The improper disclosure of confidential information constitutes a criminal offence. The employee’s record of medical surveillance must be stored safely for a period of at least 40 years from the date on which the last surveillance of the employee was conducted.

Every occupational medical practitioner must prepare an annual report analysing the health of employees at the mine. This report is based on the employee’s record of medical surveillance. The purpose of the report is to analyse the health of employees as a whole and the report must not disclose the names of employees. A copy of the report must be given to the employer, the Health and Safety Committee (or if there is no Committee, the health and safety representative) and to the Medical Inspector.

The employer is liable for the costs of all clinical examinations and medical tests performed in terms of MHSA. The employer must provide an employee on request with a record of any occupational hygiene measurements or medical surveillance relating to that employee.

1.2.5.5 Exit certificates

Every employee who was subject to medical surveillance, while employed at a mine, must undergo a medical examination when they leave employment with the mine. The responsibility for arranging the exit medical examination rests with the employer. The examination must be held whatever the reason for the employee’s services being terminated. The examination must be held before, or as soon as possible after, the termination of employment. The Act requires the employee to attend the examination.

The occupational medical practitioner who conducts an examination must produce an exit certificate indicating the results of all medical surveillance that the employee has undergone and whether or not the employee has any occupational disease or health disorder. A copy of the exit certificate must be entered into the record of the employee’s surveillance. The occupational medical practitioner must supply the employee with a copy of the exit certificate.

1.2.5.6 Appeals against findings of the occupational medical practitioner

MHSA gives employees the right to appeal against decisions and findings made by an occupational medical practitioner. An employee may appeal to the medical inspector against a decision that the employee is unfit to perform any particular category of work or against any finding contained in the employee’s exit certificate. The Medical Inspector must arrange for any employee who lodges an appeal to be re-examined at the State’s expense by a medical practitioner who is not employed by the employee’s employer. After the Medical Inspector has received the results of the examination he can confirm, set aside or vary the decision or finding appealed against.

1.2.5.7 Negligence: What measures are reasonably practicable

Most duties created by MHSA are qualified by the term “reasonably practicable”. This determines the standard of care required of employers, employees and OMPs. Determining what is “reasonably practicable” is a two-stage inquiry. A health and safety measure is practicable if it is feasible or can be implemented without practical difficulty. However, whether it is reasonably practicable for the employer to implement it depends on an evaluation of the following factors —
(a) the severity and scope of the hazard or risk concerned;

(b) the state of knowledge reasonably available concerning that hazard or risk and any means of removing or mitigating that hazard or risk;

(c) the availability and suitability of means to remove or mitigate that hazard or risk;

(d) the costs and the benefits of removing or mitigating that hazard or risk.

There are few South African cases that offer practical guidance on interpreting this standard of care. However, assistance can be obtained from decisions in countries whose legislation uses similar terminology. For instance, the English courts have decided that the fact that particular safety precautions are applied universally in an industry does not always mean that they are reasonably practicable. The standard may require an employer to adopt safer methods. The provision of a healthy and safe working environment must take account of the imperfections of human nature.6

The application of this standard of care to conduct by an OMP is well illustrated by a leading British case. The company involved had employed a full-time medical officer who had specialised in occupational medicine since 1941. A worker employed as a tool-setter in 1950 was required to bend over machinery covered with a film of oil. His clothing became saturated with oil and as a result, the skin of his scrotum and groin were frequently in contact with oil. The worker developed warts on his scrotum in 1965 and died the following year, aged 43. At the time, there was medical evidence that five years of continuous exposure to carcinogenic oils produce a cancerous condition in some workers. Since the 1940’s, medical scientists had recommended that workers exposed to a risk of a cancer should undergo periodical medical examinations and be warned of the risk to which they were exposed. In 1960 the Factory Inspectorate had issued a pamphlet warning workers that warts on the scrotum were potentially cancerous and recommending that they avail themselves of periodical medical examinations. The company’s medical officer did not recommend the institution of periodical medical examinations nor did he circulate the pamphlet or issue warnings to workers. He believed that periodical medical examinations were out of proportion to the risk of cancer and that warnings would frighten workers. In 1963 after a worker had died of scrotal cancer, the medical officer gave a talk on the dangers of scrotal cancer to the works council, but did not notify workers more widely of the hazard. The court found that the failure by the company to implement six-monthly medical examinations for workers exposed to the risk of cancer was a breach of its duties to employees and awarded damages to the worker’s widow.

When evaluating whether a mine had done what is reasonably practicable, the OMP’s knowledge and expertise is imputed to the mine. The OMP’s conduct will be measured against the general level of skill and diligence expected of a medical practitioner with a specialist qualification and expertise in occupational medicine. An OMP will be expected to keep abreast of developments and advise the employer of any changes that should be made to health and safety practices.

The failure by the OMP to meet the required standard of conduct has a number of possible legal consequences —

• the OMP could be prosecuted for a failure to comply with the relevant legal obligations
• the mine could institute disciplinary action against the OMP for not complying with the statutory duties
• the mine (or the OMP personally) could face civil actions or claims for increased compensation in terms of COIDA based on the employer’s failure to comply with these duties

1.2.6 Employee’s duties and rights

The Act requires employees to take reasonable care to protect their own health and safety as well as that of any other person. Employees must use and take proper care of any protective clothing, health and safety facilities or equipment issued to them. The success of any health and safety system depends on employees informing their employer of health and safety risks. Employees must advise their supervisors of any situation that they believe constitutes a risk to himself or herself or any other person.

Employees have the right to leave a working place if they believe that there is a serious danger to their
health or safety. A health and safety representative, who is of the view that there is a serious danger to health and safety, may also direct employees to leave a working place. The right may be exercised if the danger is one of a serious nature. There is no requirement that the right can only be exercised if the danger is imminent. This creates the possibility that employees may withdraw from a workplace to avoid excessive exposure to a hazard such as noise or dust even though that exposure alone may not endanger their health and safety. Every mine is required to have effective procedures to resolve any dispute over whether a workplace is dangerous. Workers who withdraw from a workplace must notify the supervisors and health and safety representatives. If they are unable to resolve the issue it may be appropriate to involve an inspector or a technical advisor. In the case of health hazards, this may require the participation of the occupational health practitioner.

1.2.7 Employee participation in health and safety

MHSA promotes active employee participation through elected health and safety representatives and committees. The Act creates two procedures for establishing the institutions for worker participation. If the majority of employees at a mine belong to a registered trade union, the employer must negotiate with that trade union on a collective agreement to regulate employee participation. (A number of trade unions acting together who represent the majority of employees at a mine may exercise these rights). At other mines, the employer must consult with registered trade unions, or in their absence, employees or their elected representatives over the election of health and safety representatives and the establishment of a health and safety committee. If a collective agreement is concluded between the employer and a representative trade union, the agreement replaces the Act as the basis for regulating employee participation in health and safety at the mine.

1.2.7.1 Health and safety representatives

Employees at mines of more than 20 employees have the right to elect health and safety representatives. There must be at least one health and safety representative for every 100 employees. A health and safety representative must be employed full-time in the working place that they are elected to represent. Health and safety representatives have the power to represent the employees within their working place on all aspects of health and safety. The functions of health and safety stewards include —

• identifying potential hazards and risks to health and safety
• conducting regular inspections of the workplace
• participating in internal health and safety audits and inspections by the employer or an inspector
• participating in the health and safety committee
• conducting investigations into accidents and other occurrences
• directing and assisting employees to leave a working place if there are circumstances that pose a serious danger to the health or safety of employees

1.2.7.2 Full-time health and safety representatives

Employees have the right to elect full-time health and safety representatives. The Act does not specify the number of full-time representatives and encourages this to be resolved by agreement. If agreement cannot be reached, the unresolved dispute may be referred to the CCMA for conciliation and, if this is not successful, to arbitration. A schedule to the Act contains guidelines for determining the number of full-time representatives. These suggest that all mines with 500 or more employees should have a full-time representative, but that an arbitrator should take into account the nature, size and location of a mine as well as its health and safety record when determining how many full-time representatives there should be.

1.2.7.3 Health and safety committees

A Health and Safety Committee must be established at every mine with 100 or more employees. The committee consists of representatives of the employees and the employer. The employee representatives are appointed by the health and safety representatives and must be broadly
representative of the workplaces at the mine. The committee’s represent employees in all aspects of health and safety and have extensive rights to consult with the employer. An employer must consult with the health and safety committee over the measures it proposes to take to eliminate, control or minimise health and safety risks. In practice, this requires an employer to notify the health and safety committee of any health and safety measure it proposes to introduce as a result of risk assessment and to disclose all relevant information so that the parties are able to exchange their views on the issue. The Act does not place any obligation upon an employer to reach agreement with the health and safety committee and once the consultation process is completed, it is the right and responsibility of the employer to determine what measures to implement. The purpose of consultation is to seek to improve the quality of decision-making and worker commitment to health and safety by allowing for greater worker participation in decisions.

1.2.7.4 Training and information

Health and safety representatives and committees are entitled to receive the training as is necessary for them to perform their functions. They may receive this training during working time and have paid time off for the purposes. The health and safety representatives and committees must be supplied with the information they require to perform their functions. The employer must notify them of any inspections, investigations or inquiries. MHSA prevents the disclosure of private personal information and establishes a procedure for regulating disputes concerning the disclosure of information.

1.2.8 Tri-partite committees

MHSA establishes a number of tri-partite institutions for consultation between the representatives of mine owners, employees and the government. The Mine Health and Safety Council was established to advise the Minister of Mineral and Energy Affairs on all aspects of safety and health in the mines. The Council is also charged with promoting a culture of health and safety in the mining industry. The Act requires the Council to establish three permanent committees. These are — the Mining Regulation Advisory Committee (MRAC); the Mine Occupational Health Advisory Committee (MOHAC); and the Safety and Mines Research Advisory Committee (SIMRAC). The Council must co-ordinate the activities of these committees and any other committees it appoints and receive reports from the committees. The Mine Qualifications Authority sets educational and training standards and qualifications for the mining industry as part of the framework established by the South African Qualifications Act.

1.2.9 Inspectorate

The MHSA establishes a national health and safety inspectorate, administered by a Chief Inspector. The Chief Inspector acts subject to the control and direction of the Minister and must advise the Minister on all aspects of health and safety in the mining industry. The Chief Inspector’s functions include —

• appointing inspectors, including a medical practitioner
• determining and implementing policies to promote health and safety in mines
• publishing and distributing an annual plan for the activities of the inspectorate and an annual report on mine health and safety
• requiring mines to prepare codes of practice on any aspect of health and safety and the publishing of guidelines for codes of practice

The powers of the Chief Inspectorate include monitoring and controlling any environmental hazard at a mine that may affect health and safety.

Mine inspectors have three chief functions: conducting inspections; issuing instructions to deal with dangerous conditions in mines and conducting investigations and inquiries into accidents and health-threatening occurrences. The MHSA sets out the powers of inspectors in considerable detail —

• an inspector may enter any mine at any time without warrant or notice to enforce compliance with the MHSA. While on the mine, an inspector may question persons, require the production of and
examine and copy any document, inspect any aspect of or matter related to work at the mine and seize any document, article or substance or machine at the mine
• in order to protect the health and safety of persons at a mine, instruct that operations at a mine or part of a mine be halted or direct that the performance of any act or any practice at a mine must be suspended or halted or the inspector may place conditions upon its performance. Before issuing an instruction to halt mining, the inspector must allow the mine’s management and representatives of the employees the opportunity to make representations, if this can be done without endangering health and safety. The instruction must be confirmed, varied or set aside by the Chief Inspector as soon as practicable
• if an inspector believes that an owner or manager has failed to comply with the provisions of this MHSA, the inspector may issue a written instruction requiring that steps specified in the instruction be taken within a specified period
• any instruction issued by an inspector must be supplied to the relevant health and safety committees and representatives and must be communicated to employees and displayed prominently at the mine

The MHSA introduces a number of reforms to facilitate the more effective conduct of investigations and inquiries. The MHSA creates mandatory and discretionary investigations. An investigation must be held into —

(a) any accident or occurrence that results in serious injury, serious illness or death;
(b) if there is a concern on health and safety grounds and a registered trade union, a health and safety representative or committee or, at a mine where there is no representative, an employee requests an inquiry.

The inspectorate may investigate any other matter affecting health and safety including a suspected breach of the provisions of this MHSA. An investigation may cover more than one mine.

The investigation procedures are not set out, however, an inspector may use all of the powers described above during an investigation.

An inquiry must be conducted into any fatal accident or occurrence and may be held into any other matter concerning health and safety. An investigation may be converted into an inquiry. Any person with a material interest in the subject matter of the inquiry is entitled to participate as well as the representative of any registered trade union whose members are affected by the inquiry and the health and safety representative responsible for a working place in respect of which the inquiry is held.

### 1.3 Laws regulating disability

| The Labour Relations Act permits an employer to dismiss an employee who is unable to work due to injury or illness only if the employer has followed a fair procedure and there is no alternative to dismissing the worker. |
| The Employment Equity Act — |
| • prohibits discrimination on grounds of disability |
| • requires employers to take affirmative action measures to promote the employment of disabled persons |

### 1.3.1 Introduction

Despite the high level of permanent disability caused by occupational accidents and disease in South Africa, particularly in the mining industry, relatively little attention has been paid to the rights of disabled workers. However, recent development in labour law have placed a series of overlapping obligations on employers in regard to the employment of disabled persons. The LRA places procedural and substantive obligations on employers who wish to dismiss employees on account of a physical incapacity to perform their job. The EEA prohibits employers from unfairly discriminating against employees on account of a disability and requires employers to take affirmative action measures to achieve an equitable of persons with disabilities in their workforce.
1.3.2 Termination of employment

The Labour Relations Act regulates the fair dismissal of employees. The Act recognises “incapacity” as one of the grounds upon which an employee’s services may be terminated. Employees who can no longer perform their duties because of either ill health or injury may be dismissed. However, the dismissal will only be fair and valid if the employer follows a fair procedure and can demonstrate that there are no alternatives to dismissing the employee.

An employer must investigate alternatives to terminating an employee’s service on account of incapacity. The employee must be allowed an opportunity to participate, assisted by a fellow employee, in investigating alternatives. The investigation should first consider whether the employee’s workstation or conditions could be adapted to accommodate the disability. If this is not reasonably possible, the employer must investigate whether there are alternative jobs that the employee could perform or could be trained to perform. Where the only jobs that the employee could perform are at a lower rate, there is no obligation on the employer to provide employment at the old rate of pay.

In general, a temporary inability to work due to illness or injury will not be considered to be a fair reason for a dismissal. An employer would only be entitled to dismiss an employee who is suffering from a temporary injury if the absence is unreasonably long and if there are no alternative solutions short of dismissal. Whether an absence will be unreasonably long will vary from case to case and depends to a large degree, on the extent to which the employer is able to find a substitute or redeploy another employee to perform the absent employee’s work. In general, there is a greater duty on an employer to accommodate the incapacity of employees injured at work or incapacitated by a work-related illness.

1.3.3 Discrimination

An employer may not discriminate unfairly against an employee due to a disability. Discrimination may be direct, for instance, refusing to hire a person because of their disability. However, most cases of discrimination involving disabled workers are likely to be indirect, where apparently neutral criteria have an adverse affect on a disproportionate number of disabled workers. For example, a requirement that an office worker who is not required to drive as part of their duties have a driver’s licence would constitute indirect discrimination against blind workers or other disabled workers who are unable to drive but who meet the other criteria for the job. It is not unfair discrimination to distinguish between persons or to exclude a person on the basis on an inherent requirement of a job.

1.3.4 Affirmative action measures

The EEA requires employers to take affirmative action measures to achieve equitable representation of blacks, women and people with disabilities in all occupational categories and levels. Disabled people are those with a long-term or recurring physical disability that substantially limits their prospects of entry into, or advancement in, employment. The most significant duties on employers are to —

• identify and eliminate barriers to the employment or advancement of disabled persons
• make reasonable accommodation for disabled persons by modifying or adjusting jobs or the working environment to enable the disabled to obtain or advance in employment
• retain, develop and provide appropriate training for disabled employees

The EEA substantially alters the approach of the law to the protection of disabled workers. Prior to the Act, the employer’s obligation arose on a case-by-case basis when an individual employee suffered an incapacitating, injury or illness. The EEA requires employers to adopt a systematic and proactive approach to the employment and advancement of disabled people, including those who contract work-related injuries or diseases.
1.4 The regulation of medical testing

The concern is often expressed that employers make decisions that may have a discriminatory effect on employees based on information derived from medical testing. As a result of this concern, provisions have been included in the Employment Equity Act to regulate the conduct of medical testing. Medical testing is defined in broad terms to include any test, question, inquiry or other means designed to ascertain, or which has the effect of enabling an employer to ascertain, whether an employee has any medical condition. Accordingly, the completion of an application form in which the employee is required to state information concerning their physical fitness constitutes a medical test.

The Act prohibits medical testing unless —

• the test is permitted or required by legislation
• it is justifiable in the light of medical facts, employment conditions, social policy, the fair distribution of employee benefits or the inherent requirements of a job

In consequence, any testing that is either required in terms of an employer’s medical surveillance programme, including a test conducted at the commencement of employment or on termination of employment, is permitted. In addition, the section would allow mines to continue to conduct tests that are necessary to determine whether employees have the physical capability to perform a particular job.

1.4.1 HIV-Testing

Section 7(2) of the Act deals with HIV testing. It provides that —

“(2) Testing of an employee to determine that employee’s HIV status is prohibited unless such testing is determined to be justifiable by the Labour Court in terms of section 59(4) of this Act.”

This provision has become extremely controversial and widely differing opinions have been expressed as to its consequences. One author has suggested that the Act prohibits all HIV testing of any person who is employed unless it has been authorised by the Labour Court and that legally only unemployed persons can be tested for HIV. This view misinterprets the purpose and meaning of the EEA. In contrast, it is suggested that —

• the requirement for court authorisation only applies to HIV tests conducted by an employer or on behalf of an employer
• court authorisation is not required for anonymous testing undertaken for epidemiological purposes or to determine the prevalence of HIV Aids among a workforce for the purposes of planning, as the tests do not determine on individual employee’s HIV status. Anonymous testing must be conducted in accordance with the prevailing medical protocols
• no authorisation is required to test an employee who requests with informed consent a test in the context of a relationship between the employee and a health professional, even if the health professional is employed by the employee’s employer

The suggestion that section 7(2) applies to all HIV testing of an employee ignores the purposes of the EEA and the location of section 7(2) within Chapter 2 of the EEA that prohibits discrimination. The purpose of Chapter 2 is to promote equal opportunity and fair treatment in employment by eliminating unfair discrimination in any employment policy or practice. This purpose is a factor that must be taken into account when interpreting the Act. While the anti-discrimination provision (including section 7(2)) applies to “all employees (including applicant for employment) and employees” it only applies to them in the context of an employment relationship between employee and employer. The EEA has no application to a situation in which a person who happens to be an employee requests a private practitioner or a pathological laboratory to perform an HIV test. The practitioner or laboratory has no obligation to inquire as to the person’s employment status.

The all-encompassing interpretation placed on section 7(2) would also have the effect of making unlawful HIV-testing which is currently provided by the health services of many major employers as part of wellness programmes. It is suggested that this is not the case and that the EEA does not require
authorisation for confidential testing requested by an employee within the confines of a patient — health professional relationship provided that the employee has given informed consent to the test. It is suggested that the courts would by applying accepted legal principles fund that an employee who requested a test in these circumstances within informed consent will be viewed as having waived the protection of section 7(2).8 The High Court has described the elements of the requirement for informed consent to HIV-testing in the following terms —

“Speaking generally, it is axiomatic that there can only be consent if the person appreciates and understands what the object and purpose of the test is, what an HIV positive result entails and what the probability of AIDS occurring thereafter is. Evidence was led in this case on the need for informed consent before the HIV test is performed. Members of the medical profession and others who have studied and worked with people who have tested HIV positive and with Aids sufferers have developed a norm or recommended minimum requirement necessary for informed consent in respect of a person who may undergo such a blood test. Because of the devastation that a positive result entails, the norm so developed contains as a requirement counselling both pre- and post-testing, the latter in the event of a positive result. These requirements have become almost universal in the Republic of South Africa.”9

The health service that conducts the testing must maintain the confidentiality of the test results and ensure that it is not disclosed without the consent of the employee concerned. The EEA does not make conducting an HIV-testing in contravention of section 7(2) a criminal offence. However, an employee or a trade union may refer a dispute concerning any violation of the provision to the Labour Court for adjudication. An employee who has been tested after giving informed consent in the circumstances described above would have no legal basis for referring a dispute unless the employee could show that the consent had been improperly obtained, that the results had been improperly disclosed or that there was some other malpractice.

Court authorisation would be required for testing conducted by an employer as part of any employment policy or practice. This would include testing —

• during an application for employment
• as a condition of employment
• during procedures related to the termination of employment
• to determine eligibility for training, staff development or employee benefits

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1.5 Basic Conditions of Employment Act

The Basic Conditions of Employment Act 75 of 1997 (BCEA) sets minimum conditions of employment for most workers in South Africa, including those employed in the mining industry. A significant feature of the BCEA is the emphasis it places on the linkage between conditions of employment, particularly the arrangement of working time, and the protection of workplace health and safety. The Act requires employers to adopt a proactive approach to the impact that working time arrangements may have on the health and safety of employees placing a general duty of employers to pay due regard to employee’s health and safety when regulating working time. The Act is accompanied by a Code of Good Practice on the Arrangement of Working Time issued by the Minister of Labour. The BCEA’s duties parallel those found in health and safety legislation. The arrangement of working time is a factor that employers must take into account in identifying and assessing risks as well as when investigating accidents and other health and safety incidents. Two specific provisions in the Act, those regulating night work and the protection of pregnant and breastfeeding employees require OMP’s to play a specific role in protecting health and safety. The BCEA’s approach to the regulation of working time will have a particular impact on sectors such as the mining industry that make extensive use of shift work and night work.
1.5.1 Night work

Regular night workers

Employers must inform night workers of any health and safety hazards associated with their work. Regular night workers are entitled to undergo a medical examination covering hazards that may flow from their work. An employee who suffers from a health problem association with performing regular night work is entitled to be transferred to suitable day work within a reasonable time, unless it is not practical for the employer to do so.

It is now generally accepted that regular night work, whether as part of a rotating shift system or on a permanent basis, has significant health consequences. The BCEA imposes three significant obligations on employers of employees who perform regular night work. Employee’s fall in this category if they work after 23:00 or before 06:00 at least five times per month or 50 times per year. This will include all workers who are permanently allocated to a night shift as well as most who work nights in terms of a rotating shift system.

An employee performing regular night work is entitled to a medical examination when commencing night work and at appropriate intervals while continuing to work regularly at night. The examination must cover any hazards flowing from the employee’s work at night. Employers must advise employees of their right to the examination and employers are liable for the cost of the examination. The Code of Good Practice on the arrangement of working time contains certain guidelines concerning the conduct of these medical examinations. It suggests that the examination should cover —

- any difficulties an employee may have in adjusting to night work
- any health problems the employee is manifesting
- any psychological, emotion and social stresses experienced by the employee as well as strategies that may assist the employee to cope with night work
- insomnia and the symptoms of sleep deprivation
- the use of any medication which depends upon circadian rhythms for its effectiveness
- diet and the use of stimulants such as caffeinated drinks, alcohol, sleeping pills and cigarettes

The Code of Practice also points out that there may be circumstances in which it is appropriate to advise individuals against shift work. These include workers who take medication that is affected by circadian rhythms, as well as workers with gastro-intestinal or cardio-vascular disorders and epileptic.

1.5.2 Pregnancy and maternity

Employees are entitled to at least four consecutive months maternity leave. OMP’s may be called upon to assist an employee to determine when she should commence maternity leave. An employee has a right to commence maternity leave at any time from four weeks before the expected date of birth. However, if a medical practitioner or midwife certifies that it is necessary for the employee’s health or that of the unborn child to commence maternity leave earlier she may do so. An employee may not return to work for at least six weeks after the birth of her child, unless a medical practitioner or midwife certifies that she is fit to do so.

The Act also places obligations on employers in respect of the health and safety of pregnant employees. An employer may not require or permit a pregnant employee or an employee who is breastfeeding her child to perform work that is hazardous to her health or the health of her child. During the period of pregnancy, and for six months afterwards, an employer must offer any employee engaged in night work or whose work may pose a danger to her health or safety or that of her child, suitable alternative employment with at least the same terms and conditions of employment unless it is not practicable to do so.
An employer must therefore take pregnancy and breastfeeding into account when identifying and assessing the health and hazards in the workplace and take appropriate steps to protect the health and safety of these employees and the foetus or infant.

The Act is accompanied by a Code of Good Practice dealing with the protection of pregnant and breastfeeding employees which contains practical guidelines for employers and employees and lists working conditions or substances that are known to affect reproductive health. The Code suggests that employers should have workplace policies that encourage employees to notify the employer of pregnancy at an early stage so as to enable the employer to adjust the employee’s work station or work conditions or to permit a transfer to alternative work.

REFERENCES

2. Section 97(6).
3. Commission of Inquiry at paragraph 4.4.3-4.
4. Has the Convention been ratified — check.
5. Initially, MHSA retained the division of responsibilities between the “owner” and the “manager” that was a feature of previous legislation. Changes introduced by the Mine Health and Safety Amendment Act 72 of 1997 have done away with this divide in order to give effect to the systems approach to health and safety.
7. MAC La Grange “The Employment Equity Act — Another HIV Calamity SAMJ 2000”.
8. C vs Minister of Correctional Services 1996(4) SA 292(T) at 301B-D.
9. The legal principles and leading cases dealing with the waiver of statutory rights are set out in NUMSA v SEIFSA 2000(21) Industrial Law Journal 1047(W) at 1049G-1050C.
CHAPTER 2

Occupational Health Management

Occupational health management systems make an important contribution to the protection of workers from hazards and the elimination of work-related injuries, illness, disease, incidents and death. This chapter is intended to give some background to the establishment and operation of occupational health management systems. It addresses management in terms of goals, structures and processes, effective decision-making and monitoring. Legislation and other factors external to the work environment have greatly influenced occupational health management of activities from hazard exposure to disability assessment. This chapter provides an overview of corporate governance, indicates the key elements that should be incorporated in an occupational health management system and expands on two important areas, namely information management and reporting and auditing. The chapter should assist the reader to implement a comprehensive management system framework and the appendices contain useful tools and relevant definitions for occupational health management, regardless of the size of the organisation.

Dr R Guild
Occupational Health & Safety Consultant

Haggis Guild is a medical practitioner with an MBA and 20 years experience in the South African mining industry. He has practised at all levels within occupational health services including delivery of medical care; development health and safety protocols; development of medical surveillance programmes, institution of quality assurance programmes and corporate management. He now consults to local and international clients, offering expertise in health risk assessment and management, information systems and corporate governance.
Glossary

Audit: systematic, independent and documented evaluation to determine whether activities and related results conform to planned arrangements and whether these arrangements are implemented effectively and are suitable for achieving the organisation’s policy and objectives.

BSI: British Standards Institute

Continual improvement: iterative process of enhancing the OH management system, to achieve improvements in overall OH performances, in line with the organisation’s policy. NB. The process need not take place in all areas of activity simultaneously.

Contractor: see Appendix 2.1

Employee: see Appendix 2.1

External audit: an audit conducted by an auditor or auditors from outside the organisation

Hazard identification: process of recognising that a hazard exists and defining its characteristics

IMS: integrated management system

Incident: an unsafe occurrence that did not give rise to but had the potential to lead to an illness or injury

IOSH: Institute of Occupational Safety and Health (UK)

Interested parties: individual or group concerned with or affected by the OH performance of an organisation

Non-conformance: any deviation from work standards, practices, procedures, regulations, management system performance etc. that could either directly or indirectly lead to injury or illness, property damage, damage to the workplace environment, or a combination of these

Objectives: quantified goals, in terms of OH performance, that an organisation sets itself to achieve.

Occupational health management system: part of the overall management system that facilitates the management of the OH risks associated with the business of the organisation. This includes the organisational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the organisation’s OH policy and objectives.

OHSAS: Occupational Health and Safety assessment series

Organisation: company, operation, firm, enterprise, institution or association, or part thereof, whether incorporated or not, public or private, that has its own functions and administration. NB. For organisations with more than one operating unit, a single operating unit may be defined as an organisation.

Performance: measurable results of the OH management system, related to the organisation’s control of health risks, based on its OH policy and objectives. N.B. Performance measurement includes measurement of OH management activities and results

Risk assessment: the process of evaluating the risks to safety and health arising from hazards at work

Tolerable risk: risk that has been reduced to a level that can be endured by the organisation having regard to its legal obligations and its own OH policy.
2.1 Introduction

Occupational health is the responsibility and duty of the employer, providing a strong incentive to establish an occupational health management system in every organisation. Occupational health (OH) management is about improving workplace conditions and eliminating illness and disability related to work. It is the management of risk, the reduction in business losses and an increased ability to meet business objectives and strengthen stakeholder confidence through systematic and structured technical and management programmes. In the mining industry, it is particularly important that OH management is not only prepared for routine issues in stable conditions but also for the challenges of change management. Both internal changes (e.g. new processes, staffing, working procedures) and external changes (mergers, legislation, technology) can impact on physical and psychosocial wellbeing of employees.

Many organisations have adopted a risk-based approach to establishing internal organisational controls, and regular review and public reporting systems have been established. Legislation has moved from a reactive and prescriptive, rule-based approach towards a proactive focus; the level of occupational risk that is regarded as intolerable has been lowered; and specific actions to manage workplace risks have to be instituted and sustained to meet worker and stakeholder expectations.

Although external factors exert pressure for improvement, the reduction or elimination of workplace risk, disease and disability mainly depends on factors where risk is managed at operational level, namely:

- technical programmes that identify and address specific hazards
- behavioural programmes that create commitment, collaboration, competence and conformance; and
- management systems that support and promote the process

There is no one perfect management system to suit all organisations. However, good OH management is recognisable and should be an integral part of every organisation, not just an exercise in meeting regulatory requirements. It will not be achieved without leadership, commitment, simple processes, ongoing involvement of all stakeholders and consistent and comprehensive communication throughout organisations.

2.2 Occupational Health Governance

Investors have become a powerful force in organisations and the ethics of management, or reputation management, has become an important issue. Occupational illness, disability and deaths can adversely affect the achievements of the organisation, increase the cost of capital and be as influential on the share price as financial performance. Therefore, the management of OH risk is as important at the executive level as at the operational level, whether the organisation is decentralised or centralised, and whether small or large. It is essential to ensure that organisational objectives are not jeopardised by undetected and unmanaged health hazards.

Stakeholders are increasingly demanding that organisations establish a system of internal controls that utilise a risk-based approach, that these controls are frequently reviewed for effectiveness, and that feedback on the efficiency and effectiveness of controls is publicly disclosed. This is known as corporate governance, the essence of which is to protect the interests of stakeholders.

2.2.1 Setting up the system

The corporate governance role requires management, with active worker participation, to address three issues:

- creating a risk management framework that will facilitate the achievement of the organisation’s main health and safety goals and specific objectives
- introducing a process that establishes, reinforces and reviews business objectives, critical success factors including key health and safety performance and risk indicators, using regular and benchmarked reporting processes; and
- ensuring that operational management implements an adequate OH management system and introduces programmes that eliminate or reduce operational risk for all employees and contractors
An executive team member assisted by an operations manager, or a well-briefed senior manager, should develop a health and safety risk management framework for consideration of the Board or CEO of the organisation (Table 2.1).

**Table 2.1 Example of Health and Safety Risk Management Framework**
*(after Jones & Sutherland, 1999)*

1. **The background such as:**
   - International benchmarks
   - National benchmarks or precedents
   - Benefits of adopting risk management

2. **Identification and prioritisation of areas of change, business objectives, critical success factors and risks which may be significant**

3. **Identification of related significant health and safety risks which could undermine:**
   - the reliability of internal and external reporting
   - the safeguarding of human resources
   - identification and proper management of liabilities

4. **Identification of key tasks to be completed in order to:**
   - develop risk management strategies and a policy document
   - align operations management to implementation
   - provide executive management with early warning mechanisms
   - monitor the system of internal controls

5. **The role and composition of the executive committee/s**

6. **Allocation of:**
   - resources
   - responsibilities for system implementation
   - responsibilities for management of significant risks

7. **Milestones and reporting**

The framework should:
- recognise that risk management is a primary function of the executive team but one which is often achieved through operational management
- recognise that risk control includes health and safety management
- create an understanding of the impact of occupational health on organisational effectiveness
- regard reviews of internal control not purely as a regulatory exercise or for the purpose of making a public statement
- develop key risk indicators for significant OH risks
- include OH performance in the reward structure of the organisation; and
- be participatory, simple, comprehensible and achievable

The framework should provide information to answer the following questions:
- How realistic and achievable is the proposed plan?
- Does the executive or CEO accept the risks being taken in the business?
- What are the early warning mechanisms for identifying potential disasters?
- Does the CEO feel confident that a “risk decision” could be justified in the event of a disaster?
- What steps are being taken to ensure that previous, unacceptable bad practices do not recur?
- Is there ownership of the plan by all stakeholders?

In smaller organisations, executive management can easily determine the implementation of management systems and technical programmes by the process of “management by walking around (MBWA)”. In larger organisations, this assurance may only be possible through regular reporting (see Appendix 2.1).
The effectiveness of the risk management governance process is dependent on:

- regular monitoring by independent auditors
- timeliness of identification and quantification of risk
- operational ability to manage risk
- reporting of new significant risks, including quantitative indicators
- speed of communication to the executive and senior management; and
- clear communication and understanding of the value of a sustained, long-term commitment to health and safety throughout the organisation

2.2.2 Reporting

The ability to involve stakeholders is dependent on the format and quality of information that is communicated. Adequate coverage requires the development of three types of internal reports — emergency reports, quarterly reports and annual reports (Appendix 2.1). This process can be extremely resource intensive and disruptive to operations if insufficient attention has been given to data management and information presentation.

**Emergency reports** should be circulated in the event of OH fatalities, major OH incidents (e.g. cholera outbreaks from contaminated mine water) that could impact on stakeholders or lead to adverse national publicity. This ensures that corporate bodies are timeously informed to deal with queries from the press and other stakeholders.

**Quarterly reports** (see Appendix 2.1) are designed to provide routine information to the organisation, including health and safety structures, on the operational progress in managing risk. They should include selected OH data and key performance indicators, instances of non-compliance with regulations and any significant occurrences and achievements.

**Annual reports** should include assurances that cover the following aspects:

- an unequivocal statement relating to the extent of implementation of management systems and technical programmes that address the significant OH risks
- comments on the extent of legal compliance (any non-compliance issues should be summarised with assurances that the necessary measures have been taken to address the problem)
- comments on the extent of compliance with organisational policy
- a review of the past year’s OH objectives and the extent to which they have been met
- objectives and plans for managing significant OH risks in the forthcoming year
- an evaluation of the effectiveness or performance of the OH risk management programme; and
- a benchmarked comparison with performance by similar organisations

Improvement in reporting (Figure 2.1) is dependent on enhancing risk awareness, benchmarking performance and increasing the speed of communication of successes and failures throughout the organisation.

2.3 Occupational health management

Improvement in workplace conditions and decrease or elimination of illness and disability are due to actions within the workplace and result from the implementation of risk prevention and control measures. However, success may only be visible months or years later and may require interventions that have to be maintained over prolonged periods. This demands continuous, co-ordinated effort to ensure sustainability of diverse OH programmes and the relevant management systems.

Research into multiple national health and safety management standards has indicated that all successful systems incorporate five generic elements as illustrated by the outer ring in Figure 2.2, namely:

- a comprehensive OH policy
- dynamic organising and careful planning
- effective implementation and operation
- monitoring and corrective action; and
- conscientious management review
<table>
<thead>
<tr>
<th>Minimal</th>
<th>Moderate</th>
<th>Leading edge</th>
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<tr>
<td>• Minimal disclosure</td>
<td>• Linked to business drivers</td>
<td>• Awareness of OH objectives throughout organisation</td>
</tr>
<tr>
<td>• Loose linkage to business objectives</td>
<td>• Buy-in obtained from different management levels</td>
<td>• Clear focus on acceptable risks</td>
</tr>
<tr>
<td>• Limited discussion by board</td>
<td>• Application of fundamentals of internal control</td>
<td>• Clear communication of performance</td>
</tr>
<tr>
<td>• Viewed mainly as a compliance exercise</td>
<td>• Simple and straightforward early warning mechanisms</td>
<td>• Internal controls established throughout the business</td>
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<td>• Monitoring heavily dependent on executive themselves</td>
<td>• Reasonable operational involvement</td>
<td>• Wide consultation on standards and controls</td>
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Figure 2.1. Benchmarking progress in reporting

Figure 2.2. Elements of successful occupational health management
An OH management system is dynamic and continuous. Each element is dependent on the one preceding it and the cycle stimulates continual improvement. The manner and extent to which individual elements are applied within a particular organisation will depend on such factors as the size of the organisation, the nature of its activities, the hazards encountered and the conditions in which it operates.

The outer circle represents the management system that drives the specific actions of risk assessment and risk management, which are delineated in the centre of the diagram. While this chapter focuses on the outer ring, it provides links to the risk assessment process that is more fully covered in Chapter 3.

2.3.1 Comprehensive occupational health policies

South African legislation (S[8] Mine Health and Safety Act: 1996 (MHSA)) requires employers to establish policy that is adequately documented, has been produced in consultation with employees and is effectively communicated. Unfortunately, this process is often seen as a sheet of paper that has been pinned to notice boards or nicely framed and placed on various office walls but seldom read and only vaguely remembered. This situation usually results from inadequate input from senior personnel, minimal line management feedback and inadequate consultation with employees in the formulation of policy.

The policy should not merely contain a “mission” statement committing the organisation to managing health and safety effectively. In order to ensure delivery of a successful OH management system, the organisation needs to support the general declaration with more detailed policy statements, together with goals, objectives and targets to implement the policy in practice. OH policy should be consistent with business policies and should establish the overall sense of direction and the principles of action for the organisation. It should not be a “bolt on” to the existing management process but an integral part of operations management that places OH processes as a prime responsibility of line management, from the most senior executive to first line supervisory level.

An effective policy should be established by top management in consultation with employees and should:

- **be specific to the organisation and appropriate to the nature and scale of the OH risks**
  Hazard analysis, risk assessment and risk control is at the heart of a successful management system and needs to be reflected in the policy. It should be consistent with a vision of the organisation and should be a realistic assessment of the risks
- **be concise, clearly written, dated and signed by the employer or CEO**
- **include a commitment to continual improvement in protecting health by preventing work-related injuries, ill health, diseases, incidents and death**
  Stakeholder expectations cause organisations to reduce the risk of illness, accidents and incidents in the workplace. In addition to meeting legal responsibilities, the organisation should aim to improve its OH performance (including the management system)
- **include a commitment to comply, as a minimum, with current applicable OH legislation and other requirements to which the organisation subscribes**
  The policy commitment is a public acknowledgement by the organisation that it has a duty to comply with, if not exceed, such legislation or other requirements, and that it intends doing so. “Other requirements” include corporate or group policies, the organisation’s own internal standards or specifications, or codes of practice to which the organisation subscribes. For example, the organisation’s OH standards or at least the equivalent should be applied to contractors as well as employees
- **be implemented and maintained**
  Planning and adequate preparation are central to successful implementation. Often, policy statements and objectives are unrealistic because there are inadequate or inappropriate resources available to deliver them. Before making any public declarations, the organisation should ensure that the necessary finance, skills and other resources are available, and that all objectives are realistic and achievable
- **be communicated and readily available to all employees with the intent that employees are made
aware of their individual obligations and are encouraged to participate in all elements of the system

The involvement and commitment of employees is vital for success. Employees need to be made aware of the effects of OH management on the quality of their own work environment and should be encouraged to contribute actively. Employees at all levels, including management levels, are unlikely to make an effective contribution to OH management unless they understand their responsibilities and accountabilities and are competent to perform their required tasks. This requires clear communication of policies and objectives by the organisation to its employees to enable them to have a framework with which they can measure their own individual performance.

- be available to interested and affected parties

Any individual or group (either internal or external) concerned with, or affected by, the OH performance of the organisation would be particularly interested in the policy statement. Therefore, a process should exist to communicate the policy to them.

- be reviewed periodically to ensure that it remains relevant and appropriate to the organisation

In order for the policy to remain effective, it should be periodically reviewed for continuing adequacy. Legislation evolves, societal expectations increase, and change is inevitable. Consequently, the organisation’s policy and management system will need to be reviewed regularly to ensure their continuing suitability and effectiveness. If changes are introduced, these should be communicated to interested parties, as soon as practicable.

In establishing the policy, management should consider information necessary to maintain and improve it. This information is gained from management reviews (see Appendix 2.3), audits (see Section 2.7) and performance measurement (see Section 2.6) and includes:

- occupational health hazards and risks within the organisation
- legal and other requirements
- historical and current OH performance by the organisation
- needs of other interested parties
- opportunities and needs for continual improvement
- resources needed; and
- contributions of employees, contractors and other external personnel

Having established the boundaries within which the organisation will address OH issues, planning and organising will assist each employee to understand the specific part that he/she has to play, the resources available and the tools that exist to implement the policy.

### 2.3.2 Planning for occupational health

The planning phase bridges the policy and implementation phases and benefits from audit and performance indicator feedback mechanisms. Adequate planning ensures that roles, responsibilities and authorities are defined, documented and communicated, and that adequate resources are provided to enable tasks to be performed. Planning is not a legislated requirement per se but the MHSA requires employers to:

- maintain a healthy and safe working environment (S[5] MHSA)
- assess and respond to risk (S[11] MHSA)
- ensure an adequate supply of health and safety equipment (S[6] MHSA)
- staff the mine with due regard to health and safety (S[7] MHSA); and
- provide health and safety training (S[10] MHSA)

The planning process should focus on three areas and clarify the links between each area and the other elements of the management system:

- hazard identification, risk assessment and risk control or elimination
- compliance with legal and other requirements; and
- OH objectives and continual improvement in occupational health performance

#### 2.3.2.1 Hazard identification, risk assessment and risk control

Using the processes of hazard identification, risk assessment and risk control or elimination (see
Chapter 3), the organisation should have a complete knowledge of all significant OH hazards in its domain and should ensure identification, evaluation and control of its OH risks on an ongoing basis.

Should there be no existing OH management system, the current position with regard to OH risks should be assessed by means of an initial review that provides a basis for establishing the management system. If an OH management system exists, the initial review is used to reinforce the system. The initial review should provide a documented baseline for measurement of improvement by covering five key areas:

- legislative and regulatory requirements
- identification of the OH risks faced by the organisation
- an examination of all existing OH&S management practices, processes and procedures
- an evaluation of feedback from the investigation of previous incidents, accidents and emergencies; and
- reference to baseline risks in similar organisations

In all cases, consideration should be given to normal and unusual operations within the organisation, and to potential emergency conditions. A suitable approach to the review may include checklists, interviews, direct inspection and measurement, results of previous audits or other reviews depending on the nature of the activities.

Typical inputs to this process are:

- OH legal and other requirements
- OH policy
- records of incidents and accidents
- non-conformances
- audit results
- communications from employees and other interested parties
- information on best practice, typical hazards related to the organisation, incidents and accidents having occurred in similar organisations
- information on the facilities, processes and activities of the organisation, including
  - site plan(s),
  - process flow-charts,
  - inventory of hazardous materials (raw materials, chemicals, wastes, products, sub-products),
  - toxicology and other OH data,
  - monitoring data,
  - workplace environmental data.

Typical outputs include documented procedures for:

- identification of hazards
- determination of the risks associated with the identified hazards
- indication of the level of the risks related to each hazard, and whether they are, or are not, tolerable
- description of, or reference to, the measures to monitor and control the risks, particularly risks that are not tolerable
- where appropriate, the objectives and actions to reduce identified risks, and any follow-up activities to monitor progress in their reduction
- identification of the competency and training requirements to implement the control measures
- necessary control measures should be detailed as part of the operational control element of the system; and
- records generated by each of the above-mentioned procedures

2.3.2.2 Legal and other requirements

The organisation needs to understand how its activities are, and will be, affected by legal and other requirements, and to communicate this information to relevant personnel. Thus the organisation has to evaluate which requirements apply, where they apply, and who needs to receive relevant information within the organisation.
Organisational and legal requirements may include:

- details of the organisation’s production or service realisation processes
- hazard identification and risk assessment results
- best practices (e.g., codes, industry association guidelines)
- legal requirements/governmental regulations
- listing of information sources
- national, foreign, regional or international standards
- internal organisational requirements; and
- requirements of interested parties

This process should result in:

- procedures for identifying and accessing information and sources (electronic or paper)
- identification of which requirements apply and where this may take the form of a register(s)
- requirements (actual text, summary or analysis, where appropriate), available in locations which are to be decided by the organisation; and
- procedures for monitoring the implementation of controls consequent to new OH legislation

2.3.2.3 Goals and objectives

OH goals and objectives must be consistent with the relevant legal and other obligations and the OH policy. To implement OH policy and achieve best OH performance throughout the organisation, goals with relevant, measurable and outcome-based objectives must be established. The goals should address both broad corporate OH issues and OH issues that are specific to individual functions and levels within the organisation, for example:

- reduction of risk levels
- introduction of additional features into the OH management system
- quality assurance steps taken to improve existing features, or the consistency of their application; and
- elimination or the reduction in frequency of particular undesired incident(s)

These goals, and the specific objectives which quantify each goal, should be communicated (e.g., via training or group briefing sessions) to relevant personnel, and be instituted through the OH management programme. They should be realistic, achievable and formulated to encourage rather than discourage personnel.

2.3.3 Implementation and operation

The ideas and philosophy contained in the policy stages must be converted into a working system. The key to success is tangible commitment from top management. This includes visiting and inspecting sites, participating in investigations, and making time available in the context of corrective action, attendance at OH meetings, promoting optimal function of health and safety committees, and issuing messages of support.

The implementation phase is aimed at:

- **co-ordinating** information and technology transfer of best OH practice
- **controlling** risks
- encouraging **co-operation** between employees
- securing effective **communication** by means of visible behaviour, written material and face to face discussion; and
- ensuring **competence** through recruitment, selection, placement, transfer and training and the provision of adequate specialist advice and technologies
Success also depends on adequate resources being made available to carry out OH programmes and activities, including performance measurement and monitoring for the maintenance of a safe workplace, equipment, human resources, expertise and training.

2.3.3.1 Structure and responsibilities

To facilitate effective risk control, the roles, responsibilities and accountabilities of all parties should be defined, documented and communicated. These parties include:

- top management
- line management at all levels in the organisation
- health and safety committee members
- process operators
- employees who are exposed to specific hazards and the general workforce
- those managing the occupational health of contractors
- those responsible for OH training
- those responsible for equipment that is critical for occupational health
- employees with OH qualifications, or other OH specialists, within the organisation; and
- employee OH representatives on consultative forums

The organisation should communicate and promote the idea that occupational health is the responsibility of everyone in the organisation and a line management responsibility, not just the responsibility of those with defined OH management system duties.

The responsibility of top management should include defining the organisation’s OH policy, and ensuring that the OH management system is implemented. As part of this commitment, top management should designate a specific management appointee with defined responsibilities and authority for implementing the OH management system. In large or complex organisations, there may be more than one such designated appointee.

The OH management appointee should be a member of top management and should demonstrate active involvement in the entire management cycle from monitoring performance of the system to periodic reviews and revision of objectives. Other personnel who have delegated responsibilities for monitoring the overall operation of the OH function must support the OH management appointee.

The organisation should ensure that any other duties or functions assigned to these personnel do not conflict with fulfilment of their OH responsibilities.

Line management responsibility should include ensuring that OH is managed within the relevant area of operations. The role and responsibilities of any specialist OH function should also be appropriately defined to avoid ambiguity with respect to responsibilities and authorities and should include arrangements to resolve any conflict between OH issues and productivity considerations.

Specialist functions (occupational hygienists, occupational medical practitioners and occupational health practitioners, who include occupational health nurses) have ethical responsibilities to both employers and employees that must be accounted for in the role definitions.

All accountabilities, responsibilities and authorities should be documented in an appropriate format and written in a way that is understood by those who have to use the documentation, for example:

- OH management system manuals
- working procedures and task descriptions
- job descriptions; and
- induction training packages

These accountabilities, responsibilities and authorities, for both normal and disaster situations, need to be effectively communicated to all those whom they affect at all levels within the organisation. This should ensure that individuals understand the scope and the interfaces between the various functions, and the channels to be used to initiate action.
2.3.3.2 Consultation and communication

Pertinent OH information should be obtained from and communicated to the employees and other interested parties (e.g. contractors, visitors). Management should ensure employee participation in:

- development and review of policies and objectives
- decisions on the implementation of processes and procedures to manage risks, including the carrying out of hazard identification
- reviewing risk assessments and risk controls relevant to their own activities; and
- changes affecting workplace OH such as the introduction of new, or modified, equipment, materials, chemicals, technologies, processes, procedures or work patterns

Employees should be adequately represented on OH committees, and should be informed of who are their employee representatives, and the specified management appointees. This can be achieved by posting the contact information and photographs of representatives in the area represented.

2.3.3.3 Training, awareness and competence

This is an important aspect of the OH management system for all members of the organisation and must include both normal and emergency procedures. The following actions should be undertaken:

- a systematic identification of both the OH awareness and competencies required at each level and function within the organisation
- arrangements to identify and remedy any shortfalls between the required OH awareness and competency levels of individuals
- provision of necessary training in a timely and systematic manner
- assessment of individuals to ensure the acquisition and maintenance of the knowledge and competency required
- maintenance of appropriate records of an individual’s training and competency

The OH awareness and training programme should be established and maintained to address:

- an understanding of the organisation’s OH arrangements and individuals’ specific roles and responsibilities for them
- a systematic programme of induction and ongoing training for employees and those who transfer between divisions, sites, departments, areas, jobs or tasks within the organisation
- training in local OH arrangements and hazards, risks, precautions to be taken and procedures to be followed, this training being provided before work commences
- training for performing hazard identification, risk assessment and risk control
- specific in-house or external training which may be required for employees with specific roles in the OH system, including employee OH representatives
- training for all individuals who manage employees, contractors and others (e.g. temporary workers), in their OH responsibilities
- the roles and responsibilities (including corporate and individual legal responsibilities) of top management for ensuring that the OH management system functions to control risks and minimise illness, disability and other losses to the organisation; and
- training and awareness programmes for contractors, temporary workers and visitors, according to the level of risk to which they are exposed

The effectiveness of training and the resulting level of competency should be evaluated. This may involve assessment as part of the training exercise, and/or appropriate field checks to establish whether competency has been attained, or to monitor the longer-term impact of training delivered. Training in emergency procedures should be evaluated by regular exercises in emergency prevention, preparedness and response.

2.3.3.4 Documentation and data control

Management systems need documentation but this documentation should be kept to a minimum to support the system and not to drive it. Documentation should describe the core elements of the system
and their interaction. The greater the number of procedures and the more complex the procedures and systems, the less people will follow or implement them. Simpler procedures and systems that are clearly documented increase the likelihood of implementation and success.

After the necessary documentation is established, procedures should be instituted to locate documents, to have them available at all operational locations and to review them. Obsolete documents and data should be removed promptly from all points of issue and points of use.

2.3.4 Monitoring and corrective action

Feedback is essential to success and should be used as a tool for effective communication and improving performance as opposed to apportioning blame. The monitoring or checking process consists of two major elements, performance measurement (see Section 2.6) and auditing (see Section 2.7).

Performance measurement must not just be reactive, dependent on failures, incidents or disease, but should also comprise predictive indicators that will contribute to operational controls and personnel training to prevent incidents and disease. Outcomes must be measured against pre-determined plans and standards in order for appropriate remedial action to be taken and input given for management reviews. The following are examples of methods that can be used to check that original policy and programme objectives are fulfilled:

- auditing of hazard identification, risk assessment and risk control processes
- systematic occupational health workplace inspections using checklists
- conformance evaluations of new plant, equipment, materials, chemicals, technologies, processes, procedures or work patterns
- environmental sampling — measuring exposure to chemical, biological or physical agents and comparison with recognised standards
- availability and effectiveness of personnel with recognised OH experience or formal qualifications
- behaviour sampling: assessing workers’ behaviour to identify unsafe work practices requiring attention
- analysis of documentation and records
- benchmarking against good OH practices in other organisations; and
- surveys to determine employee attitudes on the OH management system, OH practices, and employee consultation processes

Organisations must decide what to monitor and how often to monitor, based on the level of risk. The frequency of plant or machinery inspections may be defined by law but an inspection schedule based on hazard identification and risk assessment results, legislation, and regulations should be prepared as part of the OH management system.

Monitoring is a continuous process performed by front-line supervisors and middle managers. The formalised process is regarded as an audit. The objective of monitoring procedures is neither to record the number of non-conformances nor to apportion blame, both of which result in weak programmes because people will tend to hide or alter information. The objective is to capture constructive and useful procedures, established by experienced company personnel, to facilitate training and reduce the impact of experience lost when employees leave the organisation.

The formalised audit encompasses:

- **policy** — its intent, scope and adequacy
- **the organisation**, including:—
  - the acceptance of health responsibilities by line managers and the adequacy of arrangements to secure control,
  - the involvement of all employees in the health effort,
  - the communication of policy and relevant information, and
  - the competence of all employees
- **planning and policy implementation**, including:—
  - overall control and direction of the health programmes,
− standard-setting — its adequacy and relevance,
− the allocation of resources to implement standards,
− the extent of compliance with standards and their effectiveness in risk control, and
− the long term improvement in workplace/health outcomes
* measuring systems — their adequacy and relevance
* corrective action — whether allocated to specific persons, within specific periods and outcomes; and
* reviewing systems — the ability of the organisation to learn from experience and improve performance

2.3.5 Management review

Top management should periodically review the operation of the OH management system to assess whether it has been fully implemented and effective, and remains relevant. The management review should be conducted by the most senior accountable person and should be documented with the focus on overall performance rather than specific details. It is an assessment of whether “the right things are being performed” (see Appendix 2.3) as opposed to whether “things are being performed right” which is the ambit of the audit process.

In planning for a management review, consideration should be given to the following:

- topics to be addressed
- who should attend (managers, OH specialist advisors, other personnel)
- responsibilities of individual participants in respect of the review; and
- information to be brought to the review

The review should address:

- suitability of current policy
- setting or updating of objectives for continual improvement in the forthcoming period
- adequacy of current hazard identification, risk assessment and risk control processes
- current levels of risk and the effectiveness of existing control measures
- adequacy of resources (financial, personnel, material)
- effectiveness of the OH inspection process
- effectiveness of the hazard reporting process
- data relating to incidents and illnesses that have occurred
- recorded instances of procedures not being effective
- results of internal and external audits carried out since the previous review, their internal distribution through line management to all employees and their effectiveness
- state of preparedness for emergency
- improvements to the OH management system
- output of any investigations into illnesses and incidents
- assessment of the effects of foreseeable changes to legislation or technology; and
- assessment of employee perceptions of the usefulness of the system

The outputs of this review are utilised to identify action plans, agree priorities, and alter and improve the organisational policy and objectives if necessary. They should also include areas of emphasis to be reflected in future internal audits. It is vital to communicate the findings of the OH management review throughout the organisation so that relevant information reaches all employees.

2.4 International OH management system standards

The development of international standards has largely been focused on a third party certification process, following the trend adopted for quality whereby organisations would employ other accredited organisations that met specific standards. As greater focus is placed on corporate governance, so the certification of occupational health practices will become more important.

Currently, there is no universally accepted occupational health management standard and there is concern about the proliferation of management system frameworks and the differing approaches to
health and safety that is evident in different countries. Attempts to create a universally accepted standard have identified two major contenders for universal acceptance.

One initiative that provides a useful tool for both small and large organisations to establish an OH management system is that used within the International Labour Office (ILO) which utilises a model (Figure 2.3) developed by researchers at the University of Michigan.

The numbers in Figure 2.3 refer to the sequence in which the various steps would be considered when implementing a management system. However, the steps can be cyclical since knowledge elicited from later steps sometimes alters the decision/s made in previous step/s so that the previous step/s have to be revisited. This model incorporates the elements of policy, planning, implementation and operation, checking and corrective action, and management review but groups them in a slightly different manner.

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**Figure 2.3 A universal occupational health management system** (after Redinger and Dalrymple)

The other emerging guideline, representing the consensus view of several national standard-setting bodies and widely accepted within the United Kingdom and Europe, is the Occupational Health and Safety Assessment Series specification OHSAS 18001 (BSI, 1999). This standard was designed to be compatible with the ISO 9001:1994 (Quality management systems) and ISO 14001:1996 (Environmental management systems) standards, in order to facilitate the integration of quality, environmental and OH and safety management systems into one single framework. It is recommended that organisations intending to integrate their various management systems into one single system would benefit from implementing OHSAS 18001.

### 2.5 Integrated management systems

International experts consider integration of the OH management system with the other management systems within an organisation to be essential for its success. Some organisations may see benefits in complete integration of the various systems by integrating organisational structures, strategic decision-making, resource allocation, and the processes of auditing and reviewing performance. Other organisations may prefer different methods and extents of integration, depending on their size and complexity and the grouping of systems with similar management principles. However, the case for integrated management systems (IMS) appears overwhelming. The management processes in the health, safety, environmental and quality areas are, in principle, the same and are focused on
achieving designated performance standards. They typically involve some element of risk assessment, and the selection of technical, behavioural, organisational and procedural controls. Thus, integrated management is necessary at least for work procedures for health, safety, environmental and quality requirements. In addition, the OH management system must be compatible with the other management systems in the organisation. Organisations with an effective IMS should be able to perform optimally when challenged by many different risks and uncertainties. It should lead to:

- less duplication of effort
- development of procedures that are optimally designed to take into account the needs of each discipline; and
- avoidance of compartmentalisation of expertise

Although the benefits of integration are attractive, the process of integration is not straightforward. Integration could increase the complexity of systems that are already perceived as over bureaucratic. Furthermore, tension and misunderstanding may arise between specialists in occupational health and in the other areas and philosophical differences in approach could lead to damaging repercussions. Integration could also worsen the tendency for specialists in one discipline to underestimate the challenges of others. Organisations should consider in what circumstances an IMS could lead to inappropriate resource allocation, inefficiency and inflexibility. A well planned system should be efficient and allow optimal decision making in the face of a range of uncertainties. The process of integration presents distinctive challenges for different organisations and five issues should be evaluated carefully before considering integration:

- the case in favour of integrating management systems
- arguments for retaining largely independent systems
- organisational prerequisites for integration
- factors that should be considered when introducing an integrated management system; and
- the maintenance and development of an integrated management system

The British Institute of Occupational Safety and Health elaborates these issues very well in a policy document (IOSH, 1999). Organisations most likely to succeed in integrating their systems already possess multiple channels of communication founded on trust, respect for the expertise of colleagues, and confidence in the management of change.

2.6 Information management and reporting

No organisation can be efficiently and effectively managed without accurate information relating to all areas of performance. Measures of OH outcome and management activities are fundamental to decision-making and feedback. Stakeholder demands for increasing transparency are also intensifying and legislation (S11(1)(c), S12(3), S14, S15, S16, S17 MHSA) obliges employers to maintain specific records of:

- occupational hygiene measurements — risk assessment of workplace conditions
- hazardous work — where risk assessment indicates residual risk, individual employee records must be maintained of the hazard, frequency of exposure, level of exposure and length of exposure
- medical surveillance — individual records of health outcomes
- annual medical reports — an analysis of workers' health; and
- exit certificates — records received by individual employees on transfer or termination of employment and which reflect the results of all medical surveillance and the presence or absence of occupational disease

This chapter does not allow for discussion of information systems *per se.*

Lack of data and poor data quality are a common problem in the mining industry and what data are available are often impossible to combine or compare because data definitions have not been widely agreed. Policy and decision making will remain suboptimal unless there is a comprehensive process of data input, storage and retrieval of agreed performance indicators.

Operational personnel are often requested to find, collate and report data from a variety of sources and
in a specific format at short notice. If the requested data are not routinely captured, such reporting often diverts attention away from managing risk. The capture, storage and retrieval of data for policy and decision making need not require the use of computers, but paper based systems should be reserved for small operations that have simple business processes and few hazards. Without computerisation, it can be extremely difficult to produce the required number and variety of reports and the storage and retrieval requirements of paper-based systems present their own managerial problems.

Comprehensive performance support comprises four basic pillars that are shown in Figure 2.4. Only the “reference library” component will be addressed.

The “reference library” should contain information on both organisational performance (from the OH database of processes and outcomes) and external requirements (legislation, exposure standards etc.) that assist in policy and decision-making. It can be used to identify:

- operational processes and their potential hazards
- process consistency and sources of variation
- variable to be tracked and analysed
- association of variables
- trends, problems and causes; and
- the focus of intervention

Figure 2.4. Computer display illustrating a comprehensive information system

Reports should be simple and easy to read, contain performance over time compared with previously set targets and presented in a graphical format. A variety of statistical methods and graphical techniques can be utilised (See Appendix 2.2).

An example of a concise reporting format is illustrated in Fig. 2.5. The charting tools are explained in detail in Appendix 2.2.
In Figure 2.5, a problem is identified by the outcomes data for a specific workplace or work population in that the occupational exposure level (OEL) has been breached and the trend line indicates that the situation is deteriorating. Note that the actual performance is tracked (plotted) against a specified standard or target. This triggers a root cause analysis that determines the underlying factors that have created the problem and the causes are then categorised and further analysed, by Pareto analysis (see Appendix 2.2), to determine the greatest contributing factors and what intervention will provide the biggest return. Interventions are then prioritised and implemented using an action list, which allocates specific actions to specific people, within a specific timeframe. This action list can be followed up and the impact on the system measured by future trend data, which creates a feedback loop that assists continuous improvement.

In larger organisations, there may be a need for more complex reporting (Figures 2.6 and 2.7) that illustrates both sectional performance and total organisational performance in a format that is quick and easy to understand.

Figure 2.5. An operational reporting template (for details see Appendix 2.2)
Figure 2.6 Technical Occupational Hygiene compliance & adherence to statutory monitoring programme
Figure 2.7. Medical Surveillance Compliance
Figure 2.6 depicts the concentration of various occupational hazards (stressors) encountered within an industrial plant, during consecutive 3-month periods. Environmental measurements and biological monitoring results are normalised, or indexed, (see section 2.6.2) and compared with the relevant occupational exposure limits. The results are summarised per hazard (technical OH compliance per stressor), per area for all hazards within that area (technical OH compliance per area) and combined to show total company performance (company compliance). The sampling process is also monitored to ensure that the sampling strategy has been adequately followed (compliance with monitoring programme) — if it has not, the performance measures may not be an accurate reflection of workplace conditions. Similar concepts are used to report medical surveillance parameters (Figure 2.7).

The different aspects of operational performance can be rapidly determined and problem areas investigated.

2.6.1 Valid measurement of exposure and outcomes data (see Chapter 3)

Epidemiological studies have been the mainstay for hazard identification and health risk assessment. It is the study of “how” and “why” diseases are distributed in groups of people and the application of findings to control health problems. The more complex types of epidemiological studies are beyond the scope of this chapter. However, epidemiological principles should be applied to the routine operational monitoring of exposure and outcomes in order to ensure that reports provide meaningful conclusions to support policy and decision-making. Occupational health managers must ensure that:

- exposure and outcomes have been measured in a valid manner
- data has been analysed, and interpreted, using appropriate techniques; and
- linkage between exposure and outcome is valid

Clearly defined and objective criteria should be utilised to assess exposure and outcome. Exposure can be measured either by the ambient levels of a hazard in the workplace (e.g. dust concentration and silica content) or by biological sampling (e.g. blood lead). Outcome can be measured as a set of discrete events (e.g. death, onset of disease, sickness absenteeism) or a change in health status (improvement or deterioration of pulmonary function, hearing). Valid measurement requires that several fundamental questions need to be considered:

- Is the sampling method / instrument / test:
  - capable of measuring the specific hazard or outcome under investigation,
  - specific,
  - sensitive to changes in concentration or variation in what is being measured,
  - accurate,
  - repeatable,
  - precise, and
  - what is the limit of detection of the instrument?
- Whose exposure to measure
- Where to measure
- When to measure
- How long to measure
- How many samples
- How often to sample

This approach should ensure that the data produced are reliable estimates of exposure to workplace contaminants and that the outcomes estimate health status.

2.6.2 Appropriate analysis and interpretation of data (see Chapter 3)

The simplest measure is counting events, such as the number of new cases of TB, new silicosis certifications, number of visits to the clinic or the number of new cases with hearing impairment etc. Counts, however, are of limited use as comparisons cannot be made and differential risk cannot be assessed.
Comparisons require the use of rates. Rates comprise a numerator, a denominator and a constant where the numerator is total number of events or people affected, the denominator is the population at risk (all those to whom the event can happen) and the constant is often 100 so that the rate is expressed as a percentage. Note that the inputs are still counts but they are normalised. The main advantage of using rates is that the event or disease occurrence in two or more groups can be compared. Two rates commonly used in occupational health assessment and reporting are prevalence and incidence rates.

**Prevalence** is the number of events, cases of disease or other conditions in a specified population at either a specific point in time (point prevalence) or during a specified period in time (period prevalence). Prevalence rates measure the proportion of individuals at risk of having a disease or condition that actually have the condition. Prevalence rates are usually applied to chronic diseases such as HIV infection, tuberculosis and silicosis. For period prevalence rates, there may be problems in accurately defining the denominator or population at risk.

Point prevalence rate = \( \frac{\text{number of persons with disease at a specific point in time}}{\text{total number of at risk persons in the group at that time}} \)

Period prevalence rate = \( \frac{\text{number of persons with disease at any time in a specified period}}{\text{total number of at risk persons in the group midway through the period}} \)

Lifetime prevalence rate = \( \frac{\text{number of persons with disease for at least part of their lives}}{\text{total number of at risk persons in the group}} \)

**Incidence rates** measure the rate at which new events or new cases of disease occur in a population and they quantify the risk of a person developing the event or disease in a given period of observation. Incidence rates are typically used for acute diseases but are also used for chronic diseases such as silicosis, noise induced hearing loss, and tuberculosis. They are often expressed as an annual rate and the denominator is often the estimated population size at the mid-period, or an estimate of person years of exposure.

Incidence rate = \( \frac{\text{number of new cases of disease or incidences occurring in a given period}}{\text{total number of persons exposed to risk during the period}} \times 10^n \)

Prevalence and incidence should not be used interchangeably as they measure different things and cannot be compared with each other. Comparisons of occurrences or rates of different diseases should also not be used to determine the comparative disease burden on health services and loss of productivity from those diseases. For example, the point prevalence of pulmonary tuberculosis may be higher than that of the common cold but more workdays are lost each year due to the common cold than due to TB. This does not mean that TB is less disabling than the common cold or that workers use the common cold as an excuse to stay away from work. The number of work days lost reflects the incidence and cannot be related to the prevalence of the disease. Within the health services, the incidence of a disease indicates the need for acute health care, while the prevalence indicates the load on the health services in terms of ongoing or chronic care required. With tuberculosis, for example, both the point and annual prevalence are greater than its annual incidence because many of the cases diagnosed in the previous year still have the disease. With silicosis, from which a person never recovers, the prevalence is very much greater than the incidence rate. Both tuberculosis and silicosis have an impact on chronic health service delivery as well as on acute services. Influenza, however, which has a high incidence and low point prevalence because the disease is short lasting, impacts almost solely on acute service delivery.
In occupational settings, comparisons over time become meaningful only when the denominators include a consideration of the duration of exposure, or more specifically working time. Illness incidence rates and sickness absence rates are commonly used to assess hazards and behavioural characteristics. They are also important tools in the study of work conditions. For purposes of comparison, these rates can be expressed as relative measures, commonly given as frequency and severity rates.

Illness frequency = \[ \frac{\text{total number of new intervals of absence due to illness in a defined period}}{\text{Average population at risk in same period}} \]

Illness severity = \[ \frac{\text{total days of absence from illness in a defined period}}{\text{Average population at risk in same period}} \]

The illness frequency rate could also be expressed in relation to the number of person-hours worked. In the case of measuring rates per million person-hours, the expression would be:

Illness frequency = \[ \frac{\text{total number of new intervals of absence in a defined period} \times 1\,000\,000}{\text{Total number of person-hours worked}} \]

Relationships between exposure and outcome can be expressed in terms of rates of death, disease or disability across various exposure groups. There is no justification for conclusions to be based on numerator data alone. Evaluation of data should consider whether the appropriate rate has been chosen and the raw data should always be provided so that the reader can use other mathematical manipulations if desired.

Normalising, or indexing, is a technique used to reduce data to similar ranges for graphing purposes and it makes the comparison of actual data against a standard much more simple. For example, if an occupational exposure limit (OEL) of a particular contaminant were 5 mg/m\(^3\), and the actual level of contaminant measured in the workplace were 10 mg/m\(^3\), the target OEL would be shown as 1 on the vertical axis (horizontal red line on graphs in Figure 2.6) and the actual measurement would be shown as a vertical bar of vertical height 2 (vertical blue bars on graphs in Figure 2.6). Similarly, if the OEL were 2 mg/m\(^3\) and the actual level of contaminant measured were 1 mg/m\(^3\), the target would still be shown as 1 but the actual measurement would be shown as 0.5.

2.6.3 Validation of linkage between exposure and outcome

One of the important uses of epidemiology is to test whether a certain exposure (e.g. manganese spray) increases the risk of a health outcome (e.g. hemiballismus). This necessitates the measurement of the likelihood of this outcome in both exposed and unexposed groups. If the likelihood of the outcome is statistically dependent on exposure, an association is said to exist between the two.

The commonest way of comparing risk between exposure groups is to obtain the relative risk or risk ratio.

Relative risk = \[ \frac{\text{Incidence rate in exposed}}{\text{Incidence rate in unexposed}} \]

The difference in the rate between those exposed and those not exposed to an assumed risk factor is a measure of the rate of disease that can be attributed to the exposure. However, other factors, apart from occupational exposure, can influence disease rates and it may be important to account for these when trying to link disease with exposure. For example, the difference in disease rates between two groups could be the result of differences in age distribution as opposed to exposure and two commonly used statistics are age-adjusted mortality rates and the standardised mortality ratio. These statistics are unlikely to be used by occupational health practitioners in the mining industry and so will not be expanded on.
2.7 Auditing

Regulatory requirements are becoming increasingly complex and the penalties for non-compliance can be significant (S [92] MHSA). Boards of directors may face liability for poor health performance and need some process to demonstrate that they have been diligent in exercising their responsibilities, often in operations that they do not know intimately. Thus audits are used as a key management tool in assessing the strengths and weaknesses of management systems for occupational health. In addition, inspectors of the Department of Minerals and Energy may utilise the audit process to monitor compliance with the Mine Health and Safety Act.

Auditing is a systematic process that is based on the collection and documentation of sufficient objective evidence, rather than on an opinion based primarily on professional judgement. It involves analysis, confirmation of procedures and practices and the reporting of findings, in order to verify whether a facility or organisation is complying with regulatory or other legal requirements and/or internal company policies, procedures and practices.

It is important to distinguish between “doing things right” and “doing the right things”. Although both are required to ensure continual improvement, without the latter there can be no improvement in OH outcomes. Compliance audits generally address the former and highlight only non-conformances against an established standard, policy or procedure. Audit does not highlight “best practices”, nor will it provide recommendations for improvement, or provide an indication of root causes, the failures of the management systems that give rise to non-conformances. The latter requires a management system assessment.

Compliance audits are generally facility focused, bottom up assessments of conformance to established criteria. The process must be rigidly structured and the findings are primarily based on exceptions to, or deviations from, the established criteria. By contrast, management system assessments are systems orientated and are top down assessments. They are concerned with the quality of system design, the effectiveness of the implementation of technical programmes and the competence and adequacy of resources. The focus of the assessment is to identify underlying weaknesses, the root causes, which can present an unacceptable level of risk to an organisation. Reporting recommendations are optional in compliance auditing, the presentation of recommendations to correct deficiencies is the primary purpose of assessment of management systems.

While there are a number of parallels between the two, management system assessments require their own particular methods. A suggested assessment tool is provided in Appendix 2.3. The emphasis is far less on the application of tests for conformance to elements of technical programmes but relies much more on professional judgement, based on experience. The assessment tool (see Appendix 2.3) uses both assessment criteria (Table 2.3) and risk ranking to determine interventions and their prioritisation.

2.7.1 Audit programming and planning

Before undertaking any audits, there are several considerations that must be addressed.

It is important to determine the frequency and design of the audits. The frequency of an audit is normally determined by the level of operational risk; the higher the risk, the more frequent the audit. The design of the audit may differ depending on the question that needs to be answered: Is it an attempt to address an identified concern, or is the intent to carry out a broad evaluation of OH issues across the organisation? Is this a tool to assist management to address local concerns, or a mechanism to assess the effectiveness of management? Answers to these questions alter the scope, focus and approach to a specific audit. Audit flexibility is required to cover either the whole OH management system or selected elements of the system, as necessary.

The scope is defined in terms of the organisational context, operational boundary, functional scope and jurisdictional context. The organisational context considers the business units, operations or departments that are to be included within the scope of the audit. These will be dependent on the purpose of conducting the audit, the organisational structure of the company, corporate considerations.
and risk profile of operations. The operational boundary addresses whether the audit is confined to the facility boundaries, or whether it incorporates off site warehousing, suppliers and contractors. The functional scope can cover all aspects of OH management or address only occupational hygiene or medical surveillance or information systems. The jurisdictional context addresses the standards against which the organisation will be assessed; regulatory requirements, company policy, operational procedures, or international standards.

2.7.2 Conducting audits

There are several steps in a typical audit process that can be conveniently discussed in three broad categories; activities prior to visiting the site, on site activities, and completion of the audit (Figure 2.8).

![Figure 2.8 Typical audit process](image)

The audit programme will already have established the scope and focus of the audit unless the audit is a response to an unplanned or unforeseen event, for example, a sudden deterioration in workplace conditions or increase in occupational illness. Prior to stepping on site, the audit team leader has to undertake several tasks. The actual audit process commences with scheduling the audit with affected management for a specific start date and completion date. The audit team is then chosen with a balanced blend of skills to perform the job efficiently and effectively and their availability secured.

The gathering of background information is an efficient means of decreasing disruption to the business process and provides a more focused audit. A pre-audit questionnaire should be forwarded at least two to three weeks in advance of the audit, requesting the following information:
• recent regulatory inspections/enforcement correspondence, if any
• recent internal audit reports
• occupational health policies and procedures
• current organisational chart, depicting roles and responsibilities for OH management
• facility plans/maps
• description of operations, including identified hazards and risk control systems
• statistics — health outcomes, workplace conditions; and
• list of primary contractors on site

After the background information has been analysed, a specific audit protocol can be adopted. It will define each aspect of occupational health that has to be assessed, and will provide guidance to each auditor on the evidence to be evaluated. The protocol should reference the regulation, company standard or other procedure. This cannot be regarded as a rigid tool as no protocol can be fully comprehensive and team members should be able to determine important issues that are not addressed.

The actual approach to the audit involves the determination of how the audit will be conducted, how long will be required for the fieldwork, how quality and consistency will be maintained, what audit guides will be utilised and how the audit findings will be recorded and reported. This planning assigns responsibilities to audit member so that each person understands exactly what is expected of them and determines the audit timing. For example, assessment relies on three principal means of data collection:

• personal interviews
• physical observations; and
• document reviews

However, the amount of time spent on these activities is quite different between a compliance audit and the assessment of management systems (Figure 2.9).

![Figure 2.9 Utilisation of time in audits](image)

In management system assessment, considerably more time is spent on interviewing personnel throughout the organisation, and the analysis of findings and observations takes almost as much time as the fieldwork.

On site activities follow a five step process. Each step contains activities that are designed to produce specific outcomes as delineated in Table 2.2.
Table 2.2 Audit steps

<table>
<thead>
<tr>
<th>Step</th>
<th>Principal activities</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Understand the management system</td>
<td>Opening meeting, Site tour, Initial interviews, Document review</td>
<td>Working knowledge of key systems on site, Identification of key issues to review</td>
</tr>
<tr>
<td>2. Assess strengths and weaknesses of internal controls</td>
<td>Review of step 1 information, Audit team meetings</td>
<td>Develop verification strategies, Reallocate audit resources, if required, Identify risks and management system weaknesses</td>
</tr>
<tr>
<td>3. Gather audit evidence</td>
<td>Physical inspections, Focused interviews, Data and record examination, Verification testing</td>
<td>Analyse site programmes, Develop evidence to substantiate findings, Confirm status of compliance</td>
</tr>
<tr>
<td>4. Evaluate audit findings</td>
<td>Review data collected, Review factual accuracy of findings, Analyse/integrate findings</td>
<td>Prepare draft findings, Confirm accuracy, Identify potential root causes</td>
</tr>
<tr>
<td>5. Report audit findings</td>
<td>Daily debrief meetings, Close-out meeting</td>
<td>Early, clear, consistent communication, Understand facility concerns, Prepare preliminary draft report</td>
</tr>
</tbody>
</table>

The assessment of management systems focuses on the quality of process design and the effectiveness of implementation that are highly subjective. Sensitivity can be largely removed by assigning clear criteria to the characteristics required of each process (Table 2.3).

Table 2.3 Setting objective criteria

<table>
<thead>
<tr>
<th>Process attribute</th>
<th>Needs improvement</th>
<th>Meets expectations</th>
<th>Significant strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appropriate scope, coverage</td>
<td>Some, not all applicable requirements</td>
<td>All applicable legal requirements</td>
<td>Applicable legal requirements, company policies and standards</td>
</tr>
<tr>
<td>Clear ownership, assignment of responsibilities</td>
<td>Occupational health staff driven</td>
<td>Line managers accountable</td>
<td>Line management driven</td>
</tr>
<tr>
<td>Reliability, reproducibility of results</td>
<td>Uneven, poor data</td>
<td>Mostly in compliance</td>
<td>Compliance routinely achieved, strong systems in place</td>
</tr>
<tr>
<td>Utility, value of results</td>
<td>Typically not measured, managed</td>
<td>Routinely measured, low management value</td>
<td>Measured, managed, drive continuous improvement</td>
</tr>
<tr>
<td>Efficiency, cost-effectiveness</td>
<td>Heavy occupational staff use, every time non-routine</td>
<td>Sub-process defined, performance improvements possible with fewer resources devoted</td>
<td>Sub-process streamlined, operations staff well leveraged</td>
</tr>
<tr>
<td>Flexibility in identifying, handling exceptions</td>
<td>Loose inspection, poor follow-up</td>
<td>Effective inspection, persistent exceptions</td>
<td>Strong root cause assessment, treat root causes</td>
</tr>
</tbody>
</table>

Furthermore, impressions should be tested by interviewing representatives of all levels of line management and staff throughout the organisation.

Having gathered the evidence and evaluated the findings, the most important aspect of the post-site activities is developing an audit report that is clear and concise and provides information with which management can initiate corrective action.
A typical report will have the following structure:

- **Executive Summary** describes the most important findings, particularly those that may present significant liability or are indicative of a serious failing in the management system.
- **Introduction** describes the purpose, scope and methodology of the audit and any aspect included in the original scope that was not addressed and the reason why.
- **Findings** which should not be directed at individuals, as this creates a blame mentality, but rather focused on the management system or technical programme; and
- **Conclusion** which should compare findings with previous audits and comment on whether or not the OH management system is complying with legislation, achieving continual improvement and effective in meeting the organisation’s policy and objectives.

Compliance audits largely focus on non-conformance to legislation or company policies, standards and procedures. Assessment of the management system, however, evaluates not only the elements of the management system but also how well expectations have been communicated throughout the organisation, how well they are understood and the level to which they are actually implemented. Findings are focused on root causes of deficiencies, for example:

- A lack of clear policy and expectations
- Insufficient commitment by senior management
- Lack of line management accountability
- Inappropriate OH organisation
- Confused roles and responsibilities
- Inadequate resources
- Occupational health activities not aligned to business requirements
- Ineffective training and awareness
- Lack of procedural guidance
- Failure to periodically measure performance; and
- Failure to take appropriate action or follow up etc.

The auditor can never expect to know the business being assessed as well as the management team responsible for the operation does. Recommendations should, therefore, be directional rather than firm, and focus on what needs to be done, rather than providing advice on how to achieve it.

Audits can drive the process of continuous improvement providing that a systematic approach is implemented and that findings are utilised to improve the management system and technical programmes as opposed to “blame finding.”

### 2.8 Guide to information resources

#### Useful reading

CD-ROM databases

The following may provide useful information on the assessment and management of occupational health risk.

1. CHEMINFO

A database available from the Canadian Centre for Occupational Health and Safety (CCOHS), which provides details of the health effects of chemicals, personal protective equipment, trade names and regulatory requirements. Although the regulatory information relates to Canadian legislation, the health hazard information is applicable in any country.

2. OSH-ROM

A bibliographic database produced by SilverPlatter Information Limited that incorporates six databases. CISDOC, produced by the International Labour Office Health and Safety Centre, covers references from many countries. These include legislation, research results, materials and chemical safety data sheets, conference proceedings and journal articles.

RILOSH, produced by the Ryerson Technical University, Toronto, covers a wide range of references from worldwide resources with an emphasis on American and Canadian information.

OEM, is a subset of the US National Library of Medicine information and covers references in occupational and environmental medicine.

HSELINE, produced by Health and Safety Executive (HSE) Information Service, UK, contains worldwide information relating to codes of practice, EU directives and HSE requirements.

NIOSHTIC, produced by the National Institute for Occupational Safety and Health, USA, contains reference to NIOSH documents such as occupational hazards assessments, special hazard reviews, analytical methods and occupational health recommendations.

MHIDAS, developed by AEA Technology Ltd., UK, provides summaries of major chemical accidents and incidents that have occurred worldwide.

3. RTECS (Registry of Toxic Effects of Chemicals)

This is the computerised version of the NIOSH compendium of toxicity data and is available from CCOHS. It gives information on the toxic effects of chemicals, health hazards and mutagenic and carcinogenic data. It is also available with four other chemical databases on CHEMBANK produced by SilverPlatter.

4. TOXLINE

This is produced by the USA National Library of Medicine and supplied by SilverPlatter and CCOHS. It is an international bibliographic database containing toxicological information published in journals, books and reports, dated from 1966 to present.

Software packages

The following illustrates software packages that may assist occupational health professionals in the conduct of workplace assessment and in the recording and analysis of the data collected.

1. AIMS — Accident information management system

Records accidents, diseases and dangerous occurrences. Analyses incidents to reveal patterns.
Supplier: Deltasoft Ltd.
PO Box 107, Tasburgh, Norwich, Norfolk NR15 1QT
Tel: +44 707 1233234
Fax: +44 707 1250910

2. ARRAN, AUDIT, RISK, COSHH
Four systems covering accident reporting and analysis, health and safety auditing, quantified risk assessment and control of hazardous substances.
Supplier: Norton Waugh Computing Ltd.
The Old School, Weston-under-Lizard, Shifnal, Shropshire TF11 8SZ
Tel: +44 195 2850333
Fax: +44 195 2850649

3. DNV PRO
Hazard study software for hazard and operability (HAZOP) studies, failure mode effect analysis (FMEA), “what if?”, checklists and audit.
Supplier: DNV TECHNICA
Palace House, 3 Cathedral Street, London SE1 9DE
Tel: +44 171 3576080
Fax: +44 171 3577297
www.dnv.com/technica

4. EQS_INFORMATION MANAGEMENT SOFTWARE
Consists of three core components, together with the management facility, which manages common information. An integrated management system, designed to facilitate and promote management systems compliance to ISO 9000, ISO 14000 and OHSAS 18000
Supplier: Granherne Information Systems Ltd.
Chester House, 78-86 Chertsey Road, Woking, Surrey GU21 5BJ
Tel: +44 148 3729661
Fax: +44 148 3750418
e-mail: ashar@granherne.co.uk

5. PSI — PERFORMANCE SUPPORT INTERNATIONAL
Risk management — risk assessment, incident/event reporting and analysis and corporate stress management
Supplier: PSI Ltd
6-16 Huntsworth Mews, London NW1 6DD
Tel: +44 171 7248599
Fax: +44 171 7248627

6. SHE6 — SAFETY HEALTH AND ENVIRONMENT MANAGEMENT SOLUTIONS
Extensive database analysis with full management graphics covering risk assessments, incident/accident reporting and audit functions.
Supplier: Lexware International Ltd.
Brunel Building, Scottish Enterprise Technology Park, East Kilbride G75 0QD
Tel: +44 135 5272444
Fax: +44 135 5272445
www.dnv.com/technica
e-mail: mail@lexware.co.uk
Appendix 2.1

Reporting format, terms and definitions

Format of Occupational Health reporting Form

To measure the success of interventions designed to improve workplace conditions and reduce and eliminate illness, death and disability, performance indicators have traditionally been based on the frequency and severity of failures. Some deem this to be the final arbiter of success or failure whereas others regard this as negative reporting and have attempted to define indicators that can track system improvements. The latter are still in their infancy as it is difficult to measure what does not happen and a tremendous amount of research still has to be undertaken. Therefore, only the former indicators will be included here.

Emergency reporting provides corporate entities or head offices with the facts relating to the crisis, steps that have been taken to address the incident and prevent a recurrence and possible lessons that have been learned. It is designed to disseminate information that can be used elsewhere to prevent similar incidents and is more commonly utilised for safety reporting than OH issues.

Quarterly reporting provides a means of tracking operational improvements and comparing performance with other operations in an attempt to identify “best practice” and learn from it. However, different operations often have contrasting reporting formats and practices that create difficulties when attempting to compare OH performance. Benchmarking requires agreement on what items should be benchmarked, common data definitions and an agreed statistical basis for calculation of rates. One proposed format is provided overleaf and requires the capture and storage of specific information as follows:

Name of Organisation: Indicate reporting operation

Reportable business or operation: The decision to include any business or operation from a corporate or head office perspective should be based on the degree of management influence exercised over the operation. The following suggestions are made regarding exclusion or inclusion in reporting.

<table>
<thead>
<tr>
<th>Scope of influence</th>
<th>Equity holding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company managed</td>
<td>100% Include</td>
</tr>
<tr>
<td>Provision of senior management — operating service agreement</td>
<td>Include Include Include</td>
</tr>
<tr>
<td>Provision of advice — technical service agreement</td>
<td>Include Include Exclude</td>
</tr>
<tr>
<td>No provision of advice or service agreement</td>
<td>Include Exclude Exclude</td>
</tr>
</tbody>
</table>

Reporting Period: Indicate the period covered by the report

Terms and Definitions

Data definitions ensure that the base data includes or excludes specific incidents and illness in a pre-defined manner. Therefore data captured over time will be comparable. These definitions were developed a priori in an effort to reduce the number of loopholes that can distort reporting. However, cognisance was taken of various definitions used by mining directorates in the USA, Europe, Australia and South Africa and those used by the ILO.

Terms and definitions used in the reporting sheet are listed in alphabetical order for easy convenience
## OCCUPATIONAL HEALTH REPORTING

<table>
<thead>
<tr>
<th>OPERATIONAL PROCESS</th>
<th>POPULATION REPORTED</th>
<th>NO. OF PERSONS AT WORK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mining:</td>
<td>Metalliferous Employees only</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non Metalliferous</td>
<td></td>
</tr>
<tr>
<td>Refining/Smelting</td>
<td>Employees &amp; Contractors</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### HYGIENE¹ HAZARD

<table>
<thead>
<tr>
<th>Dust</th>
<th>Noise</th>
<th>Heat</th>
<th>(Name)</th>
<th>(Name)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of persons exposed to &gt;50% of OEL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total number of persons exposed to hazard</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### CLASSIFICATION

<table>
<thead>
<tr>
<th>Skin diseases and disorders</th>
<th>Fatalities</th>
<th>Lost Time Cases</th>
<th>Non Lost Time Cases</th>
<th>Lost days</th>
<th>Restricted Work Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dust diseases of the lungs (incl. TB)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiratory condition due to toxic agents</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poisoning (systemic effects of toxic materials)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disorders due to physical agents</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disorders associated with repeated trauma</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other illnesses and disorders</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### RATES

<table>
<thead>
<tr>
<th>FFR</th>
<th>LTIFR</th>
<th>TRIFR</th>
<th>Severity</th>
</tr>
</thead>
</table>

¹ Indicate the type of hazard. OEL is the abbreviation for occupational exposure limit.
Definitions for Completion of Occupational Health Report

Categorisation: Categorisation enables operations to better target interventions as it could provide some idea of the root cause of the process. Aggregated data hides valuable detail.

Classification of Illness/Disease: Classification integrates both the target organ and the cause of illness

• Skin diseases & disorders: Examples: contact dermatitis, allergic dermatitis, rash caused by primary irritants and sensitisers or poisonous plants, oil acne, chrome ulcers, chemical burns or inflammations

• Respiratory conditions due to dust: Examples: silicosis, asbestosis, coal workers’ pneumoconiosis and tuberculosis associated with silica exposure

• Respiratory conditions due to toxic agents: Examples: pneumonitis, bronchitis, alveolitis, asthma, pharyngitis, rhinitis or acute congestion due to chemicals, gases or fumes

• Poisonsing (Systemic effects of toxic materials): Examples: pathological effects of lead, mercury, arsenic, cadmium and other metals, carbon monoxide, hydrogen sulphide or other gases, solvents, pesticides, formaldehyde, plastics and resins

• Disorders due to physical agents: Examples: heatstroke, heat exhaustion, sunstroke, freezing, frostbite, caisson disease, ruptured eardrums due to high atmospheric pressure, effects of ionising (isotopes, X-rays, radium) and non-ionising (welding flash, ultraviolet rays, microwaves, sunburn) radiation

• Disorders associated with repeated trauma: Examples: noise induced hearing loss, synovitis, tenosynovitis, bursitis, Raynaud’s phenomenon, other disorders of musculoskeletal system and connective tissue associated with repeated trauma

• Other illnesses and disorders:
  • Disorders due to mental stress: Examples: tension headache, depression, neurosis, functional disorders of the gastrointestinal tract
  • Cancers & malignant blood diseases: Examples: mesothelioma, bladder cancer, leukaemia and other malignant diseases of blood and blood forming organs
  • Other: Examples: benign tumours, eye conditions due to dust & toxic agents, other non malignant diseases of blood and blood forming organs

Contractor: Any person who undertakes work at an operation, in a part-time or full-time capacity, but is not permanently employed by that operation.

Employee: Any person who is employed or working at a mine.

Fatalities: A death resulting from an occupational illness or disease, regardless of the time intervening between the beginning of the illness or disease and the occurrence of the death. No lost days should be attributed to a fatality.

Hours at work: The total number of hours worked including overtime and training. Leave, sickness and other absences should be excluded. If actual hours are not available, an estimate should be based on scheduled work.

Hygiene hazard: This refers to any workplace stressor that has the potential of resulting in a harmful effect on the health of workers, or cause discomfort, through short term or long term exposure e.g. dust, noise, heat, manganese, chrome, cyanides, radiation. Indicate the relevant hazard/s in the cells (boxes) provided.
**Lost Days:** The total number of calendar days that the ill or diseased person is not at work, excluding the day of onset of illness or disease, will be recorded as lost days. Lost days should be accumulated until the ill or diseased person can resume the full duties of his/her regular work, or is assigned to restricted work activities or is assigned to another designation on a permanent basis and able to perform the full duties of the alternative designation or is medically discharged from the company.

**Lost Time Cases:** Any occupational illness or disease that renders the person unable to perform the full duties of his/her regular work on the next calendar day (including weekends and public holidays), after the day of the illness, is to be recorded as a lost time case. Persons categorised as restricted work cases (light duties etc.) are regarded as lost time cases.

**Non Lost Time Cases:** Any work-related illness or disease that does not prevent the person returning to his/her regular work on the next calendar day (including weekends and public holidays), after the day on which the illness or disease was reported.

**Occupational vs. Non occupational:** Occupational health statistics are designed to reflect fatalities, illness or disease arising out of or in connection with work processes and do not reflect issues not directly related to the workplace. Occupational incidents should include those related to travel or transport in which employees are involved and which arise out of, or in the course of, work; (i.e. at work, or otherwise carrying on the business of the employer).

Non occupational incidents include those:

- travel incidents occurring on the habitual route, in either direction, between the place of work or work related event and an employee’s place of residence
- illness or disease endemic or epidemic to a geographical position and not resulting from production processes

**OEL or Occupational Exposure Limit:** Refers to airborne concentrations of chemical agents and levels of physical agents, and represents conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse effect. OEL’s may be found in national regulatory documentation but arguably the most generally recognised are the Threshold Limit Values (TLV) published by the American Conference of Governmental Industrial Hygienists (ACGIH).

The OEL is regarded as the time-weighted average concentration for a normal 8-hour workday and a 40-hour work week, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect. It is not the short-term exposure limit or ceiling values.

It is recognised that OELs change as the burden of scientific evidence over time may indicate that “safe” levels should be lowered and that different scientific bodies may not even agree on the so called “safe” level. Furthermore, different limits could be legislated at different times making comparison difficult. However, there does not appear to be a more useful indicator of hygiene quality at present.

**Occupational injury vs. occupational illness:** Whether a case involves a work injury or illness is determined by the nature of the original event or exposure that caused the case, not by the resulting condition of the affected employee. The basic determinant is the single incident concept.

Occupational injuries result from a single event or a number of events close together in time. For example, a one time blow that damages the tendons of the hand is considered an injury whilst repeated trauma or repetitious movement that produces tendonitis is considered an occupational illness.

**Operational Process:** Tick the box to which the supplied data refers so that data is not aggregated between operations that have inherently different risk profiles. One organisation could submit up to three separate subsets of data that cover the different categories of operational process within that organisation.

**Persons at work:** Refers to the average number of full time or part time employees on site during the reporting period.
Population reported: Some companies make extensive use of contractors on site but report only those figures relating to employees. Operations should include contractor figures where possible as they are an intimate part of the business and form part of the occupational risk. Tick the appropriate box.

Rates: The formulae for OH metrics are provided below. The denominator can be altered to suit the requirements of the report but the raw numbers underlying the metrics should be reported so that the figures can be presented in an alternative manner should it be desired.

- **Fatality frequency rate (FFR):** the number of fatalities per million person-hours worked
  \[
  FFR = \frac{\text{no. of fatalities}}{\text{total working hours}} \times 1\,000\,000
  \]

- **Lost time illness frequency rate (LTIFR):** the number of the lost time cases per million person-hours worked
  \[
  LTIFR = \frac{\text{no. of lost time cases}}{\text{total working hours}} \times 1\,000\,000
  \]

- **Total recordable illness frequency rate (TRIFR):** the sum of fatalities, lost time and non lost time cases per million person hours worked
  \[
  TRIFR = \frac{\text{no. of cases (fatal + lost time + non lost time)}}{\text{total working hours}} \times 1\,000\,000
  \]

- **Severity rate:** the total number of lost days and restricted workdays, resulting from illness, divided by the total number of lost time cases
  \[
  \text{Severity} = \frac{\text{lost days + restricted work days}}{\text{no. of lost time cases}}
  \]

Restricted Work Days: The total number of calendar days, for which work activity is restricted, counting from the day of starting restricted work, will be recorded as restricted workdays. Restricted workdays will be accumulated until the ill or diseased person is able to perform the full duties of his/her regular work or is assigned to another designation on a permanent basis and is able to perform the full duties of the alternative designation or is medically discharged from the company.

When work activities are restricted, following a period of lost days, the restricted workdays are to be recorded in addition to the number of lost days, but the occupational illness is recorded as a single lost time case only.

**Workplace 50 exposure:** the percentage of the workforce exposed to greater than 50% of the OEL, for a specific hazard

\[
\text{Workplace 50 exposure} = \frac{\text{no. of persons exposed >50\% of OEL}}{\text{total no. of persons exposed}} \times 100
\]

This could also be expressed as the **workplace exposure frequency** that is the number of persons exposed to greater than 50% of the OEL per million person-hours worked

\[
\text{Workplace exposure frequency} = \frac{\text{no. of persons exposed >50\% of OEL}}{\text{total working hours}} \times 1\,000\,000
\]
Appendix 2.2

Charting Tools

What does the process look like?
The use of process flow charts is helpful as the physical and chemical business processes are concisely defined. Potential hazards can be relatively easily identified.

Where does the process stand? What are the trends?
A simple frequency chart can be used to study observed data of a process performance measure or outcome over time.

Is the process predictable? What are the sources of variation?
A control chart can be used to monitor, and improve process performance over time by studying variation against a target (UCL) or within various parts of a process.

How can a distinct variable in the process be tracked & analysed?
A histogram can summarise data into a frequency distribution from which the centre, spread and shape of outcomes can be viewed.
Are the variables connected?

A scatter diagram can indicate relationships between the changes observed in two sets of variables. For example, the frequency of silicosis within a particular work area compared against silica dust levels in that same area.

What is causing the problem?

A cause and effect diagram is useful in identifying, exploring and graphically displaying in increasing detail all possible causes related to a specific problem or condition.

What should be the focus?

Pareto charts provide a focus on those problems that offer the greatest potential for improvement by showing their relative frequency in a descending bar graph. Alternatively a pie chart can be utilised.
## Appendix 2.3

Criteria for reviewing and auditing management systems

<table>
<thead>
<tr>
<th>ISSUES</th>
<th>ASSESSMENT</th>
<th>RISK RANKING</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Policy</td>
<td>I E S L M H</td>
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</tr>
<tr>
<td>• Is there an occupational health policy?</td>
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<tr>
<td>• Were the employees involved in formulating the policy?</td>
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<tr>
<td>• Is the policy documented, implemented and maintained?</td>
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<tr>
<td>• Does the policy consider occupational health impacts in all business practices and decision-making?</td>
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<tr>
<td>• Is it based on the systematic identification of hazards and the control of risk?</td>
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<tr>
<td>• Does the policy include a commitment to at least comply with current applicable occupational health legislation and with other requirements to which the organisation subscribes?</td>
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<tr>
<td>• Has top management made available adequate resources to create the appropriate organisational structure that supports risk control?</td>
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<tr>
<td>• Has the policy been communicated to all employees and are employees made aware of their individual obligations?</td>
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<tr>
<td>• Is the policy available to interested parties?</td>
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<tr>
<td>• Is the policy reviewed periodically to ensure that it remains relevant and appropriate to the organisation?</td>
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<tr>
<td>• Is there a commitment to continual improvement?</td>
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<tr>
<td>• Is it appropriate to the nature and scale of the organisation’s risk?</td>
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</tbody>
</table>

I = needs improvement  
E = meets expectations  
S = significant strength  
L = low  
M = medium  
H = high
<table>
<thead>
<tr>
<th>ISSUES</th>
<th>ASSESSMENT</th>
<th>RISK RANKING</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLANNING</td>
<td>I</td>
<td>E</td>
<td>S</td>
</tr>
<tr>
<td>• Does the plan identify objectives and targets for their achievement within a specific period?</td>
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</tr>
<tr>
<td>• Are there set performance standards for management actions designed to initiate, develop, maintain and improve the manner in which people apply themselves in four key areas — control, competence, communication and co-operation?</td>
<td></td>
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<tr>
<td>• Are there set performance standards for the control of risks both to employees and to others who may be affected by the organisation’s activities, products and services?</td>
<td></td>
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<tr>
<td>• Are the performance standards for the control of risks based on hazard identification and risk evaluation, taking legal requirements as the minimum acceptable standard of performance?</td>
<td></td>
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<tr>
<td>• Is the elimination of risks by the substitution of safer premises, plant or substances emphasised?</td>
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<tr>
<td>• Are priorities established for the provision and maintenance of control measures by the use of risk assessment techniques, giving priority to high-risk areas and adopting temporary control measures to minimise risks where satisfactory control cannot be achieved immediately?</td>
<td></td>
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<tr>
<td>• Does the plan address monitoring of the above actions to ensure both the effectiveness and timeliness of their implementation?</td>
<td></td>
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<tr>
<td>• Is the plan amended when changes to the activities, products, services, or operating conditions of the organisation occur?</td>
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<tr>
<td>• Does the plan ensure the adequate documentation of all performance standards — the detail of documentation reflecting the degree of risk.</td>
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</tr>
</tbody>
</table>

I = needs improvement  
E = meets expectations  
M = medium  
S = significant strength  
H = high
<table>
<thead>
<tr>
<th>ISSUES: IMPLEMENTATION &amp; OPERATION</th>
<th>ASSESSMENT</th>
<th>RISK RANKING</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Does the operation secure control by ...?</td>
<td>I E S L M H</td>
<td></td>
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<tr>
<td>* managers who lead by example?</td>
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<tr>
<td>* clear allocation of responsibilities for policy formulation and development; for planning and reviewing health activities; for the implementation of plans; and for reporting on performance</td>
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<tr>
<td>* the allocation of occupational health responsibilities to line managers with specialists acting as advisers</td>
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<tr>
<td>* the allocation of health responsibilities to people with necessary authority and competence who are given the time and resources to carry out their duties effectively</td>
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<tr>
<td>* ensuring that individuals are held accountable for their health responsibilities and are motivated by systems of target setting and positive reinforcement</td>
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<tr>
<td>* the provision of adequate supervision, instruction and guidance</td>
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<tr>
<td>* instituting payment and reward systems, which avoid conflict between achieving, output targets and health requirements</td>
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<tr>
<td>* establishing and maintaining procedures related to the identified risks of goods, equipment and services purchased and/or used by the organisation</td>
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<tr>
<td>* establishing and maintaining procedures for the design of workplace, process, installations, machinery, operating procedures and work organisation, including their adaptation to human capabilities, in order to eliminate or reduce risks at their source</td>
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</tbody>
</table>

I = needs improvement  
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M = medium  
S = significant strength  
H = high  
L = low
### IMPLEMENTATION & OPERATION (cont)

<table>
<thead>
<tr>
<th>ISSUES</th>
</tr>
</thead>
</table>
| - Does the operation encourage **participation and co-operation** of employees and health and safety representatives by ....?  
  * involving them in policy formulation and development and in planning, implementing, measuring, auditing and reviewing performance  
  * making arrangements for involvement at the operational level to supplement more formal participative arrangements  
  * establishing and maintaining procedures related to the identified risks of goods, equipment and services purchased and/or used by the organisation  
- Does the operation secure effective **communication** by means of visible behaviour, written material and face-to-face discussion?  
- Is this communication extended to suppliers and contractors?  
- Does the organisation ensure **competence** through recruitment, selection, placement, transfer and training and the provision of adequate specialist advice?  
- Is there a systematic programme of induction and ongoing training instituted for all individuals who manage employees, contractors and others (e.g. temporary workers), in their occupational health responsibilities?  
- Is the training provided before any work commences?  
- Does the training programme address....?  
  * the organisation’s occupational health arrangements and the individuals’ specific roles and responsibilities for them.  
  * hazards, risks, precautions to be taken and procedures to be followed  
  * hazard identification, risk assessment and risk control.  
  * specific in-house or external training that may be required for employees with specific roles in the OH system, including employee OH representatives |

<table>
<thead>
<tr>
<th>ASSESSMENT</th>
<th>RISK RANKING</th>
<th>COMMENTS</th>
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<td>I</td>
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| I = needs improvement | L = low  
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<th>ASSESSMENT</th>
<th>RISK RANKING</th>
<th>COMMENTS</th>
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</thead>
<tbody>
<tr>
<td>CHECKING &amp; CORRECTIVE ACTION</td>
<td>I</td>
<td>E</td>
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<tr>
<td>• Are there active monitoring systems that ....?</td>
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<tr>
<td>* measure the achievement of objectives and specified standards</td>
<td></td>
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<tr>
<td>* reflect risk control priorities by concentrating on high-risk activities that are monitored in more depth and/or more frequently</td>
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<tr>
<td>• Are there reactive monitoring systems that collect and analyse information that could suggest failures in health performance?</td>
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<tr>
<td>• Does the system report ....?</td>
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<tr>
<td>* cases of ill health</td>
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<tr>
<td>* incidents that had the potential to cause ill health</td>
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<tr>
<td>* hazards and workplace risk assessment</td>
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<tr>
<td>* weaknesses or omissions in performance</td>
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<tr>
<td>• Do the reporting and response systems ensure that the information from active and reactive monitoring is evaluated by people competent to identify situations that create an immediate risk to health and to ensure that appropriate remedial action is taken?</td>
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<tr>
<td>• Do the investigation systems ensure that ....?</td>
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<tr>
<td>* priority is given to those circumstances which present the greatest risk</td>
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<tr>
<td>* both immediate and underlying causes of events are identified</td>
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<tr>
<td>* information is referred to the level of management with authority to initiate the necessary remedial action, including organisational and policy changes</td>
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<tr>
<td>* there is adequate analysis of all collected data to identify common features or trends and initiate improvements</td>
<td>I = needs improvement</td>
<td>E = meets expectations</td>
<td>S = significant strength</td>
</tr>
<tr>
<td>ISSUES</td>
<td>ASSESSMENT</td>
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<td>I  E  S</td>
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<tr>
<td>MANAGEME NT REVIEW</td>
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<tr>
<td>• Does the review address ....?</td>
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<tr>
<td>* suitability of current policy</td>
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<tr>
<td>* an assessment of the effects of foreseeable changes to legislation or technology</td>
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<tr>
<td>* adequacy of current hazard identification, risk assessment and risk control processes</td>
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<tr>
<td>* current levels of risk and the effectiveness of existing control measures</td>
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<tr>
<td>* adequacy of resources (financial, personnel, material)</td>
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<tr>
<td>* the integration of the elements of occupational health management into other key functions of the organisation</td>
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<tr>
<td>* the effectiveness of the occupational health surveillance process</td>
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<tr>
<td>* the effectiveness of the hazard reporting process</td>
<td></td>
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<tr>
<td>* data relating to workplace conditions and disease that have occurred</td>
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<tr>
<td>* recorded instances of procedures not being effective</td>
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<tr>
<td>* results of internal/external audits completed since the previous review and their effectiveness</td>
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<td>* the state of preparedness for emergency</td>
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<tr>
<td>* improvements to the occupational health management system</td>
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<tr>
<td>* output of any investigations into workplace conditions or disease</td>
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<tr>
<td>* setting or updating of objectives for continual improvement in the forthcoming period</td>
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<tr>
<td>• Are the findings of the review available to all stakeholders and disseminated to all employees?</td>
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</table>

I= needs improvement  L = low  
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CHAPTER 3

Hazard Identification and Risk Assessment

The aim of this section is to provide a structured and systematic approach to the identification of hazards, evaluation of risks and prioritisation of decisions required to reduce potential risks to a tolerable level.

It is important to understand that there is no such thing as an exact assessment that can be evaluated against exposure standards. Published exposure standards should not be regarded as fine dividing lines between safe and dangerous concentrations of hazards that can then be compared against measured workplace conditions. Professional judgement is required and thus an understanding of the factors that affect assessment and experience of the work processes contribute greatly to good decision making.

Dr R Guild
Occupational Health & Safety Consultant

Haggis Guild is a medical practitioner with an MBA and 20 years experience in the South African mining industry. He has practised at all levels within occupational health services including delivery of medical care; development health and safety protocols; development of medical surveillance programmes, institution of quality assurance programmes and corporate management. He now consults to local and international clients, offering expertise in health risk assessment and management, information systems and corporate governance.

Mr D Marais
Occupational Hygienist

Mr Dion Marais has many years experience in the South African mining industry. Dion has practised at all levels of occupational hygiene and currently consults to a wide range of national and international clients, offering expertise in risk assessment and ventilation systems.
GLOSSARY

Absorption: to take into the body via lungs, skin or intestinal passage

Distribution: to disperse throughout the body

Dose-response assessment: the basis for determining or predicting health effects of substances at specific doses

Excretion: to expel waste matter via the lungs, liver, kidneys, intestine or skin

Exposure assessment: the presence of a hazard does not imply that an individual has been exposed since exposure is dependent on the emission, dispersal and ultimately type of contact with workers

Hazard identification: the nature and effect of hazards can be deduced by identifying equipment failures and human errors that could, or are, occurring within the mining, metallurgical and engineering processes

Metabolisation: chemical processes in the body that alter one substance to another

Qualitative: observations or information characterised by measurement on a categorical scale (i.e. dichotomous or nominal scale) or, if the categories are ordered, an ordinal scale e.g. “low”, “medium”, “high”, sex

Quantitative: data in numerical quantities such as continuous measurements or counts e.g. percentile, rates

Risk assessment: the process of determining the likelihood that hazard exposure will result in illness

Risk characterisation: the estimation of the incidence and severity of the adverse health effect likely to occur due to actual or predicted exposure to a workplace hazard. This term encompasses risk assessment

Risk rating: placing risk outcome in a rank or class in some form of prioritisation

Semi-quantitative: a mixture of both mathematical and non-mathematical techniques
3.1 Introduction

Increasingly, managers and occupational health practitioners are expected to demonstrate how existing and foreseeable risks have been addressed, including the actions required to reduce the risk to tolerable levels. It is important to note that risk management is not synonymous with hazard identification and risk assessment (HIRA). The latter forms only a part of the more comprehensive management approach.

The risk assessment process (Figure 3.1) ensures that factors influencing health are fully understood and adequately quantified so that decisions are taken in a consistent and cost-effective manner.

Figure 3.1 Risk assessment process
This process framework incorporates the risk assessment tools introduced in chapter 2:

- **hazard identification** — the nature and effect of hazards can be deduced by identifying equipment failures and human errors that could, or are, occurring within the mining, metallurgical and engineering processes
- **dose-response assessment** — toxicological and epidemiological studies provide the basis for determining or predicting health effects of substances at specific doses
- **exposure assessment** — the presence of a hazard does not imply that an individual has been exposed since exposure is dependent on the emission, dispersal and ultimately type of contact with workers
- **risk characterisation** — the estimation of the incidence and severity of the adverse health effect likely to occur due to actual or predicted exposure to a workplace hazard can be used to develop control strategies and communicate risks present in the workplace to workers

The process framework (Figure 3.1) and these tools will be used to elaborate the structured and systematic process for the identification of hazards, evaluation of risks and prioritisation of decisions in order to reduce risks to a tolerable level. This process is iterative or repeated. Once controls have been implemented, further assessment is required to determine the residual risk. Based on the outcome of this second assessment, a monitoring and control procedure needs to be designed and implemented with an assessment component to ensure that the risk remains within acceptable limits. This procedure is referred to as the “continuous risk assessment process”. In addition, any change that may materially affect the risk must also be followed by a risk assessment.

### 3.2 The legislative framework

The Mine Health and Safety Act [S 11(1)(b)(c)] requires that every employer must “assess the risk to health or safety to which employees may be exposed while they are at work” and to “record the significant hazards identified and risks assessed”. Risk assessment is not a once-off function but an ongoing requirement of Section 11(4)(a) that every employer must “periodically review the hazards identified and risks assessed, including the results of occupational hygiene measurements and medical surveillance to determine whether further elimination, control and minimisation of risk is possible”.

The employer responsibility is not only to employees but also to any person who could be exposed to a hazard arising from the mining operation or related process as stated in Section 5 (2)(b), which requires that:

“as far as reasonably practicable, every employer must—

(a) identify the relevant hazards and assess the related risks to which persons who are not employees may be exposed; and
(b) ensure that persons who are not employees, but who may be directly affected by the activities at the mine, are not exposed to any hazards to their health and safety”.

where “reasonably practicable” is defined as “practicable having regard to:—

(a) the severity and scope of the hazard or risk concerned;
(b) the state of knowledge reasonably available concerning that hazard or risk and of any means of removing or mitigating that hazard or risk;
(c) the availability and suitability of means to remove or mitigate that hazard or risk; and
(d) the costs and the benefits of removing or mitigating that hazard or risk”.

Therefore, the responsibilities placed on employers, regarding hazard identification and risk assessment, look both inwards at the workplace and outwards at persons who are not part of the mining activities, as regards their health and safety. This implies both a social responsibility and also a potential legal liability.

### 3.3 STEP ONE: Define the objectives of the assessment

The process design of the assessment will depend on its objectives, which must be clearly defined,
preferably in terms of measurable outcomes. It is useful to limit the study to specific desired outcomes as the approach to the assessment could change depending on whether the assessment is, for example, for compliance, or the introduction of a new technology.

3.4 STEP TWO: Define the assessment process

There are three processes that are commonly utilised. Each process focuses on a different aspect of risk assessment and therefore each process is inter-related.

3.4.1 The baseline process

The purpose of this process is to determine the current status of occupational health risk associated with the business and a set of risk profiles are obtained. This is a very wide-ranging process that encompasses all potential exposures related to processes and activities surrounding those processes (Figure 3.2). It allows for a prioritisation of interventions to remedy those conditions that are found to be unacceptable.
The step-wise process defines what is covered by the risk assessment process AND what is not covered. The reason for doing this is not to understand in great detail the process/activities to be covered but to be clear on what is included in the assessment. This avoids later confusion and defines the borders and interfaces with other processes and activities.

Geographic or area based: A specific site or area is reviewed such as a workshop, stope, section, etc.

Process or activity based: Develop a clear understanding of the process being evaluated, which usually involves consultations with a process engineer, metallurgist, chemist or operational personnel.

Occupation and task based: An occupation (furnace attendant, miner, rock drill operator, etc.) or an activity within an occupation (e.g. installing ventilation curtains, preparing an assay sample, etc.) is selected and studied to establish the presence of hazards and then to determine their particular risk levels.

Having proceeded through the steps, risk profiles can be compiled and risks listed in order of significance (see 3.2).

3.4.2 Issue based process

This processes is designed to more distinctly and clearly delineate and quantify risks associated with particular aspects of the work activity, process or activity (Table 3.1).

Table 3.1 Categories of potential hazards

<table>
<thead>
<tr>
<th>Category</th>
<th>Definition</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical</td>
<td>Chemicals that are toxic or irritating to the body</td>
<td>Toxic dusts, fibres, fumes, vapours, mists, and poisonous, asphyxiating, irritating, explosive and flammable gases and chemicals</td>
</tr>
<tr>
<td>Physical</td>
<td>Physical agents that can cause tissue trauma or other damage</td>
<td>Noise, ionising and non-ionising radiation (e.g. sunburn), chafing, cutting, bruising, etc.</td>
</tr>
<tr>
<td>Biological</td>
<td>Infectious biological agents such as bacteria, viruses, fungal infections or parasites</td>
<td>Tuberculosis, Athlete’s foot, cholera, human immuno-deficiency virus (HIV), hepatitis B virus, tuberculosis, etc.</td>
</tr>
<tr>
<td>Ergonomic</td>
<td>The study of human characteristics, behavioural and biological, for the appropriate design of the working environment</td>
<td>Skeletal and muscular stress, fatigue and stressors, load handling, visual rules of line of sight, posture, man/machine interfaces, tactile feedback, climate, etc.</td>
</tr>
<tr>
<td>Psychological</td>
<td>Factors or situations encountered in the workplace that create stress, emotional strain or interpersonal problems</td>
<td>The effects of boredom, shiftwork, stressful environments, etc.</td>
</tr>
</tbody>
</table>

This type of risk assessment often requires specialist skills as the complexities of the problem may be beyond the scope of the practitioner employed at the mine or place of work. The output is clear management recommendations for treatment of risk or input into training programmes, standards, procedures etc.
Figure 3.3 Issue based risk assessment process

3.4.3 Continuous process

The purpose of ongoing assessment or scheduled, periodic reviews is to verify that workplace conditions have remained the same, or to identify where changes have occurred and to what extent such changes occurred (other than those dealt with under issue based risk assessments).

Figure 3.4 Inter-relationship between different risk assessment processes
During the baseline risk assessment, significant issues requiring immediate attention are closely monitored through the continuous HIRA process (2). Data from the continuous HIRA process is used during the baseline HIRA process (3). Outcomes from continuous HIRA might require more in-depth analysis through the issue-based HIRA (4). The outcome of the issue-based HIRA needs to be monitored through the continuous HIRA process to ensure that recommendations are complied with and are effective (5). Baseline risk profiles can be used to prioritise and scope issue-based HIRA (6). As part of the continuous and issue-based HIRA, the integrity and effectiveness of management systems is evaluated (7). The results from the complete risk management process manifest themselves in the baseline risk profiles

3.5 STEP THREE: Identify the hazards

The hazard identification process involves understanding the adverse effects of a substance or preparation to which workers may be exposed. Occupational health practitioners can utilise several means to anticipate possible hazards:

- Acquire a working knowledge of the specific mining, refining and smelting process — the raw materials utilised, the products and by-products produced and the physical, chemical or metallurgical processes involved in the processing
- Identify and understand the effects on the human body associated with each of the materials and processes
- When using new technology or changes to current technology, investigate similar processes elsewhere and learn from other people’s experience
- Examine literature reviews and study relevant material safety data sheets (MSDS’s) for hazardous chemical substances
- Study previous operational and health reports — if available
- Perform walk-through surveys yourself to observe and apply your own experience and common sense
- Talk to supervisors and workers (this is often a very useful tool if approached correctly) regarding possible work discomforts — nausea, dizziness, painful throat or other symptoms that may be associated with a specific work activity
- Talk to other specialists (e.g. occupational hygiene and medical practitioners, safety officers, etc.).
- Perform task/job analyses
- Use checklists and guidelines (the first are sometimes available in textbooks on specific subjects, e.g. ergonomics whilst the latter may be available from the legislator)

While potential hazards can be identified, it does not necessarily follow that these hazards will be present or, if present, will be relevant or significant. It is therefore necessary to rely on some or other form of observation or measurement to verify that the hazard exists. In some situations, this is easy as the hazard is clearly discernible by sight, smell, hearing or touch. Under other circumstances, measurement may be needed to ascertain whether the substance is present or whether an expected condition exists. For example, gases such as carbon monoxide or methane cannot be sensed and have to be measured using an appropriate device.

The anticipation of hazards requires knowledge of the harmful effects of substances and the disorders that are attributable to a specific occupational process. Knowledge of the former is gained from toxicological studies whilst that of the latter is acquired from epidemiological studies.

Occupational health practitioners are likely to undertake epidemiological studies but it is unlikely that they will be involved in toxicological studies although knowledge of both topics is useful in understanding occupational exposure limits.

3.5.1 Biological effect basis of hazard identification

Understand the health effects associated with exposures in the workplace and the evaluation of the data is dependent on the nature of the exposure. In this chapter, chemical exposure is used to illustrate the following fundamentals:
• the dose-response assessment
• the manner in which the substance is absorbed, distributed, metabolised and excreted
• the organs in the body that are at risk, and
• the types of toxic effect

Dose-response provides a basis for estimating the response associated with a particular chemical exposure and can be expressed either in terms of ‘severity of a graded response’ or the ‘percentage of the population that could be adversely affected’.

For example, a graded response could be applied to irritation of the airways caused by exposure to ammonia. The response could be graded from ‘slight irritation of the nasal passages’ to ‘bronchial constriction’ and ‘pulmonary oedema’.

Alternatively, the percentage of the population affected can be represented by a cumulative frequency distribution curve as demonstrated in Figure 3.5

The curve demonstrates the small proportion of the population who are sensitive and respond to a low dose, the small proportion of the population who are resistant and only respond to a high dose, and the majority of people who respond around the mid-point.

The intoxication threshold, or dose at which the human body is capable of receiving and detoxifying with no observable adverse effect, is important for determining occupational exposure limits. For certain substances, however, such as those known to cause cancer and affecting cell replication, there is no ‘safe’ or minimum threshold that can be identified with any certainty. At any dose, no matter how small, a response can occur in a sensitive population. For example, with certain respiratory sensitisers such as platinum salts the risk of exposure is not tolerable at any level.

![Figure 3.5 A typical dose-response curve](image)

Knowledge of the absorption, distribution, metabolisation and excretion of substances provides a basis for understanding the most appropriate means of monitoring and control.
Absorption can occur through the lungs, skin and mouth. Inhalation routes are best monitored by environmental methods (Ch4) and control requires the use of ventilation or enclosing process (Ch4). Skin penetration is best assessed by biological monitoring (Ch9) of urinary metabolites and blood samples.

Knowledge of the distribution process of a substance, once absorbed, or its metabolites, within the body provides an indication of target organs that are likely to be affected and provides another means of determining the appropriate biological monitoring process.

Knowledge of the metabolisation of an absorbed substance into one or more chemically different substances (metabolites) provides a means of determining the possible interactions that may occur between different chemicals. The metabolic process may result in bioactivation (a non-toxic substance is changed to a toxic metabolite) or detoxification (a toxic substance is altered to a non-toxic state). For many substances, several metabolic pathways exist resulting in bioactivation and detoxification. Toxicity may arise if a detoxification pathway fails or becomes saturated.

Knowledge of the excretion process by which substances, once absorbed, or its metabolites are eliminated from the body provides another method for biological monitoring (e.g. mercury in the urine, carbon monoxide in the breath) as adjunct to air measurements.

Knowledge of the target organ/s and the chemical action (accumulation, metabolism) also provides an indication of the appropriate biological monitoring method. Some substances and target organs are provided in Table 3.2.

Table 3.2 Certain hazardous substances and their target organs

<table>
<thead>
<tr>
<th>Target Organ</th>
<th>Substances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood</td>
<td>Aniline, benzene, lead, 4-nitroaniline, tetraethyl lead</td>
</tr>
<tr>
<td>Central nervous system</td>
<td>Lead, mercury and inorganic mercury compounds, tetraethyl lead, trichloroethylene</td>
</tr>
<tr>
<td>Eyes</td>
<td>Ammonia, chlorine, silver compounds</td>
</tr>
<tr>
<td>Heart</td>
<td>Carbon disulphide</td>
</tr>
<tr>
<td>Kidney</td>
<td>Cadmium, lead, mercury and inorganic mercury compounds, tetraethyl lead</td>
</tr>
<tr>
<td>Liver</td>
<td>Carbon tetrachloride, N,N-dimethylformamide, 2-nitropropane, tetraethyl lead</td>
</tr>
<tr>
<td>Peripheral nervous system</td>
<td>Acrylamide, n-hexane</td>
</tr>
<tr>
<td>Reproductive system</td>
<td>2-ethoxyethanol, isoflurane, 2-methoxyethanol, 2-methoxyethylacetate</td>
</tr>
<tr>
<td>Respiratory tract</td>
<td>Acid anhydrides, ammonia, cadmium, chlorine, chromium VI compounds, cobalt, glutaraldehyde, isocyanates, kaolin, platinum salts, talc, hardwood and softwood dusts</td>
</tr>
<tr>
<td>Skin</td>
<td>Chromium VI compounds, soluble nickel salts</td>
</tr>
</tbody>
</table>

Another useful way of assessing risk is by classifying the type of toxic effect as follows:

- **Duration of exposure** — probably the most useful way of describing toxic effects as it is essential to recognise that acute exposure can give rise to substantially different effects from those that occur with chronic exposure. This may require different approaches to monitoring exposure and different strategies in risk management
- **Site of tissue damage** — local or systemic effects may occur. For example, chromic acid has a local effect on the skin whereas organic solvents, although absorbed through the skin or inhaled, affect the liver
• **Immediate or delayed effect** — identification of the causative agent is much easier when the effect is immediate rather than delayed. For example, chromic acid ulcers are evident soon after contact but silicosis only occurs 10-20 years after first exposure.

• **Reversibility of effect** — the effects of platinum salts are reversible, the toxic effects subsiding when exposure ceases but silica exposure is cumulative and the effects irreversible and progressive even after exposure ceases.

• **Specific toxic effects** — carcinogenesis, sensitisation, mutagenesis.

The approach to hazard identification differs according to whether the substance is a listed one or a new and unlisted one. In Europe, known substances are listed in the European Inventory of Existing Commercial Chemical Substances (EINECS) which contains over 100,000 substances. Any substance not listed in EINECS is called a new substance, the toxicological assessment of which is beyond the scope of this chapter.

Suppliers of substances that are defined as dangerous, are required to provide information on the hazardous properties so that users can take the necessary precautions to protect their health. This information is provided in safety data sheets and on the container labels (see Chapter 9).

### 3.5.2 Epidemiological basis of hazard verification (see Chapter 2)

Hazards can be present in the workplace but they may not be identified until a number of workers in specific occupations develop illness or disability. For example, there is ongoing debate on whether or not exposure to strong magnetic fields in the smelting industry is a direct cause of increased illness and disability. Epidemiological studies are designed to determine whether there are connections between certain occupations and diseases and, if so, how they can be prevented.

This approach can also be applied to the study of work-related diseases that are multi-causal in nature, such as chronic obstructive airways disease where silica exposure plays an important role but is not the sole factor in the development of disease.

### 3.6 STEP FOUR: Assess exposure

Exposure models use a wide variety of techniques to predict exposures to hazards (i.e. the level of exposure expected for a given set of circumstances) and can involve simple algorithms, complex numerical techniques or scale models. The models are useful for extrapolating information from limited exposure data in order to predict exposures at other times and for circumstances different from those for which data is available. The most common uses for modelling are:

• Prior to the introduction of a new process, equipment or substance

• Prior to process modification

• In the selection of substitutes for hazardous substances

• To predict potential exposures that could result from accidental releases — spills, leaks, venting

• To assist in reconstructing exposures in retrospective epidemiology

All models consist of a source, a transmission path and a receiver as shown in Figure 3.6 but they do not usually consider dose or effect.

Every stage of exposure modelling is subject to considerable uncertainty and it must be remembered that exposures are often highly variable for a given process. It is not valid to predict a single value of exposure but account should be taken of ranges or distributions of model parameters in order to calculate the probability distribution of predicted exposures. This may use the Monte Carlo simulation, but a variety of other statistical techniques can be utilised.

Therefore, an understanding of the workplace, work practices and existing control measures will assist in predicting the probability that exposure will result in a particular health effect.
3.7 STEP FIVE: Risk rating

Risk rating or characterisation is the process for estimating the incidence and severity of adverse health effects likely to occur due to actual or predicted exposure to workplace hazards. It is the final product of the risk assessment process that can be used by a risk manager to develop and prioritise control strategies and to communicate risks.

One of the most important steps is to determine whether the level of risk is acceptable by assigning a risk rank level to the situation under review. The estimations can be defined in qualitative, quantitative or semi-quantitative terms:

- **Qualitative** — judgement is used and a simple ranking mechanism of ‘low’, ‘moderate’ or ‘high’ is utilised. This is especially useful when performing the ‘baseline’ type risk assessment where the object is simply to identify the ‘significant’ risks that are then more comprehensively measured and/or analysed. It is difficult to prioritise interventions with this method.

- **Quantitative** — involves the use of a mathematical equation that is an extension of the low, medium and high scenarios and describes risk as a frequency of death. It may not be any more precise than the semi-quantitative option described below.

- **Semi quantitative** — involves the use of a matrix based on the rating of hazards and the rating of likelihood of exposure similar to the model shown in Figure 3.7. Risks can be rated as low, moderate or high. It provides a useful means for ranking risk on a comparative scale and is more practical than the quantitative method. This method is described below.

The probability that a worker is exposed to a hazard and the consequence of such exposure is assessed according to the table shown. This estimation enables one to position the hazard within the risk matrix above and so determine the acceptability of the risk, according to one of three categories:

- intolerable risk where immediate action is required no matter what the cost, designated by the red area.
- broadly acceptable where further reduction of risk is unnecessary, designated by the green area.
- tolerability that takes into account economic issues such that the risk should be reduced to as low as reasonably possible, designated by the amber area.

Fig. 3.6. Simplified exposure model
Corrective or preventive action is focused on reducing the probability of the occurrence of the hazard and/or reducing the consequences of the outcome. It is important to ensure that corrective actions do not introduce any new hazards.

If the risk is regarded as tolerable, it is important to ensure that the existing system and risk does not change and so ongoing monitoring should be implemented.

This simple approach is useful for preliminary (baseline risk) assessment, an example of which is provided in Appendix 1 but it is likely that the risk assessment team will be uncertain of the level of risk and will require more information from a monitoring programme (see section 3.9), the results of which are compared to exposure standards (see section 3.8).

Alternative categorisation methods produce a numerical result, as illustrated in the following method.

**RISK RATING = CONSEQUENCE RATING × LIKELIHOOD RATING**

where,

- consequence is based on severity of harm or damage that can occur;
- likelihood rating is based on the chance of exposure and the proportion of time exposed to the hazard.

The likelihood rating is based on both level of exposure to a hazard and the longevity of exposure, thus,

**RISK RATING = CONSEQUENCE × PROBABILITY OF EXPOSURE × PERIOD OF EXPOSURE**

The values allocated to the various elements are based on some form of grading system as illustrated in Table 3.3 below.
Table 3.3 — Grading system for ascertaining risk of potential hazards

<table>
<thead>
<tr>
<th>RISK FACTOR</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probability of exceeding OEL</td>
<td></td>
</tr>
<tr>
<td>Continuously exceeding</td>
<td>10</td>
</tr>
<tr>
<td>Intermittently</td>
<td>6</td>
</tr>
<tr>
<td>Unusual, but possible</td>
<td>3</td>
</tr>
<tr>
<td>Only remotely possible (has happened somewhere)</td>
<td>1</td>
</tr>
<tr>
<td>Conceivable, but very unlikely (has not happened yet)</td>
<td>0,5</td>
</tr>
<tr>
<td>Period exposed</td>
<td></td>
</tr>
<tr>
<td>Continuous for 8 hour shift</td>
<td>10</td>
</tr>
<tr>
<td>Continuous for between 2 and 4 hours per shift</td>
<td>6</td>
</tr>
<tr>
<td>Continuous for between 1 and 2 hours per shift</td>
<td>3</td>
</tr>
<tr>
<td>Short periods of time (a few times per month)</td>
<td>2</td>
</tr>
<tr>
<td>Unusual (a few times per year)</td>
<td>1</td>
</tr>
<tr>
<td>Rare (once per year)</td>
<td>0,5</td>
</tr>
<tr>
<td>Consequence</td>
<td></td>
</tr>
<tr>
<td>One or more fatalities</td>
<td>100</td>
</tr>
<tr>
<td>Major disability</td>
<td>50</td>
</tr>
<tr>
<td>Serious illness — absent for longer than 14 days</td>
<td>15</td>
</tr>
<tr>
<td>Major illness — absent for longer than 7 days but less than 14 days</td>
<td>7</td>
</tr>
<tr>
<td>Minor illnesses — absent for 7 days or less</td>
<td>1</td>
</tr>
</tbody>
</table>

The numerically calculated risk rating is then assessed against a tabulated risk classification (Table 3.4) and the appropriate action is undertaken.

Table 3.4. — Criteria for tolerability of risk

<table>
<thead>
<tr>
<th>CALCULATED RISK</th>
<th>RISK CLASSIFICATION</th>
<th>ACTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>400 and above</td>
<td>Intolerable risk</td>
<td>Consider discontinuation</td>
</tr>
<tr>
<td>200-399</td>
<td>Very high risk</td>
<td>Immediate action required</td>
</tr>
<tr>
<td>70-199</td>
<td>High risk</td>
<td>Correction required</td>
</tr>
<tr>
<td>20 —69</td>
<td>Potential risk</td>
<td>Attention necessary</td>
</tr>
<tr>
<td>Under 20</td>
<td>Tolerable risk</td>
<td>Monitor</td>
</tr>
</tbody>
</table>

Various risk determinants can be utilised, including:

- the number of potentially exposed individuals
- the toxicity of the substance/s
- the quantities of toxic substances used or encountered over some arbitrary period
- the exposure dose i.e. the likely duration and concentration of exposure (plus exposure via routes other than inhalation)
- the existence of and confidence in control measures
- the likelihood and magnitude of change to the process and its controls
- the presence of substances that may be potentiators or act synergistically or antagonistically

3.7.1 Establishing a priority list for corrective action

Having assigned various hazards within the ranking matrix and established the tolerance levels, there may be several hazards that require intervention and some form of prioritisation may be necessary if there are insufficient resources to tackle all issues simultaneously. The highest priority should be given to the risk that has the greatest consequence and the highest probability of occurring and should be managed first, followed by the next greatest risk in accordance with the numbers inserted within the blocks in figure 3.7. Thus number 1 should be tackled first, number 2 second, and so on.

Once remedial actions have been implemented, it is necessary to monitor the situation to ensure that any residual risk remains within tolerable limits.
3.7.2 Cautionary notes on risk assessment interpretation

The following extract from a note on risk assessment considerations by the Technical Workshop on Exposure Duration and Toxicity Relationships (U.S. Environmental Protection Agency Risk Assessment Forum, 1998) is very relevant to risk assessment outcomes:

“Current risk assessment procedures are typically based on overall daily exposure levels, and tend to emphasize effects resulting from continuous exposures over a lifetime. This basis is widely recognized to be an oversimplification. There has been an increasing realization that exposures are more likely to be experienced as episodes (i.e., bursts or spikes, or intermittent exposures) of varying levels. As scientists delve further into the subject, they are discovering that Haber’s Law (i.e., concentration multiplied by duration) does not properly explain the relationship between exposure/dose and an effect.

The complexities of exposure effects on toxic responses require consideration of the entire exposure profile, including the timing, duration, and intermittent nature of exposures reflecting realistic scenarios encountered in practical settings. The proper metric for exposure may be highly dependent on the pharmacokinetic properties of the chemical or exposure in question. The toxic effects considered in models must be carefully chosen to reflect the sensitive endpoints based on the exposure characteristics.

Models have been developed, over the last decade, that begin to address the effect of duration of exposure in addition to exposure levels. However, most of these models do not incorporate mechanistic information. In addition, only limited work has been done on developing efficient designs for studying dose-rate effects, and these designs tend to be simplistic.”

On the basis of the above, it is important that occupational health practitioners constantly update themselves on procedures and methods as these evolve (see section 3.9).

3.8 STEP SIX: Deciding risk acceptability

The control of occupational health hazards is guided by exposure standards, which represents an airborne concentration of a particular substance in the worker’s breathing zone, exposure to which, according to current knowledge, should not cause adverse health effects nor cause undue discomfort to nearly all workers. If the standard is exceeded, then the risk is not acceptable.

The standards can be provided in one of three forms:

- Time weighted average (TWA)
- Peak exposure limit (Peak)
- Short term exposure limit (STEL)

Exposure standards are guides to be used in the control of occupational hazards but they should not be regarded as accurate levels dividing safe from dangerous concentrations of chemicals. They are not a measure of relative toxicity and should not be applied in the control of community air pollution. They are largely based on the concept of threshold intoxication but not all chemical and physical agents are based on toxicity (see section 3.5.1).

The majority of exposure standards for airborne contaminants are expressed as a TWA concentration over an entire eight-hour working shift. During this averaging period, excursions above the TWA standard are allowed, provided these excursions are balanced by equivalent excursions below the standard during the shift. Because some substances can give rise to acute health effects even after brief exposures to high concentration, it is prudent that excursions above the TWA concentration are restricted.

For some rapidly acting substances and irritants, the TWA concentration is inappropriate as acute effects can be induced after relatively brief exposures. Therefore, exposure standards for these substances represent a maximum exposure to which workers may be exposed. It is recognised that there are analytical limitations to measurement of “peak limitation” exposure standards but a single determination should not exceed 15 minutes.
Some substances cause acute effects upon brief exposure, even though the major toxic effects may be due to long term exposure through accumulation of substances in the body or gradual health impairment with repeated exposures. Exposure should be controlled to avoid both acute and chronic health effects.

Short-term exposure limits (STELs) are useful exposure standards to complement TWA exposure standards. STELs provide guidelines for the control of short-term exposures as opposed to the total intake over relatively long periods of time. Application of STELs generally minimise the risk of:

- Intolerable irritation
- Chronic or irreversible tissue change, and
- Narcosis to an extent that could cause or initiate industrial accidents

STELs are expressed as airborne concentrations of substances, averaged over a period of 15 minutes. This short-term concentration should not be exceeded at any time during normal eight-hour working day or for more than four such periods per working day. A minimum of 60 minutes should elapse between successive exposures at the STEL concentration.

It should be understood that exposure standards are not finite values dividing safe and unsafe exposures and should be regarded as target concentrations. They are really guides for use in the control of potential health problems and thus the true target should be zero. The ultimate aim is to eliminate or control exposure to all contaminants likely to adversely affect health. The application to situations outside the norm, such as 12-hour shifts, for which they were not designed, could lead to illness, disability or death.

With many new products continuously being produced, it is impossible to develop appropriate exposure standards for each before they are in commercial use. Therefore, occupational health practitioners should compare new substances to other compounds of similar type and utilise common sense that will assist the reduction of unnecessary exposure.

### 3.9 Monitoring programmes

Exposure monitoring is undertaken for a number of reasons:

- compliance with legislation
- assessment of potential health risk
- evaluation of control measures and auditing their ongoing performance
- collection of data for epidemiological purposes
- resolution of complaints or industrial disputes

Frequently decisions are dependent on measurements so it is essential that the measurements be made using appropriate sampling and analysis methods with the inherent limitations fully understood. However, measurement results are not the sole indicator of whether a risk exists or not, as neither the monitoring results nor exposure limits (see 3.8) to which they are compared are absolute. Both have shortcomings and thus should be interpreted only by individuals experienced in this task.

#### 3.9.1 Workplace exposure monitoring methods (Biological sampling not addressed)

There are several sampling techniques, categorised according to factors such as time, location and method of collection and analysis. Two types are generally employed in the workplace — personal and static (or area) monitoring.

In relation to airborne pollutants, personal monitoring provides the best assessment of an individual’s exposure to a workplace contaminant and exposure standards are usually based on this method. Therefore only results collected in this manner can be reasonably compared against exposure standards.

Non-personal samples are generally referred to as static samples and in most instances do not correlate well with personal exposure. They still have a role in the overall assessment of the workplace and are:
• often used to check the performance of control devices
• of use in identifying and quantifying contaminant sources in the workplace
• of use in delineating areas of unacceptable/acceptable contamination

3.9.2 Preliminary considerations

Having determined the reason for sampling, whether it is assessment of potential health risk or evaluation of control measures etc., it is then necessary to prioritise which contaminants and/or processes are associated with the highest degree of risk (see section 3.7). Surveys can be broken down into four levels related to the priority assigned:

• initial assessment
• preliminary survey
• detailed survey, and
• routine monitoring

The level of the survey is related to the reason for the survey and the magnitude of the survey is related to the factors involved (numbers of people, variability etc.). Figure 3.8 overleaf shows a self-explanatory flow diagram that will aid the understanding of this process.

Occupational health practitioners are accustomed to comparing measured exposure data with relevant exposure limits. However, this approach may overlook the instrumental and analytical errors, as well as the normal but larger variations in workplace concentrations over space and time. Selecting the most appropriate sampling and analytical methods and understanding variations in individual exposure and fluctuations in emissions may reduce these errors. The following factors should be considered.

For sampling methods:

• the physical, chemical properties of contaminants
• the stability of sampling method
• the compatibility of sampling method with subsequent analytical method
• the pump flow rate range and ability to sample over periods relevant to OEL
• the capacity and collection efficiency of sampling medium
• the type and analysis of info required
• the intrinsic safety of equipment
• the portability, reliability and ease of equipment maintenance

For analytical methods:

• specificity — the ability to measure the contaminant of interest in the presence of interferences
• sensitivity — the ratio of the change of the instrument response with the corresponding change in the concentration of the substance analysed
• accuracy — the difference between the mean of a set of measurements and the true or correct value for the quantity measured
• precision — a measure of the method’s variability when repeatedly applied and commonly expressed as the standard deviation
• limit of detection — the smallest amount of a contaminant that will produce a reliable instrument reading that is distinguishable from the background

An individual’s exposure to a specific agent can vary greatly due to many different factors and these must be carefully understood and considered in the design of sampling strategies. The main sources of variation include:

• shift in the patterns and the average exposure of individuals
• differences associated with the type and nature of the processes
• changes in the contaminant concentration in the breathing zone of operators over the duration of the shift
• deviation in individual exposure levels, even when working in the same place carrying out the same tasks on the same shift
Fig. 3.8 A sampling strategy decision logic flow diagram (after Harrington and Gardiner, 1995)
Fluctuations in exposure concentrations within and between shifts can be due to any combination of the following variations in:

- the number of emission sources
- the rate of release of the contaminant from a source
- the dispersion of a contaminant due to air currents and turbulence in the workplace
- ambient conditions such as air temperature and humidity

Careful consideration of the foregoing issues will maximise the validity of the generated data and ensure the most cost-effective approach.

3.9.3 Sampling strategy

Having determined the reason for monitoring and having selected a sampling method suitable for the pollutant of interest, six fundamental questions need to be considered in designing a sampling programme:

- where should the samples be taken?
- whose exposure should be measured?
- when to measure?
- how long to sample for?
- how many samples to take?
- how often to sample?

Answers to these questions will result from careful consideration of the issues discussed in section 3.9.2 and should be made before commencement of sampling. It should, however, be borne in mind that legislative requirements may dictate the frequency and number of samples to be taken, in which case the programme needs to take this into account. Reference should be made to the draft guidelines published by the Department of Minerals and Energy:

- Guideline for the compilation of a mandatory Code of Practice for an Occupational Health Management Programme: No. 1 — Exposure to Airborne Pollutants

Standard methods of sampling and analysis should always be used and various national bodies have published useful compendia — the Health and Safety Executive in the United Kingdom (HSE, 1981-1998), the National Institute for Occupational Safety and Health (NIOSH, 1994), the Occupational Safety and Health Administration in the USA (OSHA, 1985).

Other publications (Harrington and Gardiner, 1995; SAIOH, 2001) may also be useful.

3.9.4 Data capturing and management

Clear, concise records of the risk assessment process and the data obtained should be maintained in the operational files, indicating who conducted the review, the basis of assessment, the result of the assessment, any recommendations for control strategies and the date of implementation of such controls. A useful sample record sheet is provided in Appendix 2.

3.10 Guide to information resources

In compiling this Chapter, the following resources were consulted:

Barbara A Plog, Jill Niland, Patricia J Quinlan (eds), 1996 (4th ed.) Fundamentals of Industrial Hygiene, National Safety Council, USA


Department of Minerals and Energy, Draft Guideline for the Compilation of a Mandatory Code of Practice for an Occupational Health Management Programme, No. 1 Personal Exposure to Airborne Pollutants

European Committee for Standardization (CEN) British Standard BS EN 689:1996, BS 6069: Section 3.7:1996, Workplace atmospheres — Guidance for the assessment of exposure by inhalation to chemical agents for comparison with limit values and measurement strategy.


National Institute Occupational Safety and Health, Occupational Exposure Sampling Strategy Method DHEW(NIOSH) Publ. No. 77-173. NIOSH, Cincinnati, Ohio

Occupational Safety and Health Administration, 1985 OSHA Analytical Methods Manual, OSHA Analytical Laboratories, Salt Lake City, Utah


3.11 Suggested Internet Web Sites

Association for Occupational Health and Safety (ASOSH) website: http://www.asosh.org


Department of Minerals and Energy website: http://www.dme.gov.za

Safety In Mines Research Advisory Committee (SIMRAC) website: http://www.SIMRAC.co.za

UK Health and Safety Executive website: http://www.hse.gov.uk
# Preliminary Risk Rating Assessment

**Appendix 3.1**

**Observer:**

**Mine/Organization:**

**Address/Location:**

**Site/Activity/Plant/W-Shop Description:**

## No of Employees in This Area:

<table>
<thead>
<tr>
<th>Physical</th>
<th>Chemical</th>
<th>Biological</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Acute Effect</strong></td>
<td><strong>Chronic Effect</strong></td>
<td><strong>Acute Effect</strong></td>
</tr>
<tr>
<td>Lightning</td>
<td>Vibration</td>
<td>Tens</td>
</tr>
<tr>
<td>Heat</td>
<td>Abasement</td>
<td>Asphyxiant</td>
</tr>
<tr>
<td>Cold</td>
<td>Fatigue</td>
<td>CNS's</td>
</tr>
<tr>
<td>Fires</td>
<td>Illumination</td>
<td>Mutagens</td>
</tr>
<tr>
<td>Explosions</td>
<td>Noise</td>
<td>Neurotoxins</td>
</tr>
<tr>
<td>Dreaming</td>
<td>Shiftwork</td>
<td>Other</td>
</tr>
<tr>
<td>Other</td>
<td>Posture</td>
<td>Pain</td>
</tr>
<tr>
<td>Non-visual Radi</td>
<td>Other</td>
<td>Other</td>
</tr>
</tbody>
</table>

| Sub Total | 0 | Sub Total | 0 | Sub Total | 0 | Sub Total | 0 | Sub Total | 0 | OVERALL SCORE | 0 |

**Comments:**

**Notes:**

1. Risk rating is based on "low, medium & high", i.e. L/MH, where L score = 1, M score = 2, H score = 3.
2. No. in determination as follows: 0 to 5 employees potentially exposed, score = 1; 6 to 20 potentially exposed, score = 2; more than 20 potentially exposed, score = 3. **Bacterial** - fungal or viral
## Appendix 3.2 Sample Record Sheet

**SAMPLE RECORD SHEET**

<table>
<thead>
<tr>
<th>Author</th>
<th>Tel no.</th>
<th>Date of sampling</th>
<th>Contaminant</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
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<td></td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name of operation</th>
<th>CAS No.</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Address of premises/ location/ identity</th>
<th>Product/ trade name</th>
<th>Sampling/ analysis details</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Total no. of people on site</th>
<th>Total no. of people in area/ process of interest</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Ref. No.</th>
<th>Male/ Female (M/F)</th>
<th>Personal identifier</th>
<th>Sample type (personal static)</th>
<th>Sample description (name, task, process, equipment)</th>
<th>Reason for sampling</th>
<th>Exposure modifier (other routes of absorption etc.)</th>
<th>Work period (Shift)</th>
<th>Start/ stop times</th>
<th>Duration (min')</th>
<th>Result</th>
<th>TWA ppm or mg m⁻³</th>
<th>Result</th>
<th>TWA ppm or mg m⁻³</th>
<th>Result</th>
<th>TWA ppm or mg m⁻³</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Current occupational exposure limits

8 hour

15 minutes
CHAPTER 4

Airborne Pollutants

This chapter describes and classifies the various airborne pollutants. The hazards posed by these pollutants and their occurrence and origins are discussed together with sampling and monitoring techniques and strategies. The legal limits of exposure to airborne pollutants are set out and control methods applicable to these pollutants are described.

A D Unsted
Consultant

Dave Unsted has over 45 years experience in mines and industry, of which 15 years were in a research environment. He has run an independent consultancy since 1997, offering expertise in airborne dust, occupational hygiene, hazard recognition and management, computerised ventilation networks, pollutant measurement and control, mine environmental control, and escape and rescue strategies. He is a Fellow of the Mine Ventilation Society of South Africa (MVSSA) and was President for the 1978/1979 year. He is also a member of the National Association of Clean Air and the South African Institute of Occupational Hygiene. He has published extensively.
Glossary

**ACGIH**: American Conference of Governmental Industrial Hygienists

**Aerodynamic size**: relating to airborne particles of unit density: a means to facilitate comparison of the behaviour of aerosols

**Aerosol**: generic name for airborne entities such as dusts, smokes, mists, fumes

**Asbestos**: collective term for mineral silicates of the serpentine and amphibole groups

**Aspect ratio**: for fibres, the length to breadth ratio

**Gravimetric**: relating to weighing e.g. of dust-collecting filters

**Halides**: compounds of the gases chlorine, bromine, fluorine and iodine

**HEG**: Homogeneous Exposure Group: a group of persons generally exposed to similar dusty conditions

**I/min**: litres per minute — a flow rate

**mg/m³**: milligrams per cubic metre — a measurement of concentration

**Mineral fibres**: fibrous materials such as slag and glass wool

**NIOSH** (USA): National Institute for Occupational Safety and Health

**Noxious**: harmful, injurious

**Occupational hygienist**: an individual trained to anticipate, recognise, evaluate and control health risk factors at the workplace

**OEL**: Occupational Exposure Limit: a guide to permissible exposure to airborne substances

**OHSA** (USA): Occupational Health and Safety Administration

**Particulate**: referring to particles

**Pollutant**: contaminant of air, water etc.

**ppm**: parts per million — a measure of concentration

**PNOC**: Particles Not Otherwise Classified

**Respirable**: of such an aerodynamic size (< 7µ in diameter) as to be capable of inhalation into the lung depths

**RPE**: Respiratory protective equipment

**RPM**: Respirable particulate matter

**SABS**: South African Bureau of Standards

**Solvent**: a substance used to dissolve other substances

**SiO₂**: Silicon dioxide (silica)

**STEL**: Short term exposure limit

**STP**: Standard temperature and pressure (25°C and 101,3 kPa)

**TLV**: Threshold limit value

**TPM**: Total particulate matter

**TWA**: Time weighted average

**µm**: micrometre (micro = millionth)

**µg**: microgram
4.1 Introduction

South African mining legislation has existed for many years to protect workers from the adverse health effects of inhaling airborne pollutants such as airborne dust, noxious fumes or harmful gases. Under early mine health and safety regulations Occupational Exposure Limits (OELs) have been published for carbon dioxide, carbon monoxide, oxides of nitrogen and hydrogen sulphide levels in air. In 1992 some fifty particulate airborne pollutants were assigned OELs under the Guidelines for the Gravimetric Sampling of Airborne Particulates for Risk Assessment in Terms of the Occupational Diseases in Mines and Works Act No. 78 of 1973. Recently, all mine OELs have been updated in a schedule to the Occupational Hygiene Regulations (2001) under the Mine Health and Safety Act, 1996. OELs are now prescribed for hundreds of chemical airborne pollutants including particulates, gases and vapours.

4.2 Types of airborne pollutants

Airborne pollutants refer to dusts, smokes, fumes, mists, gases, vapours, fungi, bacteria, algae and viruses. Based on their physical properties airborne pollutants can generally be grouped as:

4.2.1 Dusts

Dusts are generated during the handling, pulverisation, grinding, crushing, rapid impact and decrepitation (crackling through heat exposure) of organic and inorganic substances such as rock, ore, metal, coal and wood.

These particles may be so small, (sub-micrometre) that, because of collisions with air molecules, they do not always move in the expected direction i.e. downwards. The resistance offered by the air hampers the free fall of such bodies. The air resistance depends on the density and viscosity of the air and on the aerodynamic size and speed of the falling body. A one micrometre dust particle liberated two metres above the footwall (floor of a mine) will take about 10 hours to settle on the floor in still air. On the other hand, clearly visible road dust of 100µm diameter will settle in about five seconds.

4.2.2 Fumes

Fumes are solid particles generated by condensation from the gaseous state, generally after volatilisation from molten metals. In the case of metals this process is often coupled with a process of oxidation so that the metallic fumes present in the air are partly in the form of an oxide. Fumes can flocculate or coalesce.

4.2.3 Mists

Mists consist of small liquid droplets generated by condensation from the gaseous state or by the breaking-up of a liquid into a dispersed state by, for example, splashing, foaming or atomising. Mist is formed when a finely divided liquid is suspended in air, for instance during spraying operations.

4.2.4 Gases

Gases are formless, diffusing fluids, which completely fill the containers in which they are kept. They can be transformed to the liquid state only by the combined effect of increased pressure and decreased temperature.

4.2.5 Vapours

Vapours are gaseous forms of substances which can be transformed to the liquid phase either by increasing the pressure or decreasing the temperature alone. Vapours will diffuse in the air or in any other gas.

4.3 Specific Entities

4.3.1 Asbestos

Asbestos (translated from the Greek word: unquenchable) is a collective term for some of the metamorphic, fibrous, mineral silicates of the serpentine and amphibole groups. They have different
physical and chemical properties but share a fibrous form. Mineralogists have generally taken a particle with a length-to-breadth ratio (aspect ratio) of 10:1 or more to be a fibre. In milled asbestos most of the particles have aspect ratios that range from 5:1 to 20:1 or more and, in the case of chrysotile, mostly greater than 50:1. In medical and environmental literature a regulated fibre has been defined as a mineral particle with a length which is at least three times greater than its diameter, of length greater than 5 micrometres and diameter less than 3 micrometres. This definition has been the basis of all fibre counting for dose-response studies since 1965.

Amongst the most valuable characteristics of asbestos are its durability, which, unfortunately, also causes it to persist in lung tissue, and its fine diameter, which gives it a very high surface-to-weight ratio but also renders it respirable.

There are essentially two major varieties of asbestos viz. serpentine and amphibole. Serpentine is an hydrous magnesium silicate, which occurs as a plating variety (antigorite), or as a fibrous variety (chrysotile), which in long fibres is chrysotile asbestos. Chrysotile is found in both igneous and metamorphic rocks.

Amphiboles typically contain magnesium or calcium and can form fibrous structures due to the ease with which their molecular chains can be separated. The species and varieties are as follows:

<table>
<thead>
<tr>
<th>Table 4.1 Asbestos</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPECIES</td>
</tr>
<tr>
<td>Chrysotile</td>
</tr>
<tr>
<td>Anthophyllite</td>
</tr>
<tr>
<td>Amosite</td>
</tr>
<tr>
<td>Actinolite</td>
</tr>
<tr>
<td>Tremolite</td>
</tr>
<tr>
<td>Crocidolite</td>
</tr>
</tbody>
</table>

Amphiboles are commonly found as a component of igneous and metamorphic rocks of basic or mafic types and comprise about five percent of the earth’s crust. The two commercially significant fibres, crocidolite and amosite, occur in sedimentary strata known as banded ironstones.

Chrysotile is known as white asbestos, crocidolite as blue asbestos and amosite (found only in South Africa) as brown asbestos.

It has been known for some time that inhalation of asbestos fibres increases the risk of lung disease. The three diseases associated with asbestos are:

- Asbestosis, a non-malignant fibrotic condition
- Bronchogenic carcinoma
- Mesothelioma, a rare cancer of the lining of the chest or abdominal cavity

The limit for airborne asbestos concentrations for regulated fibres was set at 2f/ml for many years but in a revision to the regulations this has been lowered to 1 f/ml.

4.3.2 Mineral Fibres (synthetic i.e. man-made)

Synthetic mineral fibres fall into the following main groups:

- Slag or rock wool (mineral wool)
- Glass wool
- Continuous filament glass
- Ceramic fibre

The mineral wools are made from melts of specific argillaceous limestones and smelter slags, sometimes with the addition of wollastonite and kaolin. Glass wool (or fibreglass) is made from different types of silicate glass. They are all glassy minerals, which, unlike asbestos materials, are
amorphous silicates. Diameters of ordinary glass fibres are usually greater than 3µm but may vary down to diameters of less than 1µm. “Melts” at a temperature of 1000 to 1500°C are “fiberised” by drawing, blowing or centrifugal methods. The diameters and lengths of fibres differ according to the use for which they required, and are manufactured to a controlled “nominal” (specified) diameter.

Man-made mineral fibres (MMMF) are commonly coated with a binder, which is usually a biologically inert, fully polymerised, thermosetting resin. They have also been coated with mineral oil to reduce dust emissions and to serve as a lubricant between fibres to improve handling properties. Unlike asbestos fibres, which split longitudinally into numerous fibrils of much smaller diameter, MMMF break transversely with the same diameter.

Even though fibres of “respirable” dimensions have been present in most products since manufacture began in the late 1840’s, epidemiological and radiological studies have not revealed any evidence of pneumoconiosis. This holds for both long and short fibres. Nevertheless, rock or slag wool, fibrous glass and ceramic fibres have been classified as a “possible human carcinogen”. Continuous glass filaments were found not to be classifiable.

Under mining regulations no limits have been set for the concentration of mineral fibres but the ACGIH has specified a limit of 1f/ml.

4.3.3 Biological agents

- A biological agent is of vegetable or animal origin and can cause illness or disease at the workplace. Such agents include vegetable scraps, micro-organisms, parasites, biological allergens and toxins. However, the presence of these biological agents and the resulting illnesses may not always be recognised. It has been noted that some 193 biological agents are known to produce infectious, allergic, toxic and carcinogenic reactions at the workplace. Most of the identified agents can be placed into the following groups
  - Micro-organisms and their associated toxins (viruses, bacteria, fungi, and their products), infection, exposure, or allergic reaction
  - Arthropods (arachnids, insects and crustaceans): bites and stings, transmission of infectious agents, or allergic reaction
  - Allergens and toxins from certain plants: dermatitis from skin contact, rhinitis/asthma from inhalation
  - Allergens from certain animals (from urine, faeces, hair or saliva)

Other groups that pose a potential biohazard include plants other than fungi e.g. lichens, liverworts and ferns and animals other than arthropods viz. parasites such as protozoa, flatworms and roundworms.

Some of the better known diseases caused by biological agents include anthrax, athlete’s foot, legionnaires’ disease, malaria, psittacosis, rabies, ringworm, sporotrichosis, tetanus and tuberculosis.

It must be stressed that only illnesses arising from daily exposure to biological agents at the workplace can be classified as occupational.

4.3.4 Blasting Fumes

Several oxides of nitrogen are usually found together in the same atmosphere and collectively they are known in mining circles as nitrous fumes.

Nitrous fumes are commonly a mixture of NO, NO₂, N₂O₄ with possible some N₂O₃.

They occur in the gases formed by the detonation of nitro-explosives (see Table 4.2). The burning of such explosives produces significantly greater quantities of these gases. They are also present in the exhaust gases of diesel-powered engines and are also produced in small quantities by both oxy-acetylene and arc welding.
Nitrous fumes make up an irritant gas mixture, and if inhaled cause irritation in the nose, throat and windpipe and may lead to delayed pulmonary oedema, a potentially fatal condition in which fluid accumulates in the lungs. In the case of gassing it is important that the employee concerned receives prompt medical attention.

**Table 4.2 Gases produced by explosives**

<table>
<thead>
<tr>
<th>Gas</th>
<th>Volume m$^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon monoxide</td>
<td>1.2-4.0</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>10-27</td>
</tr>
<tr>
<td>Nitrous fumes</td>
<td>0.6-4.4</td>
</tr>
<tr>
<td>Ammonia</td>
<td>0.03-0.3</td>
</tr>
</tbody>
</table>

4.3.5 Chlorine

Cl$_2$ is a heavy, greenish-yellow gas, that is irritant with a pungent odour. It is extremely poisonous. As in the case of nitrous fumes, oedema (waterlogging) of the lungs may occur several hours after exposure.

There are simple tests available for the detection of chlorine gas but are usually not necessary since chlorine is not commonly found in underground workings and generally only occurs where chlorine is being used to disinfect water. The gas’s distinct smell will usually make its presence known.

4.3.6 Diesel engine exhaust emissions

Where diesel-powered vehicles are deployed in close proximity to each other the potential to superimpose exhaust emissions is high. In addition to dust from the mechanised sections where diesel-powered vehicles are used, the exhaust gases are also emitted into confined spaces of the workings. Included in the exhaust emissions is soot, or as it is also technically known, Respirable Combustible Dust (RCD) or Diesel Particulate Matter (DPM). The concern with diesel soot is the Polynuclear Aromatic Hydrocarbons (PAH). Included amongst the PAH is benzo-a-pyrene, which is one of the most powerful carcinogens known to man. The need to control and dilute diesel soot in the workings and remove it to prevent exposures is thus clear.

**Table 4.3. Constituents of diesel exhaust emissions**

<table>
<thead>
<tr>
<th>Emission</th>
<th>Pollutant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gaseous</td>
<td>Nitrous fumes NO$_x$</td>
</tr>
<tr>
<td>Gaseous</td>
<td>Sulphur fumes SO$_x$</td>
</tr>
<tr>
<td>Gaseous</td>
<td>Formaldehyde HCHO</td>
</tr>
<tr>
<td>Particulates</td>
<td>Diesel Particulate Matter DPM</td>
</tr>
<tr>
<td>Particulates</td>
<td>Sulphur</td>
</tr>
</tbody>
</table>

**Note.** “Tailpipe” gases are discussed under section 4.3.8

4.3.7 Dust

The largest quantities of airborne dust particles are produced in a mine by blasting operations and mechanical mining systems. Additional dust is produced by other mechanical operations such as drilling, scraping, barring, lashing, tipping and loading.

Some of the fine dust produced during blasting is carried away by the ventilating airstream. To minimise exposure to dust and blasting fumes a re-entry period is specified and applied. Persons are removed from the mine during blasting operations and may not re-enter the mine for a period of four
hours after blasting (general re-entry period). However, a large amount of dust is trapped with the rock broken by blasting. Some of the coarse particles that have become airborne settle out on the footwall and some of the finer particles collide with each other and aggregate to form larger particles, which settle out. However, if precautions are not taken, these settled particles, if disturbed, can become airborne during the shift when persons are present in the workings and thus become available for inhalation.

One cubic millimetre of rock crushed to cubes of one micrometre size would yield 1000 million dust particles. In drilling a 40 mm diameter hole one metre deep the volume of rock removed is 1.2 million cubic millimetres and drilling such a hole takes less than 10 minutes. Assuming an airflow rate of 20 m³/s in the working place (stope), such a hole could add 100 000 particles of dust per millilitre of air or, in terms of mass, approximately 3 500 milligrams of dust. Fortunately, however, very much less than one per cent of the rock drillings is as small as one micrometre and most is prevented from becoming airborne through engineering intervention.

Most of the dust produced by drilling is captured by water flowing down the drill steel and exits the hole being drilled as sludge. Unfortunately, all the dust is not controlled in this way because some compressed air usually leaks past the piston of the rockdrill and finds its way down the drill steel to the bottom of the hole where it collects some dust before escaping to the atmosphere. Modern sealed-spline rock drills allow less air to escape than the old exposed-spline machines. The front head release ports allow some of the air, which gets past the piston to escape to atmosphere without passing down the hole being drilled.

The dust created and liberated into the atmosphere by scraping, barring, lashing and loading can, to a large extent, be kept out of the ventilating air by ensuring that the rock is kept sufficiently wet.

When a piece of rock covered with fine dust is allowed to fall, as happens when it is transferred from one conveyor belt to another or when it is dropped into a tip or on to a stockpile, it is subject to gravitational acceleration and subsequently to a sudden stop or deceleration. These processes release dust into the air and if the tip is, for example, upcasting this dust is then carried into the ventilating air.

Table 4.4 Sources of airborne dust in a mine

<table>
<thead>
<tr>
<th>Approx severity</th>
<th>Dust producing operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Blasting</td>
</tr>
<tr>
<td>2</td>
<td>Drilling</td>
</tr>
<tr>
<td>3</td>
<td>Crushing</td>
</tr>
<tr>
<td>4</td>
<td>Grinding</td>
</tr>
<tr>
<td>5</td>
<td>Scraping</td>
</tr>
<tr>
<td>6</td>
<td>Barring</td>
</tr>
<tr>
<td>7</td>
<td>Lashing</td>
</tr>
<tr>
<td>8</td>
<td>Tipping</td>
</tr>
<tr>
<td>9</td>
<td>Loading</td>
</tr>
</tbody>
</table>

4.3.7.1 Crystalline silica

The most common form of crystalline silica or silicon dioxide (SiO₂) is quartz. Other forms of crystalline silica include tridymite and cristobalite. Quartz itself is given various names such as rock crystal, amethyst, smoky quartz and milky quartz depending on its colour, which is caused by various impurities, and its shape. Silica and silicates, i.e. silica combined with some other base, occur very freely in nature and actually form a very high percentage of the earth’s crust. The gold-bearing ore in South African mines can contain up to 100 per cent silicate. One of the problems confronting the occupational hygienist is the fact that the silica content in ore being mined is neither uniform nor homogeneous. This results in variable silica content of airborne dust samples
4.3.8 General mine gases

A summary of common gases encountered in mines, together with relevant properties and places of occurrence is set out in Table 4.5. Knowledge of the specific gravities of the various gases is useful in assisting with testing techniques. For example, a gas with a specific gravity less than unity (i.e. lighter than air) could be expected to be found against the hanging wall (roof), before any mixing takes place. Therefore it would be logical to test for such a gas above one’s head and not at floor level.

The Occupational Exposure Limits provided in the table are taken from the Regulations for Occupational Hygiene under the Mine Health and Safety Act.

Table 4.5 Common mine gases and properties

<table>
<thead>
<tr>
<th>Name</th>
<th>Chemical Symbol</th>
<th>Specific Gravity Relative to Air</th>
<th>OEL: ppm</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon dioxide</td>
<td>CO₂</td>
<td>1.5</td>
<td>5000</td>
<td>Breathing, oxidation, blasting, diesel exhaust, fires</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>CO</td>
<td>0.97</td>
<td>25</td>
<td>Blasting, diesel exhaust, fires</td>
</tr>
<tr>
<td>Hydrogen sulphide</td>
<td>H₂S</td>
<td>1.2</td>
<td>10</td>
<td>Fissures, stagnant water</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>N₂</td>
<td>0.97</td>
<td></td>
<td>Normal air</td>
</tr>
<tr>
<td>Nitrous fumes</td>
<td>NO, NO₂, etc</td>
<td>1.04, 1.6</td>
<td>25, 3</td>
<td>Blasting, diesel exhaust, welding, burning of explosives</td>
</tr>
<tr>
<td>Methane</td>
<td>CH₄</td>
<td>0.55</td>
<td></td>
<td>Fissures, coal seams</td>
</tr>
<tr>
<td>Oxygen</td>
<td>O₂</td>
<td>1.0</td>
<td>&gt; 19%</td>
<td>Normal air</td>
</tr>
<tr>
<td>Sulphur dioxide</td>
<td>SO₂</td>
<td>2.22</td>
<td>2</td>
<td>Smelting operations, diesel exhaust fumes, sulphur in coal seams</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>H₂</td>
<td>0.07</td>
<td></td>
<td>Simple asphyxiant Explosive hazard</td>
</tr>
<tr>
<td>Chlorine</td>
<td>Cl₂</td>
<td>2.5</td>
<td>10</td>
<td>Chlorination of water</td>
</tr>
<tr>
<td>Aldehydes</td>
<td>HCHO, etc</td>
<td>1.04</td>
<td></td>
<td>Diesel exhaust</td>
</tr>
<tr>
<td>Ammonia</td>
<td>NH₃</td>
<td>0.6</td>
<td>25</td>
<td>Cooling plants, blasting</td>
</tr>
<tr>
<td>Acetylene</td>
<td>C₂H₂</td>
<td>0.93</td>
<td></td>
<td>Welding and cutting</td>
</tr>
</tbody>
</table>

4.3.8.1 Oxygen

Most gases can, under certain conditions, constitute a danger to life. The first step towards guarding against these dangers is to know their properties in order to understand where to expect a dangerous condition, how to recognise it and what to do about it.

Oxygen is a colourless, odourless and tasteless gas at normal temperatures but the only normal way that oxygen can pose a danger in underground workings is by its absence. Air that has stagnated for a long period may have had much of the oxygen removed by oxidation of metals and minerals and
also by decaying timber. Some or all of the oxygen may have been replaced by CO₂ and such a mixture, which has an oxygen deficiency but is neither poisonous nor explosive, is called black-damp in coal mining. It is important to note that if stagnant workings have to be entered, for whatever reason, the atmosphere should be carefully tested for oxygen content as well as for the presence of flammable gas.

4.3.8.2 Nitrogen

Nitrogen is the most common gas in the atmosphere, comprising nearly 80 percent by volume. It is colourless, odourless, and tasteless and is almost insoluble in water. It does not burn nor support combustion and is obviously not poisonous. While nitrogen gas is chemically inactive the element nitrogen occurs in many active compounds such as nitrates, ammonia and others. Nitrogen in the atmosphere dilutes oxygen. This is very important because without this dilution an oxygen-rich atmosphere would result in uncontrollable fires.

Nitrogen combines directly with some metals to form nitrides at high temperatures. Examples are aluminium nitride (AlN) and iron nitride (Fe₃N₂). It is also a constituent of nitric acid, HNO₃, which in turn forms nitrates such as sodium nitrate, (NaNO₃) and calcium nitrate (Ca(NO₃)₂). It is also found in nitrous acid, (HNO₂), which forms nitrites such as sodium nitrite (NaNO₂) and calcium nitrite (Ca(NO₂)₂).

4.3.8.3 Carbon dioxide

Carbon dioxide, (CO₂), is formed by breathing and by the burning of matter containing carbon such as wood coal and fossilised fuels. It sometimes issues from rock formations and may have methane accompanying it. In collieries it is formed by oxidation of fine coal dust.

Carbon dioxide is odourless and colourless but it does have a slight acid taste. It is approximately one and a half times heavier than air and when stratified will therefore be found low down in places such as winzes or sumps.

Carbon dioxide has been called the “miners’ friend” as far as gases go because it gives a warning of its presence, probably accompanied by other more dangerous gases, by causing rapid breathing and a headache and by its slightly acid taste.

4.3.8.4 Carbon monoxide

Carbon monoxide (CO) is a very much more dangerous gas because it is extremely poisonous and interferes with the blood’s ability to transport oxygen. It is colourless, odourless, tasteless and very slightly lighter than air. CO is the product of the incomplete combustion of carbon. When any substance containing carbon is burnt when sufficient oxygen is present it forms CO₂. But if the supply of oxygen is limited it only burns partially to CO. To some extent this happens in nearly all fires, but more especially in mine fires where the supply of oxygen is more limited.

CO is also present in the exhaust gases of internal combustion engines and in blasting fumes.

4.3.8.5 Hydrogen

This is a very rare gas in nature, but it is sometimes mixed with methane which issues from rock fissures. It is a very light gas and is colourless, odourless and non-poisonous. It burns with a scarcely visible flame but does not support combustion. It is explosive (5 to 75%) and the explosive limits are not the same as for methane, the most violent explosion being with 30 percent hydrogen in air. Burning hydrogen develops more heat than burning methane. Hydrogen may be detected with a resistance type methanometer which indicates the summation of the methane and hydrogen percentages. Such a methanometer must be fitted with special flashback arrestors.

In some areas hydrogen and methane are known to occur together. Distinguishing between these two hazards is difficult and extreme vigilance and caution are needed in such cases.
4.3.8.6 Methane

Methane, (CH₄) is explosive and is believed to have caused more loss of life in mines than any other gas. It is, unfortunately, a colourless, odourless and tasteless gas, which, unless it is present in a big enough concentration to cause suffocation by reducing the oxygen concentration, does not affect breathing in any way. As a result it can lurk undetected by human senses and can strike unexpectedly.

In most coal mines methane is always either present or expected and consequently precautionary measures are applied. Anything up to 100m³ of methane can be released with each ton of coal mined.

Certain types of coal produce more methane than others and deep coal seams tend to be gassier than shallow seams. In metalliferous mines the gas may occur rarely and in unsuspected places potentially posing a bigger threat to the workforce than known sources of the gas. Of course, some gold mines are also very gassy in which case the usual precautions are enforced.

Methane gas burns but does not support combustion. When a jar containing methane is inverted and a burning taper inserted into it, the methane will immediately start burning at the bottom of the jar where it is in contact with the air. The taper, which is immersed in the gas, will be extinguished. The ignition temperature of methane is about 650°C, which means that only flames or hot sparks are hot enough to ignite it. When methane, however dilute, is brought into contact with a flame, it will burn. When the gas concentration is low i.e. less than five percent, the molecules are far apart and one burning molecule does not generate a sufficiently high temperature to “ignite” the molecule nearest to it. When the concentration is high enough (between 5 and 15 percent) each molecule “ignites” the one nearest to it and the flame rapidly spreads throughout the mixture. This causes an explosion. If the mixture contains too much methane, the amount of oxygen is reduced and in turn the rate of combustion is reduced to the extent that insufficient heat is developed to propagate a flame and thus there is no explosion in these high concentrations.

Because methane is very much lighter than air it is more likely to accumulate in high places such as raises and roof cavities. When the air movement in a tunnel is poor any methane issuing from the rock may form a thin layer above the air. However, once mixed with the air the methane never separates out again.

Sometimes methane can be heard issuing from a fissure (it is then called a blower) or it can be seen bubbling through the water in a drill hole or on the footwall. In such cases immediate precautions must be taken to dilute it to a safe concentration. The most dangerous conditions often occur when a very small flow of methane issues unseen and unheard. It may then accumulate in a high spot due to insufficient ventilation or to a temporary fan stoppage, and an explosion may then take place by a spark from an electric motor or switch. In addition to the violence of the explosion, damage to life and property is caused by the terrific heat generated.

4.3.8.7 Hydrogen sulphide

H₂S is an extremely poisonous gas that sometimes emits from rock fissures together with water or other gases. It can also be formed by the action of acids on sulphurous minerals such as iron pyrites (FeS₂) or copper pyrites (CuFeS₂). Water can dissolve significant quantities of this gas under normal conditions and very much more under great pressure. This has implications for the safety of workers. For example, when a winze that has long been filled with stagnant water is drained by drilling into it from below, sufficient gas may be released to cause unsafe conditions if the working place is not ventilated.

Hydrogen sulphide is a colourless gas, slightly heavier than air. It has a very distinct smell — like rotten eggs. In mild cases of exposure there is irritation of the mucous membranes of the eyes, the pharynx and the upper respiratory tract. With more serious poisoning there is giddiness, vomiting, sudden loss of consciousness and paralysis of the respiratory centre.
When the gas is expected, testing apparatus such as electronic detectors should be used to warn of its presence as exposure to even small concentrations impairs the sense of smell which may be lost within a few minutes. This may lead to a false sense of safety.

**4.3.8.8 Sulphur dioxide**

A colourless, pungent gas formed when sulphur burns in air, SO₂ is considered to be one of the most important air pollutants either alone or in combination with other gases and substances. Most of the sulphur dioxide in the general atmosphere comes from the combustion of the sulphur present in most fuels. All the sulphur in oil and from 80 to 90 percent of that in coal or coke is emitted in stacks or chimneys as sulphur dioxide, with a small proportion already converted to sulphur trioxide (SO₃).

This gas is dangerous to the eyes as it causes irritation and inflammation of the conjunctivae. It has a suffocating odour and is corrosive and poisonous. In moist air or fog it combines with water to form sulphurous acid, but is only very slowly oxidised to sulphuric acid. Concentrations of 6 to 12 ppm cause immediate irritation of the nose and throat, while 0,3 to 1 ppm can be detected by the average individual possibly by taste rather than by the sense of smell.

It chiefly affects the upper respiratory tract and bronchi. It may cause oedema of the lungs or glottis and can produce respiratory paralysis.

**4.3.8.9 Nitrous fumes**

Several oxides of nitrogen are usually found together in the same atmosphere and collectively they are known in mining terms as nitrous fumes.

*Nitric oxide. (NO).* A colourless gas with a faint smell and very poisonous. It is only slightly heavier than air and is relatively soluble in water. In concentrated form it combines readily with oxygen to form nitrogen dioxide. However this reaction is very slow when the concentration of NO is low, as is usually the case in mine air.

*Nitrogen Dioxide. (NO₂).* This is a reddish-brown gas, 1,6 times as heavy as air and with a distinct, pungent smell. It is five times more poisonous than NO and is very soluble in water.

*Nitrogen Trioxide, (N₂O₃).* This is also a reddish-brown, soluble gas that is of little importance, as such, because at the normal temperatures found in mines it rapidly decomposes to NO and NO₂.

Nitrous fumes are commonly a mixture of NO, NO₂, N₂O₄ with possible some N₂O₅. They occur in the gases formed by the detonation of nitro-explosives. The burning of such explosives produces even more of these gases. They are also present in the exhaust gases of diesel-powered engines and are also produced in small quantities by both oxy-acetylene welding and arc welding.

Nitrous fumes make up a gas mixture which causes irritation in the nose, throat and windpipe. After a short time in fresh air this irritation may disappear for several hours. However, during this period, damage to the lungs may be continuing (unnoticed). The inhaled gases combine with moisture (water) in the lungs and damage the lung tissue which results in bleeding and the accumulation of moisture in the lungs. One of the big dangers of exposure to these fumes is that the affected person, if not treated correctly, may eventually die from suffocation due to the filling of the lungs with moisture and froth. This is one of the reasons that it is mandatory to report all cases of gassing to ensure that appropriate measures are implemented to prevent any possible tragedy.

*Note:* Regulation 8.11 of the Mine Health and Safety Act and Regulations states that: the ganger or miner shall report without delay any case of gassing, however slight, to the manager, mine overseer or shift boss, who shall ensure the employee concerned receives prompt medical attention.

Even when the concentration of nitrous fumes is so low that it does not cause immediate irritation it may still cause lung damage, which, amongst other effects, could predispose to the development of silicosis.
Exposure to 0.1 percent nitrous fumes even for short periods is considered dangerous and 0.01 percent may be dangerous if breathed for more than 30 minutes.

Previously, all the nitrous fumes used to be grouped together and the set limit for exposure was 5 ppm. Under proposed legislation NO has been separated from NO\textsubscript{2} etc, and the proposed limits for exposure are 20 ppm and 3 ppm respectively.

4.3.8.10 Aldehydes

These are a series of organic compounds with the general formula: C\textsubscript{n}H\textsubscript{2n}O. Several aldehydes, with formaldehyde predominating, are present in the exhaust gases of diesel-powered engines. They have a very distinct and pungent smell and are intensely irritating to the eyes, the mucous membranes and the skin. At high concentrations they may be so pungent as to be suffocating.

Aldehydes can be smelt at concentrations far too low even to cause irritation.

4.3.9 Hydrogen cyanide

HCN is also known as prussic acid. It is extremely toxic and affects respiration.

This is a colourless gas that has a distinct odour of bitter almonds. It is slightly lighter than air. The gas may occur in mines where acid water comes into contact with cyanide in sand that has been used for sanddressing. Where this is practised precautions must be taken to prevent exposure of persons to this highly dangerous gas. Cyanides are also used in the gold extraction process.

4.3.10 Lead

A number of minerals, especially metals, become airborne in the form of metallic fumes during the refining process. The inhalation of these metallic compounds can cause acute inflammation of the lung tissue. The acute effects are characteristic of gassing incidents in many ways and are often classified as such, even where the inhaled material has been a fume.

Lead poisoning (plumbism) is one of the longest known occupational diseases in the mining industry. In gold mining, lead is used mainly in the zinc-preparation of cyanide-extracted gold and also in the assay of gold-bearing ores. Metallic lead at normal temperatures does not pose a high health risk, unless in the form of fine dust.

4.3.11 Mercury

This is an extremely toxic substance. Mercury is used in some reduction works to recover gold - known as the amalgam process. Because mercury is a liquid with a significant vapour pressure even at room temperature it evaporates into the atmosphere. Well-ventilated areas are required where mercury is handled and the vapour should be captured via an extraction system. Captured vapour should never be discharged to atmosphere but absorbed in activated charcoal.

4.3.12 Refrigerants (Ammonia and Freons)

4.3.12.1 Ammonia, NH\textsubscript{3} - is a light, colourless gas with a very pungent smell. It is very soluble in water. Ammonia can sometimes be smelt after blasting with ammon-explosives has taken place. However, it can only appear in dangerous amounts when leaking from cooling plants where it is used as a refrigerant. In such cases it will cause intense irritation of the eyes, nose and throat and will produce coughing. In high concentrations it may arrest respiration.

4.3.12.2 Freon. This is a trade name given to various methane halides (chlorine, bromine, fluorine and iodine are called halogens) which are used in refrigeration plants because they are safer than ammonia and in the past were considered to have some other advantages.

Both Freon 11 (trichloromonofluoromethane - CCL\textsubscript{3}F) and Freon 12 (dichlorodifluoromethane - CC\textsubscript{2}F\textsubscript{2}) are colourless and heavy gases. They are neither flammable nor poisonous but very high
concentrations can cause suffocation. However, in the presence of an open flame, Freon decomposes to form phosgene gas - \( \text{COCl}_2 \), which is very poisonous.

Freon gas leaks are tested by means of acetylene or alcohol gas flames, which change their colour if Freon is present.

**Special Note.** During the late 1980’s there was a considerable discussion worldwide concerning the depletion of the world’s ozone layer. Although the reasons are not fully understood, the use of chlorofluorocarbons - CFCs - was thought to be a major cause. Both Freon 11 and Freon 12 can be seen to be CFCs from their chemical formulae. A great deal of international support has been given to efforts directed at limiting CFC production and use, and there has been widespread public concern on this issue. International agreement on measures for the protection of the ozone layer (The Montreal Protocol) was achieved under the auspices of the United Nations Environmental Programme (UNEP) in September 1987.

Alternatives to CFCs were developed e.g. HFC22, Methylene Chloride and Di Methyl Ether.

### 4.3.13 Solvent vapours

Solvents are materials used to dissolve other materials where water is inadequate. They are used in processes such as extraction, degreasing, dry cleaning and ore flotation. Solvents are often an integral part of some products such as paints, varnishes, glues, pastes and many others. Organic solvents include naphtha, mineral spirits, turpentine, benzene, alcohol, perchloroethylene and trichloroethane.

There are certain dangers associated with using solvents.

- **Flash point.** This is the lowest temperature at which a liquid will give off a vapour in sufficient concentration to form an ignitable mixture with air when an ignition source is brought close to the surface of the liquid.
- **Explosion limits.** Flammable liquids have a minimum vapour concentration in air below which the propagation of a flame will not occur. Furthermore, there is a maximum concentration of vapour or gas in air above which the propagation of a flame will not occur because the mixture is too rich in combustible vapour i.e. it is fuel rich and the flame will choke. (See 4.3.8.6). These two limits are known as the Lower explosive Limit (LEL) and the Upper Explosive Limit (UEL) respectively.
- **Auto-ignition temperature.** This is the lowest temperature at which a flammable gas/air or a vapour/air mixture will ignite spontaneously or on contact with a heated surface. It is important to note that this will occur without a flame or spark being present. Gases and vapours will ignite spontaneously in the presence of oxygen and the presence of a catalyst can further lower the auto-ignition point.

Halogenated hydrocarbons represent the most important and widely-used group of industrial solvents. Some are very poisonous and all are narcotic to some extent. Saturated members of this group, such as carbon tetrachloride and tetrachlorethane, cause liver and kidney damage. Some solvents give off phosgene, which is a highly poisonous gas, when heated to decomposition.

Chlorobenzene is the best known of the aromatic chlorinated hydrocarbons. It is a flammable liquid that has an acute reaction on the central nervous system and can rapidly lead to unconsciousness. Certain chlorinated naphthalenes also cause liver damage which can result in toxic jaundice.

It is interesting to note that diesel fuel is very often used as a degreasing agent or for cleaning oily machine parts. This fuel is really a mixture of hydrocarbons, but usually contains sulphur, nitrogen, and oxygen compounds. It also contains trace elements such as iron, lead, copper and aluminium. The more volatile components have a mild anaesthetic action and can produce a severe chemical pneumonitis. The fuel fractions that have a lower boiling point can cause dermatitis due to their defatting effect on the skin.

It is always advisable to consult the Material Safety Data Sheets (MSDS) for information on chemicals to be used, especially solvents, and to note precautions for safe use and the use of Personal Protective Equipment.
4.3.14 Welding fumes

Welding operations generally involve the melting of a metal in the presence of a flux or a shielding gas by means of a flame or an electric arc. The operation may produce gases or fumes from the metal, the flux, the metal surface coatings or surface contaminants. The flame or arc may also form certain toxic gases such as ozone or nitrogen dioxide. If there is an arc or spark discharge, the non-ionising radiation and the products of destruction of the electrodes should be investigated.

Welding fumes cannot be classified simply. When welding is done on a surface coated with cadmium, toxic fumes of cadmium can be involved. When zinc-coated surfaces are welded, toxic quantities of zinc oxide may be liberate. When painted surface are welded, lead or other pigment fumes may be liberated. When fluoride fluxes are used in welding very toxic fluoride fumes are involved. Also, when oily surfaces are welded, offensive and toxic fumes can be liberated and when the welding torch is improperly ignited i.e. the wrong gas mixtures are used, carbon monoxide may be evolved. In addition, oxides of nitrogen may be formed. It is therefore considered hazardous to inhale welding fumes.

4.4 Occupational Exposure Limits (OELs)

An Occupational Exposure Limit (OEL) is that concentration of an airborne substance to which nearly all workers may be repeatedly exposed day after day without adverse health effects.

The American Conference of Governmental Industrial Hygienists (ACGIH) has published threshold limit values (TLVs) for several hundred industrial materials. The information collected for one substance may run into hundreds of printed pages. The limits are not a dividing line between safe and unsafe conditions. Their main use is intended to be a link between medical doctors, the engineers who have to design control equipment and the occupational hygienist who has to monitor the occupational environment. These limits are based on the best available information from e.g. animal studies and workplace experience. The basis on which values are set may differ from substance to substance, depending on whether protection against health impairment, freedom from irritation or other forms of stress is being considered.

4.4.1 OEL _ TWA

It has been found in practice that concentrations of airborne pollutants may vary between wide limits within any one 8-hour shift. It was therefore considered that to assess worker exposure the time-weighted average concentration of the pollutant should be used. This approach has to take cognisance of any excessive peak concentrations, which in the case of some substances could cause significant health impairment and even death.

The airborne concentration to which nearly all workers may be repeatedly exposed for a normal 8-hour workshift (or a 40 hour work week) constitutes the Time-Weighted Average (TWA) limit and is a concentration expressed either in parts of vapour or gas per million parts of polluted air by volume at 25°C at 101,3 kPa pressure (ppm), or in milligrams of pollutant per cubic metre of air (mg/m³).

4.4.2 OEL _ STEL

For many substances a peak concentration exposure may be tolerable, provided that the exposure is for only a limited time. These concentration values are designated short-term exposure limits (OEL _ STEL). These 15-minute exposure limits can be found in the Department of Minerals and Energy’s Schedule as well as in other publications such as the ACGIH reference material. OEL _ STELs thus represent the maximum concentration to which a worker can be exposed continuously for a period of up to 15 minutes without adverse effects. Not more than four such excursions per day are permitted with at least 60 minutes between excursions and also the daily OEL _ TWA must not be exceeded.

OEL _ STEL values should not be used as engineering design criteria or for emergency exposure levels.

4.4.3 OEL-C

Certain hazardous substances such as chloroform, hydrogen chloride, nitrogen dioxide and vanadium fumes are predominantly fast acting. Even short-term exposure to high concentrations of substances
like these could have some adverse effect on the human body. In such cases OEL \_ TWAs are obviously unsatisfactory. Substances of this nature are best controlled by a Ceiling (C) limit that should never be exceeded. In effect, these limits constitute maximum allowable concentrations and are not to be confused with OEL \_ TWA limits

4.4.4 Lists of limits

Various organisations have compiled and published lists of substances for which OEL limits have been formulated. The ACGIH publishes a handbook on OELs (TLVs in this case) and Biological Exposure Indices, which is updated on an annual basis. The DME has selected substances from this list and set out a revised list in a schedule to mines. Only substances deemed to be relevant to the mining industry have been included. In a like manner, the Department of Labour has compiled a similar list comprising substances felt to be relevant to Industry.

4.5 Assessment of compliance with OELs

4.5.1 Analytical methods

The National Institute for Occupational Safety and Health (NIOSH) of the US Department of Health and Human Services produces a Manual of Analytical Methods. This manual is recognised world-wide as the most authoritative reference for both sampling and analytical methods/techniques. It contains over 250 sampling and analytical methods for over 400 substances. It is a compilation of methods for occupational exposures to toxic substances in air and biological samples. The methods have been developed specifically to have adequate sensitivity to detect the lowest concentrations and sufficient flexibility of range to detect concentrations exceeding safe levels of exposure, as regulated by the Occupational Safety and Health Administration (OSHA) and recommended by NIOSH.

For ease of reference the manual is available via the Internet, on computer diskettes and a compact disk. A companion Guide to Chemical Hazards has also been produced in these formats and these manuals offer definitive assistance with regard to airborne and chemical health hazards.

In South Africa the tendency is to follow the NIOSH analytical methods closely and to adhere to the NIOSH techniques. A common set of analytical methods lays the foundation for standardisation, comparisons of results and inter-laboratory checks. There is also no reason to “re-invent the wheel”, as it were, since all the methods and techniques have been well-researched and authenticated.

4.5.2 Sampling strategies

Gravimetric dust sampling strategy

When the Government Mining Engineer introduced gravimetric dust sampling in mines in 1992, guidelines were issued on precisely how the sampling was to be performed. Mines were divided into areas which, in turn were divided into statistical populations. Statistical populations were supposed to consist of persons generally exposed to similarly dusty environments. These populations embrace 200 persons. Five percent of the population was sampled over each six month sampling cycle. The broad strategy is set out in Figure 4.1.

The individual sampling results were averaged, on a person-weighted basis, for each statistical population. The results for each statistical population were then averaged to produce an area average, which is in turn was used to produce a mine average. Samples for each statistical population had to be analysed for $\alpha$ quartz content in an laboratory using approved techniques. Once the quartz content was known for each statistical population the person-weighted risk was determined and ultimately the person-weighted risk for the mine was calculated. The risk was then used to determine the levy that a mine has to pay into the compensation fund. At the time the dust-sampling programme was introduced, sampling with konimeters was no longer required. In effect, this meant that dust sampling in individual workplaces and for engineering control purposes virtually ceased.

The dust-sampling programme outlined above was for levy purposes and did not assess whether the exposures of individual workers were in compliance with occupational exposure limits.
The air sampling required by the Occupational Hygiene Regulations is as follows:

- The mine is sub-divided into working places as per the working place code list found in the guideline.
- The results of the identification process are compared to the relevant OEL and based on this, each workplace is categorised into one of three classification bands to determine the various homogeneous exposure groups (HEG) as shown below.

### Table 4.6 Classification Bands

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>PERSONAL EXPOSURE LEVEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Exposures exceeding the OEL</td>
</tr>
<tr>
<td>B</td>
<td>Exposures between 50% of the OEL and the OEL</td>
</tr>
<tr>
<td>C</td>
<td>Exposures between 10% of the OEL and 50% of the OEL</td>
</tr>
</tbody>
</table>

![Figure 4.1 Breakdown of a mine into sampling units](image)

- The number of samples to be collected in each group is formulated as per Table 4.7.

Homogeneous Exposure Groups need to be reclassified when exposure levels change due to the implementation of controls or due to a deterioration of controls. The monitoring strategy within an HEG will have to be adapted to the new frequency of monitoring when either of the above occurs.

Similarly, HEGs must also be re-evaluated when, inter alia, the following occur:

- Employee complaints
- Process changes
- Occupational illnesses
- Other events warrant re-evaluation
- New toxicological data
- New regulatory initiatives

The exposures measured for any individual worker within a homogeneous exposure group would be allocated to the medical records of the specific worker and to all other workers within that HEG. For a given HEG, samples should be randomly assigned covering all shifts (to different employees on different days over the monitoring period). All job categories within a homogeneous exposure group must be randomly sampled.
Table 4.7 Airborne Pollutants: Sampling

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>ACTION/FREQUENCY</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Verify the results&lt;br&gt;Issue appropriate Respiratory Protective Equipment (RPE) or Stop Work if no appropriate RPE is available to prevent overexposure&lt;br&gt;Inform the Regional Principal Inspector of exposures exceeding the OEL&lt;br&gt;Amend the action plan to institute control measures to eliminate overexposures.&lt;br&gt;The following must also be complied with:&lt;br&gt;Sample 5% of HEG on a monthly basis.</td>
</tr>
<tr>
<td>B</td>
<td>Sample 5% of HEG on a six monthly basis.</td>
</tr>
<tr>
<td>C</td>
<td>Sample 5% of HEG on an annual basis.</td>
</tr>
</tbody>
</table>

Although the above strategy appears to be straightforward, the previous sampling strategy ran into difficulties that were not addressed. Dust sampling can be affected by many factors and should not be over-simplified.

**Sampling Methodology**

Before sampling commences filters, either 25 mm or 37 mm diameter (depending on the anticipated dust loading but in general, most non-gold mines use 37 mm diameter filters) are numbered, dried, weighed and inserted in filter holders. Filters are weighed on an electronic microbalance with the capability of measuring to several decimals of a gram.

In addition, the pumps to be used for sampling have to have batteries charged according to the manufacturer’s specifications. The pumps then have to have the sampling flow rate set to 1.9 l/minute (as specified in the guidelines). Flow rates are set by having the pump draw air through a calibrating apparatus that makes use of an electronically-timed soap bubble. The pump draws the soap bubble vertically upwards in a calibrating tube and the time taken for the bubble to traverse between calibrating marks is electronically timed. Using such apparatus, pump flow rates can be set accurately to any desired flow rate.

The sampling pumps and all the accessories such as filter holders, cyclones, etc are attached to the workers to be monitored. A very efficient organisation is required to ensure that the pumps are allocated to the persons intended on time and started. Samples of dust present in the air are collected and deposited on the filter over the duration of the shift.

At the completion of the shift (or sampling period) the sampling pumps have to be retrieved, stopped and details of the sampling period recorded.

**Records**

Worker’s details and also
(i) Sampling instrument number<br>(ii) Filter number<br>(iii) Pump flow rate (l/min)<br>(iv) Sample duration (minutes)<br>(v) Volume of air sampled (m$^3$) = \{(iii) \times (iv)/1000\}

The pump flow rate has to be checked again and if there is a deviation of five percent or more from the pre-sampling flow rate the sample is to be rejected. Arrangements then have to be made for another sample to be collected.
After a suitable period of acclimatisation the mass of dust on the filter is determined as (mass of filter + dust) – (mass of filter) allowing for changes to the mass of the filter due to moisture changes. These changes are ascertained by checking changes to the masses of control filters during the period between initial weighing and weighing after sample collection.

Dust concentrations are then calculated from the volume of air sampled and the mass of dust collected on the filter and reported as mg/m³.

Filters may then be analysed for quartz content. Either the x-ray diffraction or the infrared method may be used. With x-ray diffraction the filter is inserted into a special holder and placed into the machine after it has been warmed up and calibrated against standards. The sample is then scanned and the diffraction patterns in the various x-ray ranges automatically plotted. The peak concentrations in the quartz range are measured and the analytical mass of quartz calculated. This method does not damage the filter in any way i.e. it is a non-destructive method and the filter is available for further analyses or storage. The Infrared method may also be used but this requires the manufacture of a pellet using potassium bromide and this destroys the original filter. Either method may be used with equal accuracy of results, but the analysing laboratory has to be approved by the South African Bureau of Standards (SABS).

Once the quartz content has been determined the quartz concentration can be calculated. It is this contaminant concentration that is compared to an OEL and the hazard potential of the inhaled air assessed.

It is necessary to ensure that all equipment necessary throughout the monitoring is properly prepared i.e. batteries for sampling pumps are charged, flow rates are set, filters are weighed and sampling cassettes are loaded and the necessary paper work completed. This is not only a necessary aspect of any investigation but vital for the compilation of exposure profiles in the mine.

It must also be noted that monitoring can take three forms:

- Personal monitoring - establishing the concentration of contamination to which the worker is exposed. The major dust sampling effort of mines has this exclusive aim
- Environmental Monitoring - establishing the environmental concentration to which it is believed that everyone working in the area is exposed. This technique can be useful for zoning hazardous areas. However, the sampling strategy outlined earlier makes no provision for this type of sampling. Because of the averaging process inherent in gravimetric sampling this type of sampling is not entirely suitable to localise dust generating processes and operations and an alternative sampling method or technique is indicated
- Special Monitoring - establishing the concentration of the contaminant for special purposes, e.g. research on the effectiveness of control measures

4.5.3 Airborne dust

4.5.3.1 Airborne dust criteria

For chemical substances present in inhaled air as suspensions of solid particles for droplets, the potential hazard depends on particle size as well as mass concentration because of:

1) effects of particle size on the deposition site within the respiratory tract
2) the tendency of many occupational diseases to be associated with material deposited in particular regions of the respiratory tract

The Chemical Substances TLV Committee of the American Conference of Governmental Industrial Hygienists (ACGIH) has recommended size-selective TLVs for crystalline silica for many years in recognition of the apparent association between silicosis and respirable mass concentrations. The Committee is now re-examining other chemical substances encountered in particulate form in occupational environments with the objective of defining:

1) the size fraction most closely associated with the health effect of concern, and
2) the mass concentration within that size fraction
Analyses of specific air contaminants and the potential diseases associated with different regions of the respiratory tract indicate that size-selective sampling is necessary for a meaningful evaluation of the inhalable hazard to the worker. Different particle size distributions of the same contaminant will cause major changes in deposition in the various regions of the respiratory tract. This changes not only the relative amount of material deposited within the region but also the probability and nature of associated disease processes. Thus, the development of Particle Size-Selective Sampling—TLVs (PSS-TLVs) is an important and necessary step toward the improvement of air contamination standards established for the protection of workers.

PSS-TLVs are expressed in three forms:

1) **Inhalable Particulate Mass TLVs (IPM-TLVs)** for those materials that are hazardous when deposited anywhere in the respiratory tract.

2) **Thoracic Particulate Mass TLVs (TPM-TLVs)** for those materials that are hazardous when deposited anywhere within the lung airways and gas exchange region.

3) **Respirable Particulate Mass TLVs (RPM-TLVs)** for those materials that are hazardous when deposited in the gas exchange region.

Collection efficiencies representative of several sizes of particles in each of the respective mass fractions are shown in Figure 4.2. The particles are collected according to defined efficiencies for their respective masses. The most significant difference from previous definitions is the increase in the median cut point for the respirable particulate matter sampler from 3.5 µm to 4.0 µm. This is in accord with the International Organization for Standardisation/European Standardisation Committee (ISO/CEN) Protocol (ACGIH, 1997).

The application of information on how the aerodynamic size of aerosols determines the inhalability, i.e. the fraction of airborne mass that actually enters the nose or mouth during inhalation, and the regional deposition of particles within the respiratory tract can lead to acquiring size-selective samples that more closely relate to aerosol inhalation hazards. Size-selective aerosol samples may be defined as reliably collected aerosol fractions which are expected to be available for deposition in the various subregions of the respiratory tract (ACGIH, 1997).

### 4.5.3.2 Dust sampling

Because fine dust particles which are the main cause of pneumoconiosis cannot be seen by the naked eye and because the dust which can be seen is coarse and comparatively harmless, the human eye is not a reliable guide to any dangerous dust in the air. It is therefore necessary to make use of dust sampling instruments which are capable of providing indications of the fine dust in the air to determine whether the dust constitutes a danger to health, what it is caused by, what can be done to reduce the concentrations of airborne dust and whether such action is having the desired effect. Any respirable dust-sampling instrument should be so designed that it will capture only dust particles of a size considered to be dangerous to health - usually smaller than about 5 to 7 micrometres.
This is achieved in some instruments through the way air is drawn in at a fixed rate via the inlet, which is designed so that the air travels very slowly at first thereby allowing the coarse particles to settle out before reaching the region where the dust is actually retained as a sample.

**Gravimetric dust sampling**

The requirements for a sampling pump are:

(i) the battery powering the pump should last longer than an eight-hour shift
(ii) the sampling flow rate should remain constant, as far as possible, irrespective of the charge remaining in the battery
(iii) the sampling flow rate should remain constant, irrespective of the dust burden on the filter. In other words the flow rate should be maintained as dust builds up on the filter
(iv) the sampling flow rate should remain constant, irrespective of the barometric pressure. Sampling pumps should be capable of use at any elevation in the workings and deliver a consistent performance. This is very important in deep mines where a large range of operating pressures can be experienced.
(v) the pump and battery should be light enough not to cause the wearer of the sampling apparatus any discomfort.
(vi) The sampling pump should be intrinsically safe.

Several manufacturers produce suitable sampling pumps with miniature batteries that meet all the criteria outlined above. The pumps feature some sort of timing device that indicates lapsed sampling duration and an adjustable rotameter that provides a rough estimate of the sampling flow rate. There is an external battery charging facility and an indicator of battery condition. Most models have security features that cover the on/off switch and the rotameter adjuster to prevent inadvertent or even deliberate changes to the settings. Some models can be programmed to start and stop at predetermined times. An example of a dust-sampling pump is shown in Figure 4.3.

![Figure 4.3 Personal air sampling pump (courtesy of Rotheroe and Mitchell)](image)
The dust-sampling pump is only one element of a sampling train, as it is called. There is also a sampling cassette, which for respirable dust sampling consists of a separating cyclone, sampling head and filter medium. The sampling head is connected to the sampling pump by a thick-walled (to prevent kinking), non-static, flexible tube.
When the pump is activated, air (with dust) is drawn into the separating cyclone, which, through centrifugal force, separates the large from the small particles. The former settle in the catchpot while the latter i.e. the respirable fraction of interest is retained on the filter.

An actual sampling cassette assembly is shown in Figure 4.4 where the various components are seen. Once all the sampling equipment has been correctly assembled it has to be attached to an employee for a full shift sample to be collected. The cassette is positioned in the breathing zone of the person being sampled. This is defined as the zone within a 30 cm radius of the nose. Since the sampling cassette will be in this zone throughout the shift it is reasonable to expect that a representative sample will be collected for the person being sampled. Figure 4.5 shows one method of attaching the equipment to the wearer.

It must be noted that the actual sampling requirements and techniques for various airborne particulates can differ. For example, lead samples are collected as “total dust” samples and asbestos fibres are collected via an anti-static tube onto the open face of a filter. In addition, to prevent overloading of filters with fibres and background dust such samples are collected for ten-minute periods during each hour’s sampling. Evaluation and sampling are in accordance with the Asbestos International Association (AIA) Recommended Technical Methods or variations thereof.

A second way is to make use of a harness, which attaches the sampling train, without the long tube, to the chest of the wearer.

4.5.3.3 Real time monitoring

A disadvantage of the sampling methods described above is the inevitable delay before the results of dust sampling can be judged. A number of sampling instruments have been developed for making a rapid assessment of the concentration of respirable dust, using physical phenomena such as beta radiation attenuation, electrostatic precipitation coupled to a piezoelectric balance and the scattering of a light beam.

One such instrument is the digital tyndallometer, seen in Figure 4.8.

![Figure 4.8 A typical digital tyndallometer (courtesy of Hund)](image)

This is a portable instrument that makes use of the light scattering properties of dust. A beam of monochromatic light with a wavelength of 0.94 µm passes across a sensing chamber that is open to the atmosphere being investigated. The presence of dust in the path of the beam causes the beam to scatter. The intensity of the scattered light within a 70± scattering angle is measured with photocells and displayed as a digital readout. This type of instrument has an integrated data memory and an internal real-time clock. It has the capability of providing averaging over random intervals of between five seconds and up to eight hours (in battery mode). Current values are measured every second. Results can be downloaded using suitable software and deposition patterns charted.

Deposition patterns similar to the one shown in Figure 4.9 can be obtained. The instrument is designed to give a volume-proportional signal related to the concentration of fine dust in the beam, according to its deposition probability in the human lung.

Unfortunately, it is not only dust that is sensed but also all aerosols. This means that oil mists, water vapour and diesel soot are also “seen” as dust in the path of the beam but no distinction from dust particles is possible. The instrument has potential in trouble-shooting exercises and is useful for testing the effectiveness of control measures. However, in the hands of an inexperienced operator very unreliable results are possible (and inevitable).
Figure 4.9 A typical dust deposition pattern

Even though the tyndallometer may not measure dust alone, with intelligent interpretation of results very useful information can be derived. High airborne pollutant concentrations can be linked to specific events, as can be seen in Figure 4.9.

4.5.4 Gases and vapours

Different gases found in a mine require a range of sampling and detection techniques. The available techniques can be divided into two main groups:

- measurement by means of direct reading instruments
- sample collection followed by subsequent laboratory analysis

As in the case of dust measurements, an air sample should be collected over the entire working period if a time-weighted average concentration is required. Most of the direct reading apparatus operates on the principle of spot measurements or grab sampling. This means that the sample is collected over a short period of time. Some instruments have built-in recorders, or can be fitted with recorders, in order to measure maximum (peak) and minimum concentrations over a working shift. These real-time traces can be used to calculate average concentrations if required. Some direct reading equipment can be linked directly to a computer to record concentrations and the variations thereof and yet others can give real-time readings on site as well as log the data which can later be downloaded for analysis.

4.5.4.1 Sample collection

As far as mines are concerned samples are collected in three ways, usually for different reasons:

- Air is drawn into a container, most usually a tedlar bag, for whatever time period is deemed to be necessary and transported to a laboratory for analysis. This technique is used when gases in a workplace are required to be identified and concentrations quantified
- In a similar way air samples are collected from boreholes in containers, normally specified by the analysing laboratory, and transported to the laboratory within the time period and manner specified for analysis.
Points to be noted are:

(i) A large enough volume of air has to be sampled to ensure the provision of sufficient gas for analysis
(ii) The collected gas must remain in the same state as when it was collected at site and must be stable during transport to the laboratory
(iii) A minimum of manipulation in the field is required

4.5.4.2 Direct reading instruments

These are generally instruments that draw air through a collector and the reaction with the collector is indicated directly on a meter, either analogue or digital. Examples of direct reading gas monitors are shown in Figure 4.10 below. It can be seen how small the instruments are and how easy it is to read the gas concentration.

Most instruments use some form of electrochemical cells that are supposed to be specific to a given gas but when dealing with non-explosive gases cross-sensitivities to other gases are known to exist and can cause problems. There is available a carbon monoxide monitor that is attached to a miner’s cap lamp and which flashes when CO levels exceed a pre-set limit. This device is used mainly in collieries for the early detection of “heatings” but can be used in any mine where there may be a danger from fires.

Shown in Figure 4.11 is a further example of a direct reading gas monitor. The monitor is an H₂S monitor in this case.

Instead of using several separate monitors to test for different gases there are available multi-gas testing monitors. Shown in Figure 4.12 is a direct reading gas monitor equipped with various electrochemical cells and which is capable of monitoring several gases simultaneously and continuously. This is a very versatile instrument but is generally not used on a routine basis. Such an instrument could be used when the need to monitor important gases in a specific locality exists. For instance, it may be necessary to monitor different gas concentrations along a route travelled by diesel-powered vehicles. This type of monitor makes it possible to monitor levels of CO, NO and NO₂ simultaneously.

The advantages of using a direct reading instrument are:

(i) that the results are rapidly and readily available and any remedial action can be implemented with a minimum of delay by a suitably qualified person
Figure 4.11 Direct reading gas monitor (H₂S) with an electrochemical cell (courtesy of Oldham)

Figure 4.12 Multi-gas direct reading monitor (courtesy of Crowcon)
(ii) the instrument is usually capable of producing a continuous record of gas concentrations, including peaks
(iii) the instruments can readily be used to trace a source of pollution or a specific contaminant

However, certain problems concerning the use of these instruments should be noted:

(i) Calibration is not always easy and obtaining reliable calibration gases has been shown to be problematical. Inter-laboratory checks have shown significant differences in the calibrating gas concentration. This means that a close watch has to be kept on this aspect
(ii) As mentioned already, cross sensitivity to interfering gases or impurities can result in incorrect indications of gas concentrations. To a certain extent this can be dealt with if the interfering gas is either known or anticipated
(iii) This type of equipment is not always available; it cannot always be used for personal monitoring and is considered to be very expensive
(iv) Electrochemical cells have a limited shelf life, whether in use or not

4.5.4.3 Colorimetric testing methods

Chemicals or reagents are sealed in glass tubes and after the seals are broken a specified amount of air is drawn through the tube. The amount of air is determined by the manufacturers and relayed to the user by specifying the number of strokes to be used with the aspirating pump. Typically, one single stroke or aspiration will draw 100 ml of air through the sampling tube. Shown in Figure 4.13 is a sampling bellows in use with a chemical detector tube.

The contaminant in the air being sampled reacts with the reagent to produce a change in colour. The gas concentration can be deduced from the colour gradient or the intensity, or from the amount of discolouration of the reagent i.e. the length of discoloured material in the detector tube.

Detector tubes are available for a large number of different gases. Some gases, e.g. carbon monoxide, (CO), have tubes supplied in two ranges viz. low range and high range. Note: where there is any uncertainty of the range, for the sake of safety all gas concentrations should be regarded as “high” until proved otherwise.

A CO detector tube is shown in Figure 4.14.

The tubes can be used to measure concentrations of gases at the ppm level and the colour reagents are supposed to be specific for a given gas.

However, once again the problem of cross-sensitivity to interfering gases is known to exist and appropriate precautions need to be instituted to avoid complications.

Advantages of this method are that it gives a rapid response, the equipment is highly portable and it is relatively inexpensive. It does provide a quick indication of the presence of an atmospheric contaminant.

Figure 4.13 Sampling bellows for chemical detector tubes (courtesy of Drager)

Figure 4.14 Chemical detector tube for carbon monoxide
Disadvantages of this method are:

(i) Poor accuracy. The relative standard deviation can often be as much as 40%
(ii) Sampling tubes have a limited shelf life
(iii) Built-in differences as a result of the manufacturing process can occur
(iv) Although there are long-duration sampling tubes this type of monitor is not very suitable for personal monitoring
(v) The colour reaction can be influenced by environmental contaminants in the air that is being sampled. This is especially important if diesel exhaust emissions are to be measured. If the manufacturer’s cooling fins are not used then inaccurate measurements are a foregone conclusion. Furthermore, if corrections for ambient pressures are not made additional inaccuracies will result. The manufacturer’s handbook should be referred to for the calculations to correct for temperature and pressure.

On occasion it is desirable to collect gas samples over a number of hours instead of the short time needed for the standard chemical detector tubes. There is a monitor known as a polymeter that uses special chemical tubes for long duration sampling. The air is drawn through the tube by means of a battery driven, mechanical sampling pump and the sampler can be set to sample over the required number of hours. It is therefore possible to determine 8-hour TWA exposure levels using this equipment. The apparatus is shown in Figure 4.15.

4.5.4.4 Chemical badges
Chemical badges are available to determine shift-long exposure levels for selected gases. These badges are attached to the wearer at the commencement of the shift and removed at the completion of the shift. A simple colour comparison will give the exposure in terms of ppm.hours which, if the sample duration is known, can be converted to an 8-hour time-weighted average (TWA) value. A second similar type of badge has to be sealed after removal from the wearer and then analysed in a computerised analytical procedure.

4.5.4.5 Sorbent tubes
Many of the substances of importance in occupational hygiene appear in the working environment in the form of gases and vapours and therefore cannot be collected like particles on a filter medium. Many industrial biological processes produce and release gases. Many of them can be toxic and others can cause asphyxiation in confined places.

There is a large variety of gases and vapours present in industry and they require a wide range of sampling and detection techniques. Broadly, the available techniques fall into two main groups, namely:

- Direct measurement by means of direct-reading instruments and,
- Indirect analysis in which an air sample is collected in the workplace and then analysed in a laboratory.

One way of sampling chemicals (impurities) in the atmosphere is by drawing the air through an absorbent or adsorbent such as activated charcoal. This will concentrate specific gases or vapours for analysis at a later stage. This concentration makes the analysis more reliable.

The most commonly used adsorbers are:

- activated charcoal tubes
- silica gel tubes as well as tubes equipped with specialised adsorption materials e.g. Tenax.
- Whatever method is deployed certain general considerations must be observed; and
passive monitors that work on the principle of diffusing the contaminant in question through a membrane of sorts. The gas or vapour is then adsorbed onto an activated charcoal disk for later analysis.

When charcoal or silica gel tubes are utilised air pumps are used to draw air through the tubes at a fixed, known rate for a specific period of time.

Adsorption is usually a dry method of sample collection.

**4.5.4.6 Bubblers**

Another commonly used method is glass impinger tubes and glass containers which have porous glass bubblers. Contaminated air is drawn through a specific liquid i.e. the collection medium, usually at a rate of between 2-3l/min during which time a chemical reaction takes place between the contaminant and the absorber. One or more impinger tubes are placed in series to ensure total absorption of the contaminant.

Absorption is a wet method of sample collection.

- The integrity of the sample must be maintained to prevent degradations or reactions in the collection medium.
- The sampling procedure should be optimal for the analytical procedure to be used.
- It must be ensured that the gas or vapour sampled is stable and capable of being stored without wall losses in the container used for sampling.
- Precautions are necessary to prevent leaks and sample contamination.

As far as possible the time interval between sample collection and sample analysis should be kept to a minimum and samples should be protected from exposure to direct sunlight and temperature extremes.

**4.5.5 Diesel exhaust emissions**

As noted in Table 4.2 diesel exhaust emissions consist of gaseous and particulate components and their respective OELs must be observed.

In any mine workings both tracked and trackless vehicles may be encountered and the exhaust products may be emitted into confined spaces. Where the ventilation is not adequate, pollutant concentrations may become elevated and immediate action may be necessary.

Section 4.3.8 shows the characteristics and dangers of general airbody gases and diesel exhaust emissions were covered under this item. Because diesel-powered vehicles are mobile they are capable of spreading exhaust pollutants through large working areas. It therefore becomes important to know the working areas affected by the operation of such vehicles and to formulate a sampling strategy that will be representative of the operating atmosphere.

In addition to mobile equipment other equipment, such as drill rigs, may also be diesel-powered.

Personal gas monitors, either multiple sensor units or individual units, should be used along diesel routes and samples collected over the full shift. Operators of such vehicles should also be monitored to determine exposure levels. In a similar way, samples where stationary diesel-powered equipment is deployed are also necessary.
In addition to gas monitoring where diesel-powered equipment is operated, particulate emissions also need to be monitored. This is done by using standard gravimetric dust sampling equipment and samples are collected over the full shift. The collection of these samples is most important because of the potentially carcinogenic nature of the diesel soot. Once the samples (filters) have been returned to the laboratory and stabilised they are weighed to determine the mass of mineral dust and diesel soot. Thereafter the filters are combusted under controlled conditions to burn off the diesel soot and the filter. The importance of using ashless filters can thus be seen. From initial filter preparation data the mass of the unused filter is used together with other weighing data in calculations to determine the mass of mineral dust and the mass of diesel soot. The relevant concentrations are then calculated.

Note: In South Africa diesel fuel in use fortunately does not have a sulphur component and this can be ignored as a pollutant hazard.

It should be noted that grab samples or samples with chemical detector tubes have not been recommended for reasons given in Section 4.3.8. Such short-term samples can not be representative of full shift sampling and do not allow for comparison with OELs, which are generally 8-hour TWA based.

4.5.6 Welding fumes

Dust conditions in workshops vary widely and two primary contributors are oxy-acetylene torches and electric arc welding plants. These operations cause local contamination and also give the general atmosphere a mixed airborne contamination content, usually with a high concentration of metal fumes.

Generally, it is recommended that welding fumes be removed from the work zone by local extraction rather than general ventilation. This may be achieved by using booths, ventilated benches or adjustable hoods. Where the type of work prevents the use of local extraction e.g. cutting a steel beam, then general ventilation must ensure that all areas where welding may take place receive sufficient ventilation to dilute the fumes. A third method is to make use of a suitable respirator.

In the past most welders may not have been too concerned with the need for a respirator. However, with increasing awareness of potentially hazardous contaminants in the workplace, it is critical to understand the importance of respiratory protection. There are different respirators for different contaminants and with different filtration characteristics. One contaminant may have an OEL of 5mg/m³ and another an OEL of 0,1 mg/m³. Obviously, the required respirators for these two contaminants would differ considerably.

A fourth protective measure exists: a helmet connected to a compressed air supply that positively ventilates the helmet and prevents the ingress of contaminants to the breathing zone of the operator.

As pointed out in Section 4.3.14 welding operations can give rise to many different airborne contaminants. Hence, when exposure levels have to be determined at welding operations it is important to ask the following questions before sampling:

- What are the raw materials?
- What is produced?
- What products are formed in the process?
- What by-products may be released?
- Where is the main activity to be conducted e.g. in a workshop or outdoors?

Monitoring exposure levels at welding operations is not straightforward. Welding may take place in booths, on a shop floor, outside the workshop or in a plant or even, in some cases, in underground workplaces. Monitoring requirements can thus be seen to vary considerably.

Personal monitoring is the measurement of a particular employee’s exposure to airborne contaminants. It is usually done during a specific time period viz. full shift or over 15-minutes to ensure compliance with OELs or STELs. It is necessary to draw attention to this aspect because
welding/cutting operations are not static and do not take place throughout the day at a steady pace nor necessarily at a single place. Work may be sporadic and the operator exposed to high peak concentrations of contaminants for relatively short periods of time. Although the 8-hour OEL-TWA limit may not be exceeded, STEL values, on the other hand, could well be exceeded. Also, different materials may be cut or welded and therefore different contaminants will be liberated. It is because of this variability that it is important to observe persons being monitored. A critical aspect in personal monitoring is the position of the sampling filter head. If it is not placed inside the welder’s hood the results will not be representative of the level of contaminants being inhaled by the operator.

Area sampling is another method used to evaluate exposure. Here, exposure is measured not in terms of a particular employee, but rather in terms of the ambient air concentration of a particular substance in a given area at a given period of time. Monitors are normally placed, adjacent to workers’ normal workplaces. If area sampling is thorough, knowledge of a worker’s activity at a given place may give reasonable estimates of a person’s exposure, but the procedure is inferior to personal monitoring if true exposures are to be assessed.

Although the DME quotes the 8-hour OEL_TWA as 5 mg/m³ for welding fumes, it should be recognised that this is a “generic” value and does not take cognisance of specific contaminants. If these are known, then monitoring for them specifically should be undertaken. In addition to personal monitoring, area monitoring should also be conducted and operators should actually be observed and where applicable peak values ascertained.

4.5.7 Evaluation of results

The first step towards implementing pollutant control measures is a thorough examination of results from the identification and/or monitoring processes.

The interpretation of results is more difficult than at first appears. Interpretation is done by comparing the results obtained with the acceptable level of concentration i.e. the OEL value or health standard. However, there are many factors that can influence the acceptance of results such as their repeatability or highly changeable pollutant levels within a workplace. The following aspects should be taken into account during any analysis or interpretation of results:

- Certain environmental factors can have a detrimental effect on the body after only a short period of exposure e.g. heat while for others deleterious side effects manifest after a long exposure, for example silica dust. These deleterious effects are related to the exposure in ways not yet fully quantified or understood.
- People react in different ways to the same exposure. Some people are hypersensitive while others display a higher tolerance to the same exposure concentrations.
- Non-occupational exposure is a complicated and variable factor. It occurs when a worker is exposed to an environmental factor when not at work.
- People’s attitudes and reactions also differ greatly. It is not unknown, for instance, for a worker to try to influence the results of dust sampling by deliberately ‘salting’ the sample in the hope of securing some sort of compensation for working in an unfavourable atmosphere. Although the number of such occurrences is not accurately known they do exist and any suspicious results always need further investigation.
- If a health standard exists, it must be used. However, due caution in interpretation of results must be exercised because there are many factors that can influence them.
- The period of exposure as well as the time a worker spends in such an area, bearing in mind that OELs generally apply to an eight-hour work shift and a forty-hour working week.
- The number of samples collected must be in proportion to the number of workers in any defined exposure group. There are formalised procedures prescribed in the Guidelines of a Mandatory Code of Practice for an Occupational Hygiene Programme (Department of Minerals and Energy)
4.6 Testing for flammable gases

Air sampling and gas detection are conducted to test for the presence of noxious or flammable gases and to determine whether the composition of the atmosphere complies with the standards set for safety and health.

Air sampling means the collection of samples of air for subsequent analysis in a laboratory whereas gas detection means the use of suitable instruments on site in the atmosphere to be tested in order to obtain a result immediately.

Noxious or flammable gases may issue from faults or fissures in the rock. They may be products of oxidation or may result from mining activities such as blasting, the operation of diesel-powered engines, the charging of batteries or from accidental occurrences such as fires and gas explosions.

Wherever possible, air is tested on site and this is obvious in the case of methane. Underground workings may contain dangerous accumulations of explosive gases. The testing for these gases can be done accurately and safely provided persons are fully aware of the dangers involved and are conversant with the characteristics and limitations of the instruments being used.

The safety slogan “knowing’s not enough — do it the safe way!” should be kept well in mind when testing for gas.

Methanometers can detect low concentrations of gas — less than the legal limit of 1.4 parts per hundred (%) ± 0.2% (instruments may, however, be calibrated at a calibration concentration of 2.4 %). At the maximum allowable concentration no work may be carried out, the matter must be reported and arrangements made for the safe clearance of the gas accumulation. Gas concentrations are indicated on a graduated scale or by means of a digital display. The air sample enters the instrument through diffusion and this can make testing for gas in layers very difficult.

When combustible gases such as hydrogen or carbon monoxide are present in significant concentrations along with any methane, or on their own, methanometer readings become abnormal and difficult to interpret. In general, a combustion type methanometer will add the concentrations of the various gases together and indicate the total. In these circumstances a methanometer can only be relied on to indicate the presence of the gases and not the true concentrations. In the vast majority of cases methane is the only combustible gas present and the above complications do not arise.
Methanometers must be checked and calibrated according to specifications set out by the manufacturer. Calibration is carried out by testing the instrument with a standard methane-air mixture of known concentration, as mentioned above.

Methanometers are issued to persons working in known or suspected gassy places. They are meant to be operated continuously to warn timeously of the presence of methane. The warning may be audio or visual or both.

Methanometers are also issued to persons whose job it is to check on environmental conditions.

### 4.7 Control of airborne pollutants

General control measures, which may be deployed, include:

- Selection of workers (pre-employment examinations)
- Good housekeeping policy and education — adequate facilities, counselling, etc as part of the induction programme
- Removal of persons from the contaminant e.g. out of the mine during blasting operations
- Control of the primary causes of the problem i.e. capture at source and reject polluted air or else filter out the pollutant. For example, one potential source of dust is at tips. There are three ways of reducing the amount of dust that is liberated into the ventilating air by tipping operations:
  
  (i) making the tip openings as small as possible
  
  (ii) reducing the vertical drop distance of the rock to a minimum, and, lastly,
  
  (iii) the most expensive approach — drawing off and filtering air from underneath the tip in order to counter the updraught

As discussed earlier diesel exhaust emissions may also be a cause for concern. Here emission problems can be addressed in a number of ways:

- (i) Low emission fuel can be used
- (ii) Engines can be maintained in top condition
- (iii) Diesel particulate filters can be used to control the emission of soot
- (iv) The ventilating air should be sufficient both to dilute and remove pollutants from the working places
- (v) Series ventilation systems should be kept to a minimum
- (vi) Vehicles should not be allowed to idle unnecessarily
- (vii) Pollutant levels in working places where diesel-powered vehicles operate should be checked frequently and remedial measures instituted as required
- (viii) Personal exposure levels of vehicle operators should be frequently checked and remedial measures instituted as required.

Control of emissions at source, especially in plants is through the use of ventilation hoods, ducting and filters, either wet scrubbers or bag filters.

Water is used in rockdrills to prevent the liberation of dust during drilling and water is also used to wet rock in the working places before the rock is moved. This is a very important point to note because once dust has become airborne it is very difficult to remove from the airstream, other than by filtration, which would be too expensive and impractical to apply on a large scale. Figure 4.18 illustrates the difficulty in attempting to control or capture airborne dust with normal size water droplets. It is seen how the dust particle simply bypasses the water droplet in the slipstream of the droplet as it passes through the air. This clearly refutes the notion that dust-laden air can be sprayed with water to clean it. Water droplets more closely approximating the dust particle size are needed to collide with the dust particles, coalesce with other droplets and ultimately settle out. However, the production of a fine water mist or fog is expensive, is energy intensive and in addition the ventilating air stream can carry off the fog before it can control the dust.

Most of the above is covered by legislation, but this is under revision.
• Dilute the contaminant to acceptable concentrations
• Control the spread of the problem — containment, limiting the periods of exposure, etc
• Improve the working environment — control other factors
• Respiratory protective equipment (RPE)

Protection of individual workers by means of RPE should be a last resort, but such measures may be implemented as a first step provided they are seen as temporary. However, all too often unless care is taken, temporary measures appear to work and then become the ultimate solution. It must be realised that under hot, humid conditions RPE is likely to be both unpopular and impractical since it becomes uncomfortable and also hinders breathing and speech. Control at source, although more costly initially, should be preferred over personal protection because it can be shown to be more cost-effective in the long run.

![Figure 4.18 The effects of water droplet size on dust control](image)

The importance of educational programmes should never be overlooked. No worker can be expected to assist in making a control programme effective if he does not know the reasons for it in the first instance.

Control of the pneumoconioses can be linked to the control of dust liberation into the working environment. Pollutant levels in the workplace are therefore an indicator of risk and the possibility of the development of disease.

Control measures must be diligently applied and the success of deployment must be evaluated regularly. This means that a continual evaluation programme should be implemented.

• The results of any pollutant surveys should be made available to all employees
• The results of such surveys should be discussed at the relevant health and safety meetings and action courses, when necessary, discussed
• The reasons for the surveys should be made clear to all employees and the seriousness of non-compliance with action courses explained
• Employees should be encouraged to participate actively and in a positive manner in all pollutant control activities
4.8 Guide to information resources


Particle size-selective sampling for airborne particulate matter. American Conference of Governmental Industrial Hygienists. 1997 TLVs and BEIs. pp 47-50.


CHAPTER 5

Occupational Lung Disease

This chapter will assist readers to understand and manage occupational lung disease risks in the South African mining industry. The most important diseases are described, with an emphasis on clinical features and on the association between exposure and occurrence of disease. Where possible this is based on research conducted in South Africa. The relevant legal framework in terms of the Mine Health and Safety Act (MHSA) and the Occupational Diseases in Mines and Works Act (ODMWA) is reviewed. Medical surveillance is discussed in detail. The use of questionnaires, chest x-rays, spirometry and other investigations in screening for occupational disease is detailed, as well as how to manage the resulting information.

Prof. Neil White
Pulmonologist

Neil White has postgraduate qualifications in internal medicine, pulmonology, epidemiology and occupational medicine. He is currently associate professor in the Respiratory Clinic, Department of Medicine, University of Cape Town and Groote Schuur Hospital. He has published widely on all aspects of occupational lung disease. He currently serves as employee nominee to the Mining Occupational Health Advisory Committee.
Glossary

**Asbestosis**: Fibrosis of the lungs due to inhalation of asbestos dust

**COPD**: Chronic obstructive pulmonary disease. (Alternatively, COAD: Chronic obstructive airways disease). Condition characterised by persistent obstruction of airflow through the lungs

**CWP**: Coal worker’s pneumoconiosis. Fibrosis of the lungs due to inhalation of coal and silica dust in coalmining work

**Dose response relationship**: Association between increasing amount of exposure and likelihood of disease

**Fibrosis**: Formation of scar tissue

**ILO Classification**: International Labour Organisation Classification of Radiographs of the Pneumoconioses. Standardised system for describing pneumoconiosis radiologically

**Inflammation**: Localised or widespread reaction of the body’s defences to injury, infection, foreign substances or sometimes unknown triggers in the body

**Mesothelioma**: Cancer of the lining (pleura) of the lung or abdomen

**Occupational asthma**: Asthma caused by substances primarily encountered at work

**PMF**: Progressive massive fibrosis. Complication of silicosis characterised by appearance of large fibrotic masses in lung

**Pneumoconiosis**: Fibrosis of the lungs due to inhalation of mineral dust

**Progressive system sclerosis**: Disease characterised by thickening of the tissues under the skin and fibrosis of the lungs

**SAMODD**: South African Mining Occupational Diseases Database (maintained by Department of Minerals and Energy)

**Silicosis**: Fibrosis of the lungs due to inhalation of silica dust

**Silicotuberculosis**: Combination of silicosis and tuberculosis of the lungs

**Spirometry**: Test of lung function that measures amount and force of air breathed in and out
5.1 Introduction

Occupational lung diseases are a major preventable cause of premature retirement and death among people working in the South African mining industry. The Mine Health and Safety Act (MHSA) requires employers to take measures to assess and reduce the risk of these diseases. Anyone involved in risk assessment needs to have an understanding of the epidemiology of the common occupational lung diseases suffered by miners. Medical and nursing practitioners in the industry need to be aware of the clinical features of occupational lung disease for purposes of setting up medical surveillance programmes, diagnosis, treatment and appropriate referral for compensation.

5.1.1 Definition of occupational lung disease

The MHSA defines an occupational disease as any condition listed in either the Occupational Diseases in Mines and Works Act (ODMWA) or the Compensation for Occupational Injuries and Diseases Act (COIDA).

Table 5.1 Mining related lung diseases listed for compensation purposes in South Africa

<table>
<thead>
<tr>
<th>Occupational Diseases in Mines and Works Act as Amended, Act 208 of 1993</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Silicosis in miners and surface workers exposed to silica dust</td>
</tr>
<tr>
<td>• Silicotuberculosis in miners and surface workers</td>
</tr>
<tr>
<td>• Coal workers’ pneumoconiosis in coal miners</td>
</tr>
<tr>
<td>• Obstructive airways disease in miners</td>
</tr>
<tr>
<td>• Tuberculosis, compensable only if cardio-pulmonary organs involved, in miners or those exposed to dust on surface</td>
</tr>
<tr>
<td>• Progressive systemic sclerosis or scleroderma, in miners exposed to silica dust</td>
</tr>
</tbody>
</table>

Section 1 (e) of the Act includes any other disease of the cardio-pulmonary organs which experts consider attributable to risk work. In practice, this section covers:

• Occupational asthma in platinum salt workers (“platinosis”)
• Asbestosis (interstitial lung disease) in asbestos miners
• Malignant mesothelioma in asbestos miners
• Pleural plaques in asbestos miners
• Asbestos-related lung cancer in asbestos miners
• Bronchiolitis obliterans due to nitrous fumes in mine workers
• Hard metal pneumoconiosis, usually in drill shop workers. Stannosis in tin miners

<table>
<thead>
<tr>
<th>Compensation for Occupational Injuries and Diseases Act, Act 130 of 1993 (Third Schedule)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Of particular relevance to mining, but not included in the ODMWA list are:</td>
</tr>
<tr>
<td>• Asphyxiation due to carbon monoxide, hydrogen cyanide fumes or its derivatives, and hydrogen sulphide fumes</td>
</tr>
<tr>
<td>• Occupational asthma due to nickel, cobalt, vanadium, chromium salts, soldering or welding fumes, isocyanates, formaldehyde, anhydrides, amines and diamines, hardening agents including epoxy resins</td>
</tr>
</tbody>
</table>

5.1.2 Importance of occupational lung disease in the South African mining industry

Dust-related lung diseases overshadow mine accidents in numbers of workers affected. Among the 429 000 persons at work in all mines in 1998 there were 371 reported fatalities (0.85 per 1 000) and 6 064 reported injuries (14.1 per 1 000). By comparison there were 5 603 new or upgraded certifications for pneumoconiosis with or without tuberculosis and over 5 000 new cases of tuberculosis (> 20 per 1 000).
Occupational lung disease may result in illness, premature retirement because of disability, or death. There are significant costs involved, experienced by individuals in loss of income and medical or related expenses, and by mining companies through the loss of experienced employees and the expense of recruiting and training new employees, direct medical expenses and compensation levies.

The total direct costs of occupational lung disease in the gold mining industry were estimated in 1996 as R343 million. These costs included those for compensation, medical surveillance and treatment, and losses of output, the single largest direct cost. Included also are employers’ contributions to the compensation fund under ODMWA, which amounted to R38 million. The total direct and indirect costs of occupational lung disease to the economy is cumulative and difficult to estimate, but could be about 3 percent of the gold mining industry’s annual contribution to the gross domestic product, or approximately R558 million.

In addition, the mine labour force has contracted and stabilised over the last twenty years. This change in employment patterns has aggravated the problem of occupational disease by increasing the average period of dust exposure of underground miners.

It is vital that the mining industry come to grips with the problem of mining related lung diseases by seeking to prevent them and not merely to compensate established disease.

5.2 The occupational lung diseases

In this section, the characteristics of the more important mining related occupational lung diseases are described. The diseases are grouped into diseases due to mineral dusts, chronic obstructive pulmonary disease (COPD), occupational cancers, occupational asthma, and inhalation injuries including those due to nitrogen dioxide and fire.

5.2.1 Mineral dust disease (pneumoconiosis)

The mineral dust diseases share the common feature that they are caused by dust particles that are small enough to reach the alveoli or gas exchanging part of the lung. Such dust particles are termed respirable dust.

The relationship between particle size (“aerodynamic diameter”) and the ability of particles to penetrate the lungs is illustrated in Figure 5.1.

![Figure 5.1 Deposition in the respiratory system as a function of particle size](Reprinted from World Health Organisation. Technical Report 743, 1986, p 17)

The nasal passages are the first line of defence and will trap all particles with an aerodynamic diameter > 7 microns. The nose is less effective at preventing particles < 7 microns entering the lungs.
and below this limit particles are defined as respirable. The lung’s defences can still remove particles reaching the airway walls in the tracheobronchial tree. However, approximately 30 percent of inspired particles in the range 1-3 microns will be deposited in the lung tissue (Figure 5.1).

Dust particles in the respirable range that are deposited in the tiny airways deep in the lung will be engulfed by alveolar macrophages (defensive cells in the lung) and carried across the respiratory epithelium into the lung tissue itself. Crystalline silica (usually quartz) particles, especially when newly generated, are toxic to macrophages and result in cell death. A similar process occurs with coal and other mineral dusts. Death of the macrophage results in release of the dust particles and attracts other macrophages that engulf the particles again. This recurring cycle of defensive cell death results in a low-grade inflammatory process in the lung. Gradually the dust particles are sealed off in areas of fibrotic (scar) tissue that replaces normal lung tissue. This scar tissue is in the form of rounded nodules in the cases of silicosis and coal workers’ pneumoconiosis, whereas in asbestosis or hard metal pneumoconiosis the scars are elongated or linear.

The chest x-ray appearance of the pneumoconioses is by convention described using the International Labour Organisation’s (ILO) classification system. This system is based on comparison with a set of standard radiographs. The abnormalities in the lung fields of a chest x-ray are classified according to the type of abnormality seen (nodular or linear) and the optical density or profusion of the abnormalities (as an index of severity). The profusion is graded from 0 (no abnormality) to 3 (high profusion) with a series of intermediate grades.

5.2.2 Silicosis

Silicosis is the most important occupational lung disease in gold mining where almost all of the 183 000 people employed underground in 1998 were exposed to silica dust. The features of silicosis are well reviewed in the medical literature. (See Guide to Resources).

The dangers of silicosis from the inhalation of silica dust produced by drilling, blasting, scraping and other mining operations, have been recognised since the earliest days of gold mining operations in South Africa. The risk of silicosis occurs in all types of hard rock mining, tunnelling, quarrying and crushing where crystalline silica particles are liberated. Quartz is a pure form of silica crystal. Newly fractured quartz is the most toxic variety of crystalline silica.

Silica contained in an amorphous (i.e. non-crystalline) form appears to be less toxic than the crystalline variety, although amorphous silicas can cause silicosis. Amorphous silicas include diatomaceous earth, colloidal silica, fused silica, fumed silica and thermally generated silica fume. Although there is a tendency to treat all amorphous silicas as a group, there is evidence that their toxicities do vary, depending on the particle size and content of crystalline silica. In risk assessment where there is exposure to amorphous silica the health hazard associated with that type of amorphous silica should be considered.

Clinical features of silicosis

The clinical features of simple and complicated silicosis are described in Table 5.2.

Table 5.2 Usual clinical features of simple silicosis and complicated silicosis

<table>
<thead>
<tr>
<th>Simple silicosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Simple (chronic) silicosis is the most common manifestation of silica dust exposure</td>
</tr>
<tr>
<td>• Simple silicosis develops after 10-15 years of dust exposure</td>
</tr>
<tr>
<td>• In simple silicosis nodules 1 – 3.5 mm in size become evident on the chest x-ray, usually in the upper zones of the lung</td>
</tr>
<tr>
<td>• As the condition progresses the nodules become more numerous and may become larger, 3.5 — 10 mm. Initially this process causes relatively minor impairment of lung function</td>
</tr>
<tr>
<td>• Silicosis is often slowly progressive over time, even in the absence of further dust exposure</td>
</tr>
<tr>
<td>• With increasing lung dust burden the degree of functional impairment increases. Either obstructive or restrictive abnormality of lung function may result</td>
</tr>
<tr>
<td>• With increasing lung dust burden there is an increase in risk of pulmonary tuberculosis (TB). The risk of TB is highest with established silicosis</td>
</tr>
</tbody>
</table>
Complicated silicosis (progressive massive fibrosis)

- In approximately 5% of cases of simple silicosis the nodules in the lung coalesce into larger nodules > 1 cm in size. This is known as complicated silicosis or progressive massive fibrosis (PMF).
- The replacement of normal lung tissue by scar tissue with resulting distortion of lung tissue in complicated silicosis / PMF can produce significant lung function impairment and reduced life expectancy.
- The known determinants of progression of simple silicosis to PMF are: high cumulative dust exposure; high ILO profusion category of simple pneumoconiosis; young age of onset of pneumoconiosis; continued dust exposure in the presence of simple pneumoconiosis.

Epidemiology of silicosis

The relationship between silica dust exposure and the occurrence of silicosis in South African gold mines was first investigated by Beadle in the 1960s, and later by Hnizdo and Sluis-Cremer on a cohort of white miners. As yet there are no published studies of dose-response relationships of silica exposure among black mineworkers in the South African gold mining industry.

Beadle believed that there was little evidence of any improvement in dust exposure levels in the years between 1938 and 1969. This finding still has relevance. In 1995 the Leon Commission concluded that there had been little significant change in dust exposure in South African gold mines for fifty years. In 1999 the National Centre for Occupational Health published data based on 26 000 underground dust measurements in 48 South African gold mines from 1995 to 1997. Only 8 (17%) of these mines had all of their estimated time weighted average (TWA) measurements for respirable quartz below the DME’s standard of 0.1 mg/cubic metre. Of the remainder 21 mines (43%) had a high proportion of dust measurements in the range 0.1 — 0.4 mg/cubic metre, whilst 19 (40%) had most of their measurements above 0.4 mg/cubic metre.

Risk assessment requires an understanding of cumulative exposure response curves. These curves illustrate what proportion of mineworkers exposed to a given cumulative dose of silica (i.e. the sum of all past exposures) will develop silicosis at some stage in their lives.

The exposure-response relationships from four studies of silicosis among miners are shown in Figure 5.2 (derived from Chen 2000). Hnizdo and Sluis-Cremer’s study of white mineworkers is indicated by squares. For example, if this working population is exposed to 0.1 mg/cubic meter respirable crystalline silica for 20 years, their cumulative exposure is 2 mg/cubic metre-years (0.1 times 20). It can be inferred from Figure 5.2 that less than 10 percent of such a population will ultimately develop radiological silicosis. If this group of workers spent the same time (20 years) working at 0.2 mg/cubic metre (cumulative exposure of 4.0 mg/cubic metre-years) it can be expected that over 50% will ultimately develop silicosis.

Black workers comprise the vast majority of the mine labour force and do the jobs such as drilling or ore removal in the dustiest areas of gold mines such as stoping and development. Available information from recent studies indicates that black mineworkers have a working lifetime risk of between 220/1 000 and 360/1 000 of developing radiological silicosis from gold mining. These estimates, based on retired or retrenched men, are much higher than estimates of the prevalence of silicosis in active black gold mineworkers.

Silicosis is a condition that develops slowly over time. As a group, active miners include members with a mix of various lengths of service. The men with shorter length of service (e.g. < 10 years) are unlikely to have detectable silicosis, even if they are working in dust levels that are high enough to ultimately cause the condition. Silicosis continues to progress slowly with continued mining exposure. Cowie found that silicosis among Free State mineworkers, once established, progressed by approximately one ILO classification subcategory (e.g. 2/1 to 2/2) over a 4-5 year period. Even once exposure ceases, dust particles retained within the lung continue to be biologically active and the condition continues to develop.
The different estimates of the prevalence of silicosis in the active and retired workforce can probably all be reconciled on this basis. This natural history of silicosis has two major implications. First, the risk of silicosis can only be accurately measured by long-term follow up of cohorts of mineworker, including ex-mineworkers. Second, estimates of Occupational Exposure Limits (OEL) for silica dust exposure, as with other exposures, are usually based on studies of active workers because this is the easiest group to study. Where studies of older and retired workers have been conducted, such as those included in Figure 5.2, they indicate that there is still a risk of pneumoconiosis from long working lifetime exposures below the DME OEL of 0.1 mg/cubic metre for respirable quartz.

Certification rates of compensable pneumoconiosis are also substantially lower than the actual rates of occurrence of pneumoconiosis (>220/1,000) quoted for black workers above. There are a number of reasons for this. Firstly, epidemiological studies use sensitive radiological definitions of the presence of abnormalities consistent with pneumoconiosis. By contrast, certification of compensable pneumoconiosis, as detailed in Chapter 14, requires a more serious degree of abnormality consistent with at least a 10 percent impairment of cardio-respiratory function. The findings of two recent studies of retired black mineworkers confirm that compensation statistics substantially underestimate the occurrence of pneumoconiosis. These studies both showed that there are substantial numbers of men whose disease has either progressed since leaving the industry, or who were not referred to the Medical Bureau for Occupational Diseases (MBOD) for a benefit examination, as was their right, at the time of their exit from the industry.

**Prognosis of silicosis**

Mine medical practitioners typically diagnose simple silicosis early in the natural history of the condition in active miners. Unless the condition is already complicated by tuberculosis, there is seldom any significant observable impairment of lung function at that stage since simple silicosis is only a slowly progressive condition. This observation could give rise to an erroneous view that simple silicosis does not cause much abnormality and does not influence life expectancy.
A progressive reduction of vital capacity of the lungs with progression of x-ray changes of silicosis has been shown by a number of studies. Even ILO category 1 pneumoconiosis is associated with some loss of lung function. A recent estimate of the influence of silicosis on annual loss of FEV1 showed the following annual average losses:

- No silicosis: 37 ml/year
- ILO category 1: 57 ml/year
- ILO category 2: 100 ml/year
- ILO category 3: 128 ml/year

Although there is evidence that simple silicosis without measurable lung function abnormality does not affect life expectancy in North America, there are no comparable data for South Africa. Complicated silicosis can be expected to reduce life expectancy. The commonest complication of silicosis in South Africa is pulmonary tuberculosis, which has a significant adverse effect on life expectancy.

5.2.3 Silicotuberculosis

Both silica exposure and silicosis are risk factors for tuberculosis (TB). Tuberculosis in a person with established silicosis is termed silicotuberculosis. The risk of developing TB increases with duration of exposure to silica dust even in the absence of silicosis. The presence of radiological silicosis increases the risk of pulmonary TB approximately four fold, with the risk rising as radiological silicosis becomes more severe. This increased risk of TB associated with silicosis is lifelong, continuing after silica exposure ceases. This relationship is discussed further in Chapter 6.

The presence of silicosis in the lungs can modify the natural history of TB and may alter its radiological appearances. The interaction of TB and silicosis is very damaging to the lung, unless the TB is diagnosed and treated early. With each episode of TB lung function abnormality increases, as it does with each category of ILO category of profusion of silicosis.

Diagnosis of TB in the presence of silicosis should be according to standard guidelines for TB (see Chapter 6). However, it is well recognized that among the clinical variants of silicotuberculosis are fibrotic and initially slowly progressive cases where sputum examination is persistently negative. Silicotuberculosis may also be difficult to distinguish from PMF. Radiological suspicion of pulmonary TB in the presence of silicosis is greatly aided by comparisons with previous films, and should be prompted by the:

- Rapid appearance of new infiltrates, especially in the upper third of the lung fields
- Coalescence of nodules, especially in the upper third of the lung fields
- Appearance of a cavity, especially with an irregularly shaped inner wall, within a conglomeration of nodules
- Appearance of any > 1 cm, non-retractile opacity limited by a fissure
- Development of pericardial or pleural effusion
- Development of segmental or lobar collapse secondary to bronchial stenosis or occlusion

Treatment of silicotuberculosis is discussed in Chapter 6.

5.2.4 Coal workers' pneumoconiosis (CWP)

Coal mining in South Africa employed in excess of 57 000 people in 1998. Most coal mining is either surface mining or occurs at comparatively shallow depths, not exceeding about 300 m. The output is predominantly bituminous coal although a small amount of anthracite coal is also mined. The silica content of South African coal is generally fairly low. Mpumalanga, Gauteng and Free State coal has a quartz content of about 2 percent, whereas that of Natal contains 3 percent quartz.

Coal miners are at risk of coal workers’ pneumoconiosis (CWP). Given the size and economic importance of coal mining in South Africa, there is surprisingly little information available on CWP.
Clinical features of CWP

The clinical features of CWP are described in table 5.3.

Table 5.3: Usual clinical features of Coal Workers’ Pneumoconiosis (CWP)

- CWP develops after 10-15 years of coal mine dust exposure
- In CWP nodules < 1 mm in size become evident on the chest x-ray, usually in the upper zones of the lung
- As the condition progresses the nodules become more numerous
- CWP is frequently complicated by chronic obstructive pulmonary disease (COPD)
- CWP is usually slowly progressive over time
- The features of CWP resemble silicosis if there is appreciable silica content in the coalmine dust
- CWP differs from other pneumoconioses in that even with large dust burdens, provided that the silica content is low, fibrosis or scarring in the lungs is less severe
- With higher silica content of coal mine dust, high lung dust burden and/or infection with tuberculosis, CWP may evolve into a progressive massive fibrosis (PMF) where smaller nodules have coalesced into large nodules > 1 cm

Epidemiology of CWP

Some information relating to certification of CWP among coal miners is available from MBOD reports. Prior to 1980, certifications of pneumoconiosis (when expressed as a proxy rate of living cases certified per 1 000 miners currently employed) tended to be higher in coalmines than in gold mines (approx. 6 per 1 000 in 1980 vs 2 per 1 000 in gold mining). CWP certification rates declined in the years 1980 to 1989 although in 1989 the rate was still over 4 per 1 000, a similar rate to the silicosis rate in gold mines. The MBOD Director’s Report 1998/99 suggests a continuing decline in certifications of CWP. In that report 0.6% of all first degree pneumoconiosis certifications among miners (25 cases or < 0.5 per 1 000 currently employed miners) were for CWP among coal miners. There were no second-degree certifications apart from 6 cases of CWP and TB combined.

A recent unpublished study documented radiological abnormalities among KwaZulu-Natal anthracite miners. A total of 187 employees with more than five years exposure at a mine were included. 15.8% were thought to have CWP ILO grade 1/0 or higher, including 7.6% of grade 1/1 or greater and 1.1% (2 cases) grade 2/1 or greater. There was a positive association between presence of pneumoconiosis and length of service in a relatively young workforce (mean age 40.3 years). Findings of past or present TB were more common in those workers with CWP than those without.

A relatively low prevalence of CWP was found in another unpublished study of active and ex-coalminers from three South African mines (SIMHEALTH 607 — see SIMRAC website). In the latter study, the prevalence of pneumoconiosis was 1.8 to 4.2% depending on the chest x-ray reader. The prevalence of CWP increased with cumulative exposure to coal dust. As part of the same study autopsy findings among former miners who had had only coal exposure were examined. CWP (prevalence: 7.3%) and silicosis (prevalence: 10.8%) were detectable at autopsy, with both conditions showing strong associations with increasing years of coal exposure.

As with silicosis, it appears that MBOD certification rates underestimate the occurrence of CWP. The limited available information makes it difficult to be certain about the actual degree of underestimation, but it does seem plausible that rates of CWP have declined in the last 20 years.

The cause of this decline is speculative in the absence of trend data on coal dust exposures in South Africa. Unlike gold mining, which remains a largely labour intensive process, coal mining has become increasingly mechanised in the second half of the 20th century. On the one hand, mechanised mining greatly increases the potential for dust exposure in coal mining. On the other hand, mechanised mining usually also means that fewer miners are exposed to these higher dust levels.

Exposure-response relationships for CWP and PMF have been well documented in other coal mining regions of the world. The ability of coal dust to cause disease is generally highest for anthracite and
higher rank coals, i.e. those that have been formed under conditions of higher temperature and pressure and have higher carbon content. These dose response relationships may or may not be applicable to coal mining in South Africa, given that most South African coal is bituminous or low rank.

The DME’s current OEL for coalmine dust is 2 mg/cubic metre. As may be seen from the illustrative dose response curves based on US coal miners in Figure 5.3, after 40 years of work in coal mining at a respirable coal mine dust concentration of 2 mg/cubic metre, miners have about a 12% probability of developing ILO category 1 pneumoconiosis or greater. About 2% will develop PMF working at this concentration.

![Figure 5.3 U.S. coal miners’ predicted risk of contracting irreversible pulmonary disease](image)


5.2.5 Asbestos related diseases

Asbestos is a family of crystalline hydrated silicates forming fibres, i.e. with a ratio of length to diameter, or aspect ratio, of more than 3:1. Asbestos fibres thus differ from silica or coal dust particles, which are roughly spherical. This difference in the geometry of the particles is important for the causation of disease. The asbestos fibres that are retained in the lung can be far larger and tend to be deposited in the lower zones of the lung. Macrophages are unable to engulf such large fibres and many remain in the alveoli. Chemical reactions take place on the surface of the asbestos particles that are toxic to lung tissue, resulting in cell death and scar formation.

Asbestos mining in South Africa commenced around the turn of the century and this country became the major global supplier of asbestos of the amphibole family, crocidolite and amosite. In addition, some chrysotile was mined. The asbestos minerals share the properties of heat resistance and tensile strength. They found many uses in heat insulation, construction, textiles and engineering. Today effective and acceptable substitutes are available for all of these applications. Felix et al. (1994) have traced the history of the mining of the three major commercial forms of asbestos in South Africa and the epidemics of asbestos-related diseases that followed.

Although asbestos is no longer mined on any significant scale, there are two ways that mine occupational health services are still likely to encounter asbestos related diseases. The first occurs when individuals are recruited into mining operations with a past history of asbestos mining or residence in an area where there has been environmental contamination with asbestos. The second instance occurs with secondary uses of asbestos in the mining industry such as in boiler rooms for insulation purposes. People who apply or remove asbestos lagging have a significant risk of asbestos related diseases. The Asbestos Regulations in terms of the Occupational Health and Safety Act, while not mandatory for mining operations, contain provisions appropriate to the prevention of asbestos related diseases in this context.
Clinical features of asbestos related diseases

The general features of the asbestos related diseases are summarised in Table 5.4. The asbestos related diseases are well described in the medical literature and diagnostic criteria for these diseases have been published (see Guide to Resources).

Table 5.4: General clinical features of the asbestos related diseases. (Note: two or more of these conditions may coexist)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Description</th>
</tr>
</thead>
</table>
| Pleural plaques                                | • The most common manifestation of exposure to asbestos. They occur as hard, discrete and often calcified, flat lesions on the surface lining of the inner chest wall.  
  • Plaques have been dubbed the “visiting cards of asbestos”, a term implying a minimal health effect but a history of some exposure to asbestos. Plaques may appear where there has been only environmental exposure to asbestos.  
  • Plaques may signify an increased risk of mesothelioma because they indicate significant asbestos exposure, but are not themselves premalignant. |
| Diffuse pleural thickening and pleural effusion| • Asbestos related diffuse pleural thickening is often the consequence of a pleural effusion that has become organised with fibrosis. When widespread there may be significant functional impairment. Lung function testing is required to evaluate possible impairment. |
| Asbestosis                                     | • The term refers only to the pneumoconiosis, i.e. fibrosis of the lung tissue.  
  • It varies in severity. When severe the features include shortness of breath, cough, finger clubbing with cyanosis, basal crackles heard on auscultation of the chest, and ultimately right-sided heart failure and respiratory failure.  
  • Radiologically, the features are those of fine-to-coarse irregular and linear opacities that are initially basal. In severe cases the whole lung may be involved.  
  • Lung function testing is required to evaluate possible impairment. |
| Mesothelioma                                   | • Mesothelioma is a malignant cancer arising from the pleura or peritoneum (the membrane lining the organs and walls of the chest and abdominal cavities).  
  • Untreated, the disease has a poor prognosis, with less than 10% of sufferers surviving two years. Surgery, radiotherapy or chemotherapy may reduce pain and discomfort. |
| Lung cancer                                    | • Lung cancer is a malignancy that arises either in the bronchial tubes or in the lung tissue.  
  • Asbestos related lung cancers usually occur in people who already have asbestosis.  
  • Asbestos exposure and tobacco smoking together multiply the risk of lung cancer.  
  • Thoracic surgery may be curative, but most lung cancers are inoperable at the time of diagnosis. Radiotherapy and chemotherapy may reduce pain and discomfort. |

Epidemiology of asbestos related diseases

At its peak in the 1970s asbestos mining directly employed about 25 000 people. Employment in this sector has fallen a negligible number, largely because of a collapse in demand for the mineral consequent on its replacement by safer materials.

South Africa continues to pay the price of having mined this injurious mineral. As shown from MBOD reports the numbers of workers certified as having asbestos related diseases slowly climbed during the 1990s. In 1998/99 asbestosis accounted for 54.2% of all certifications for first-degree pneumoconiosis and 19.6% of all second-degree notifications.
All types of asbestos are known to cause asbestosis, as well as pleural disorders. The consequences of asbestosis for life expectancy have not been fully evaluated in South Africa, but survival in Australian crocidolite mine and mill workers with asbestosis has been studied. Median survival from claim for compensation was 17 years in subjects with asbestosis ILO category 1, 12 years in those with category 2, and 3 years in those with category 3 disease.

In 1960 the association between asbestos exposure and mesothelioma was established in a report of 33 asbestos workers with this rare disease from the Northern Cape crocidolite fields. There is a dose response relationship between asbestos exposure and mesothelioma, i.e. the greater the exposure the greater the risk. However, the threshold is low, i.e. even modest exposures are capable of causing this disease. Younger age of first exposure to asbestos is an additional risk factor because there is a long time lag between exposure and the appearance of the cancer. The potential of the various types of asbestos fibre to cause mesothelioma appears to be crocidolite > amosite > chrysotile.

An association between asbestos exposure, asbestosis and lung cancer (as distinct from mesothelioma) has been recognised for many years. Evidence suggests that asbestos related lung cancers occur more readily in lungs where there is existing fibrosis. However, this fibrosis may only be detectable at autopsy and may not be evident on the chest x-ray. All types of asbestos have been associated with lung cancer.

Environmental contamination has resulted in many cases of fatal asbestos related disease, primarily mesothelioma, an impact that continues in areas of the Northern Cape and Northern Province. Through a special programme the SA government, through the DME, has spent more than R40 million in the rehabilitation of abandoned and hazardous asbestos mines and works. The UK based companies that mined in these areas disinvested in the 1970s and have not made co-payments for this process, nor do they pay levies to the ODMWA Compensation Fund.

Historically, the cost of compensating such occupational diseases has had to be met from South African government revenues. In 2000 the British House of Lords upheld the right of South African former employees of Cape Plc to sue the UK based company for compensation. Cape Plc operated large crocidolite and amosite mines and mills in SA, mainly in the Northern Cape and Northern Province, for more than 70 years. More than 4 000 former employees could ultimately be party to the case.

5.2.6 Chronic obstructive pulmonary disease (COPD)

COPD is closely associated with cigarette smoking. However, COPD has been a compensable disease in the South African mining industry for nearly 40 years. Subsequent research in South Africa has confirmed the effect of underground exposures (i.e. dust, gases and other particulates) on the risk of COPD.

The usual clinical features of COPD are given in Table 5.5.

A 1989 study of black goldminers showed that the risk of chronic airflow limitation increases with duration of underground exposure and is an effect that is independent of the presence of silicosis. The magnitude of this effect has been estimated as an additional decline of 8 ml per year in lung function. In the same study the estimated direct effect of smoking 20 cigarettes a day was an excess decline of 7 ml per year. Differently expressed, the effect of gold mine air exposure on lung function is roughly equivalent to smoking twenty cigarettes a day.

Considerable attention has been paid elsewhere in the world to the relationship between exposure to the coal-mining environment and COPD. Dust related increases in prevalence of chronic bronchitis and chronic airflow limitation have been found in coal miners that are similar for smokers and non-smokers. Although measured lung function abnormalities are greater in smokers, the separate contributions of smoking and coalfume dust to COPD appear to add to each other rather than to multiply each other. An adverse effect of coal mine dust exposure on lung function has been observed even in the absence of radiographically detected CWP.
Table 5.5: Usual clinical features of Chronic Obstructive Pulmonary Disease (COPD)

- COPD is the result of a combination of environmental exposures and genetic susceptibility
- The term COPD is used to describe three inter-related disorders that are often present together to a varying degree:
  - Chronic bronchitis, which is the consequence of airway inflammation and resultant mucus gland hyperplasia. Chronic bronchitis is defined by the presence of cough and sputum production on most days for three or more months of the year for two or more consecutive years
  - Emphysema, which is the destruction of the gas exchanging tissue of the lung consequent on a chronic inflammatory response to environmental exposures
  - Chronic airflow limitation which results from narrowing of the airways as a consequence of both the inflammation occurring in chronic bronchitis and the loss of lung elastic recoil that occurs in emphysema
- Lung function tests are required both to confirm the diagnosis of COPD and to assess its severity

In an unpublished study of coalminers (HEALTH 607 — see www.simrac.co.za), the average decline in FEV1 attributable to coal dust exposure was 17 ml per mg/ml per year of coal dust exposure among active miners. This decline was of the same order as the adverse effect of smoking in this group.

Further information concerning the natural history of COPD in the mining industry can be found in past MBOD reports. These indicate the long duration of exposure required for the disease. In 1989/90 the average period of risk work prior to certification for COPD in living miners was between 25 years (first degree) and 30 years (second degree) in gold mining and somewhat shorter in coal mining. Less than a third of these certifications were in black mineworkers.

With the increased use of lung function tests in periodic and benefit examinations, the number of certifications appears to have risen. In 1989/90 a total of 363 new, upgraded or post mortem certifications for COPD were made by the MBOD. In 1998/9 there were 650 certifications (excluding post-mortem certifications which were not given). It therefore appears that certifications for COPD have approximately doubled over a ten-year period.

Although not usually included under the heading COPD, obstructive lung function loss as a complication of chronic tuberculosis is now well established. In a recent unpublished study of South African goldminers, TB was associated with accelerated loss of FEV1 and FVC (HEALTH 617 — see www.simrac.co.za). Although chronic TB adversely affects both FEV1 and FVC, the predominant effect appears to be obstructive. The implication is that any clinical evaluation of chronic TB, whether at the end of treatment or at any subsequent evaluation, e.g. for a medical benefit examination, must include lung function testing.

5.2.7 Lung cancer

Lung cancer usually arises in the airway tissues where exposure to noxious environmental agents is highest. Growth of the cancer may cause local effects such as obstruction of the airways but death is usually caused by spread of the cancer to other sites in the body. Most lung cancers are diagnosed too late for curative surgery to be undertaken. For illustration, among patients treated at Groote Schuur Hospital in one year only 11% underwent possibly curative surgery. The overall 1- and 2-year survival rates of this group were 18% and 8% respectively.

Lung cancer is the commonest fatal cancer among men in South Africa. Tobacco smoking is globally the most important single cause of lung cancer, but in addition there are a number of possible links between lung cancer and mining.

- The association between asbestos exposure, asbestosis and lung cancer is strong
- There is a link between silica dust, silicosis and lung cancer although the relationship is not as strong as for asbestos
• Certain nickel compounds encountered in the smelting process are considered to be carcinogenic.
• Exposure to radon gas underground and diesel engine emissions are other possible causes of lung cancer in the underground environment

The occurrence of lung cancer in the South African mining industry has received less attention than it warrants, given the seriousness of this condition. One of the barriers to proper assessment of risk is that lung cancer is uncommon among active miners because most cases arise in the fifth or subsequent decades of life, after most miners have retired. For example, lung cancer among asbestos miners comprised only 0.15% of all second-degree certifications by the MBOD in 1998/9.

In addition to controlling exposures of miners to carcinogenic agents, an essential part of health promotion among miners is to discourage smoking and to assist with smoking cessation.

5.2.8 Scleroderma/progressive systemic sclerosis (PSS) and rheumatoid arthritis

Progressive systemic sclerosis is a relatively rare and progressive disorder of the body’s connective tissues that is strongly associated with silica exposure. The usual clinical features are described in Table 5.6.

Table 5.6: Usual clinical features of Progressive Systemic Sclerosis (PSS)

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal connective tissues are replaced by collagen</td>
<td>A dense fibrous tissue that affects normal functioning</td>
</tr>
<tr>
<td>The process usually begins in the skin</td>
<td>Which becomes hardened, depigmented and contracts</td>
</tr>
<tr>
<td>If this process remains localised to the skin it is called morphea</td>
<td>This is considered to be a different condition and is not compensable</td>
</tr>
<tr>
<td>Once internal organs are involved the disease is considered to be</td>
<td>Systemic</td>
</tr>
<tr>
<td>Over time organs such as the lung, oesophagus and kidneys become</td>
<td>Affected by the disease process. This results in shortness of breath,</td>
</tr>
<tr>
<td>failure</td>
<td>Difficulty in swallowing and kidney failure</td>
</tr>
<tr>
<td>PSS generally has a poor prognosis (&lt; 40% 10 year survival)</td>
<td></td>
</tr>
<tr>
<td>D-penicillamine, colchicine and other agents may alleviate or slow</td>
<td>Progressive of this disorder</td>
</tr>
</tbody>
</table>

An association between PSS and exposure of Witwatersrand gold miners to dust containing a high fraction of silica was first suggested by Erasmus in 1957. Sluis-Cremer later showed an association between PSS and lifetime silica exposure rather than with silicosis. Cases appeared to have had higher intensity of exposure to silica during mining service, rather than longer duration of service.

It has been estimated that the annual incidence of PSS is 81.8 per million amongst black mineworkers in the group aged 33-57 years, compared with approximately 3.4 per million in a general population of similar age. A high incidence of tuberculosis was noted among workers suffering from PSS. Both the 1989/90 and 1998/9 MBOD reports show six certifications for PSS among living black miners. It is likely that PSS is under recognised and underreported among miners.

Rheumatoid arthritis is a disease that is sometimes grouped with scleroderma. The radiological and histological features of silicosis and CWP are sometimes modified in a characteristic manner in miners with rheumatoid arthritis — a phenomenon known as Caplan’s syndrome. In a case control study of white gold miners attending the MBOD, Sluis-Cremer showed that miners with rheumatoid arthritis were more likely to develop silicosis, that silicosis was more likely to start with larger radiological nodules (r) and that the rate of progression of silicosis in patients with rheumatoid arthritis appeared to be more rapid than for miners without rheumatoid arthritis.

5.2.9 Miscellaneous mineral dust diseases

Tin (stannosis) and iron oxides (siderosis)

Stannosis is the name given to the condition that results from the inhalation of tin in the form of tin oxide (SnO₂) as fume or dust. Tin oxide does not cause a fibrotic tissue reaction and it is arguable whether stannosis should be called a pneumoconiosis. Iron oxides, which cause siderosis, appear to
be similar in this respect. Since both tin and iron have high atomic weight and consequently absorb x-rays, chest radiographs depict these elements very clearly when they are deposited in lung tissue after inhalation.

Occurrence of stannosis has been described in South Africa. Stannosis in tin mines may be caused by the process of bagging where a highly concentrated (70-80%) tin oxide is packaged prior to transport for smelting. This can be a very dusty occupation. In the smelter itself there is exposure to tin oxide fumes, and most of the cases of stannosis seen at the MBOD have been from tin smelters. Silicaceous rock occurs where tin is mined and silicosis may occur.

There are no reports on the respiratory health of iron ore miners in South Africa. Siderosis may, however, occur in jobs involving welding or metal cutting with high temperature torches.

**Hard metal**

Hard metal is an alloy of tungsten carbide and a matrix of cobalt to which small amounts of titanium, nickel, chromium and other metals may be added. The unique properties of this compound are its extreme hardness, 90 to 95 percent that of diamond. Because of this hardness and temperature resistance, hard metal is used in numerous mining applications. Hard metal is extensively used in the mining industry in South Africa for the tips of drills. The cutting edges on drills have to be reshaped at intervals by grinding. Workers who grind drill tips will be exposed to hard metal dust unless this operation is carried out under water to prevent any respirable dust being produced.

Pneumoconiosis due to hard metal was first described in the 1940s. This pneumoconiosis takes the form of interstitial lung fibrosis. Cobalt has been identified as the most toxic component of the alloy. The prognosis of hard metal pneumoconiosis with pulmonary fibrosis is generally poor since the disease is slowly progressive despite removal from exposure. A typical end stage with respiratory failure may occur within a few years. The clinical features of this end stage disease closely resemble cryptogenic fibrosing alveolitis. In 1987 Sluis-Cremer published the details of four cases. Since that time there have been no further reports of the condition. The number of people at risk in the mining industry is unknown.

5.2.10 Occupational asthma and Reactive Airways Dysfunction Syndrome (RADS)

Asthma is a condition characterised by reversible narrowing of the airways of the lung that is accompanied by airway inflammation. This inflammation is often caused by an allergic reaction, i.e. an adverse reaction of the body’s immune system to a substance in the environment. Occupational asthma is asthma acquired as a result of sensitisation or reaction to a substance present in the workplace environment.

The usual clinical features of occupational asthma are described in Table 5.7.

**Table 5.7 Usual clinical features of occupational asthma**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asthmatic narrowing of the bronchial airways results in coughing, wheezing or breathing difficulty</td>
<td></td>
</tr>
<tr>
<td>This airway narrowing is episodic and can be reversed or prevented by the use of medication</td>
<td></td>
</tr>
<tr>
<td>Sensitisation to a substance is a permanent condition and re-exposure to the causative substance, even in relatively low dose, will predictably result in recurrence of asthma</td>
<td></td>
</tr>
<tr>
<td>Exposure to the causative substance usually results in an asthmatic reaction within 30 minutes (the early response) but this reaction may even occur 18 to 24 hours following exposure (the late response)</td>
<td></td>
</tr>
<tr>
<td>Symptoms of allergic rhinitis (hay fever) and conjunctivitis and skin rashes may accompany occupational asthma, or may precede it</td>
<td></td>
</tr>
<tr>
<td>Smokers and atopic individuals (i.e. people with a predisposition to allergic diseases) are generally at increased risk of developing occupational asthma</td>
<td></td>
</tr>
<tr>
<td>Permanent removal of sensitised individuals from further exposure to the causative agent may result in the asthmatic condition improving, although this is not always the case</td>
<td></td>
</tr>
<tr>
<td>Continuing exposure despite symptoms usually results in progression of the disease and reduces the chances of a complete recovery following removal from exposure</td>
<td></td>
</tr>
</tbody>
</table>
The smelting and processing of certain minerals can give rise to airborne exposures to metallic compounds that are known to result in sensitisation and occupational asthma. This is certainly the case for platinum and nickel compounds. It is probably the case for vanadium as well.

Platinum refining results in exposures to various salts of platinum that are capable of causing sensitisation, allergic rhinitis (hayfever) and asthma. The most potent sensitising agent is ammonium hexachloroplatinate (ACP). Platinum is a very important mineral in South Africa and platinum sensitisation has been studied in some detail in the industry.

Chest tightness and wheezing are the most common symptoms that bring a platinum refinery worker to his doctor. Most sensitised workers have these symptoms immediately following exposure to an atmosphere with soluble platinum salts. They may also experience delayed symptoms, which occur when they are at home in the evening or asleep, commonly at about 2 a.m. The existence of an allergy to platinum salts can be confirmed by skin prick tests in which a dilute solution of the offending salt results in a skin reaction. These tests often become positive a few months before symptoms develop, but are occasionally negative even in the presence of work-related symptoms.

A study carried out at a local platinum refinery showed that most cases of occupational asthma developed early, usually in the first or second year following employment. Conversion to a positive skin prick test was most common in workers who were atopic, as defined by positive skin prick tests to common aero-allergens such as pollens or house dust, and was also more common in cigarette smokers.

Diagnosis does not usually present much difficulty. Although medical treatment may suppress symptoms for a while, the only way to effectively deal with this problem is to withdraw symptomatic individuals from exposure. This must be permanent.

Advances in platinum refining are capable of greatly reducing, but not altogether eliminating opportunities for exposure to platinum salts. Great care must be taken in dealing with chemical spills or other possible sources of accidental exposure. Even under optimal conditions it has been shown that the incidence of sensitisation can range from 0.73 to 6.8 cases per 100 person-months worked, with symptomatic platinum salt sensitivity ranging from 0.59 to 2.4 cases per 100 person-months worked. The DME’s OEL for soluble platinum salts is 0.002 mg/cubic meter. Even at exposures below this level it is possible for susceptible individuals to become sensitised. Individuals who have become sensitised to platinum salts will experience symptoms even at exposure levels well below the OEL.

Nickel exposure or exposure to its compounds has been linked to occupational asthma but this appears to be a rare phenomenon and most cases have been in nickel-plating processes, rather than in refining. Vanadium in the form of vanadium pentoxide is a known skin and respiratory irritant. There is some evidence that vanadium pentoxide can result in asthma-like symptoms.

Irritant induced asthma, also known as Reactive Airways Dysfunction Syndrome (RADS), can occur following single high dose exposures to a variety of irritant airborne exposures such as sulphur dioxide, ammonia and chlorine as well as the substances causing inhalation injuries as detailed below. RADS should be suspected when a previously well person has persistent symptoms of airflow obstruction three months after an accidental high dose exposure incident. Lung function tests should show airflow obstruction, or a histamine or metacholine challenge test should be positive, to make the diagnosis.

RADS differs from occupational asthma caused by sensitisation to a substance in the workplace in that it represents a response to direct injury to the airways and the symptoms of airflow obstruction do not necessarily have any relationship to ongoing workplace exposure. However, like asthma, it may become a long-lasting condition.

5.2.11 Inhalation injuries and asphyxia

Inhalation injuries in the mining industry may occur after underground fires with smoke inhalation or from exposure to nitrous fumes from gelignite used in blasting operations. Many other agents are
capable to causing inhalation injuries but only these two sources will be dealt with in any detail. The usual clinical features of inhalation injuries are detailed in Table 5.8.

**Table 5.8 Usual clinical features of inhalation injuries**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>The inhaled agent is usually directly toxic to the epithelial or subepithelial tissues of the respiratory tract</td>
<td></td>
</tr>
<tr>
<td>Acute effects &lt; 48 hours include: laryngeal oedema, lower airway obstruction, pneumonitis or adult respiratory distress syndrome</td>
<td></td>
</tr>
<tr>
<td>Persistent effects (after weeks or months) include: irritant induced asthma and constrictive bronchiolitis (a condition characterized by fixed airflow obstruction in small airways)</td>
<td></td>
</tr>
<tr>
<td>The site and nature of injury to the respiratory tract depends not only on the dose/amount of the offending agent, but also on particle size and solubility</td>
<td></td>
</tr>
<tr>
<td>Highly soluble agents (e.g. sulphur dioxide, ammonia, aldehydes) have an effect very early (within minutes of exposure) and cause damage and related symptoms to the conjunctivae, upper respiratory tract and proximal bronchi</td>
<td></td>
</tr>
<tr>
<td>Low solubility agents (e.g. nitrogen dioxide, nitrous oxide, ozone and phosgene) have a much later effect (hours to days) and predominantly affect the distal airways and alveoli. Because of the delayed effects and symptoms, exposure is often not noted early by the subject and exposure can thus be prolonged and more damaging</td>
<td></td>
</tr>
<tr>
<td>Smoke inhalation injuries vary from upper airway thermal injury to lower respiratory tract injury, depending on the nature of the exposure and accompanying injuries, especially burns</td>
<td></td>
</tr>
<tr>
<td>Following an exposure incident where there is a possibility of an inhalation injury affected persons must be referred to an inpatient facility for 24-48 hours of observation for possible delayed effects</td>
<td></td>
</tr>
<tr>
<td>In all cases where there is respiratory difficulty supplemental oxygen must be given. IV steroids are indicated for severe nitrous inhalation injuries</td>
<td></td>
</tr>
<tr>
<td>All persons with inhalation injuries should be re-evaluated after three months. Lung function tests should be carried out to detect persistent effects (RADS or constrictive bronchiolitis)</td>
<td></td>
</tr>
</tbody>
</table>

Asphyxia among miners may result because of the development of a non-respirable atmosphere in the mine secondary to an explosion or a fire. Carbon monoxide and other products of combustion may contribute to the tissue deprivation of oxygen that results in asphyxia. Self-contained self-rescue apparatus and safety bays underground where oxygen is available are essential to prevent deaths from asphyxia. A second important cause of asphyxia occurs when miners trapped under rock falls experience chest compression. Relief of the compression using hydraulic jacks within the first ten minutes may be life saving.

**Nitrogen dioxide**

Nitrogen dioxide is a heavy red/brown pungent gas produced by explosives. It is denser than air and therefore accumulates close to the ground in the workings following blasting. Adequate time is required for the gas to be cleared from the area after blasting is done. This requirement has set the pattern of work in the gold mines for more than half a century, in which all blasting is done at the end of the shift and no one is allowed to enter the workings until the next morning when the dust has settled and the nitrous fumes have dispersed. Very high concentrations of nitrogen dioxide may result if explosives burn during underground fires.

The DME OEL for nitrogen dioxide is 3 ppm. Because of the gas’s low solubility, the conjunctivae and upper respiratory tract are not irritated at this or higher levels and 50 ppm can be breathed for some time before discomfort results. This lack of an irritative response at toxic levels of the gas can result in prolonged exposure and delayed presentation of the lung injury. Because of the gas’s low solubility, damage is deep in the respiratory tract at the level of the small conducting airways and adjacent respiratory bronchioles.

Following high dose or prolonged exposure, the onset of shortness of breath and cough is delayed for about three hours, but ranging from half an hour to 30 hours after exposure. Cases should be observed for at least 48 hours following exposure incidents, even if asymptomatic and with a normal chest
x-ray. Because of the marked variation in individual response to inhalation injury, follow-up lung function tests should be performed after 3 months to ensure a return to normality or to document presence of persistent airflow obstruction that could be a consequence of irritant induced asthma or constrictive bronchiolitis.

**Smoke inhalation injuries**

Underground fires are an extremely serious occurrence with risks of asphyxia and smoke inhalation injuries. Fires underground occur usually in coal and gold mines where methane gas deposits initiate explosions that are then propagated as fires. Propagation of fires in coalmines is a special hazard since the coal dust particles suspended by the original explosion are combustible. Underground fires burn any combustible material in the mine, making the resultant fire smoke a complex mixture of different ingredients, which vary not only from fire to fire, but also within the time course of a single fire.

Fires deplete atmospheric oxygen underground creating a danger of asphyxia but also increasing the rate of incomplete combustion with production of carbon monoxide and other toxic gases. Incomplete combustion of plastics and polyurethanes will emit both carbon monoxide and hydrogen cyanide and is therefore especially hazardous.

Inhalation injury causes 50 to 70 percent of the mortality of all burns patients. Simple fires usually result in pure thermal burns affecting only the upper respiratory tract because of the low heat-carrying capacity of dry smoke. However, in patients with severe burns and upper airway injury, most also have involvement of the lower respiratory tract. Inhalation injury can occur in the absence of surface burns.

Patients judged to be at risk of inhalation injury from fire and/or smoke exposure should be observed in hospital for at least 24-48 hours, as symptoms are often delayed. Inspired air should be humidified and supplemental oxygen given. The possibility of carbon monoxide or cyanide poisoning should be considered.

Again, because of the marked variation in individual response, follow-up lung function tests should be performed after 3 months to ensure a return to normality or to document presence of persistent airflow obstruction that could be a consequence of irritant induced asthma or constrictive bronchiolitis.

### 5.3 Legal framework for prevention and compensation of occupational lung disease

The legal framework relevant to prevention of occupational lung diseases in the mining industry is the Mine Health and Safety Act and certain regulations, guidelines or guidance notes that have been published or will be published in terms of that Act. This legal framework is described in Chapter 1 and only aspects of direct relevance to the medical prevention of occupational lung disease will be considered here, specifically medical surveillance.

The starting point for prevention is hazard identification and risk assessment, considered in Chapter 3. Measurement of airborne pollutants is dealt with in Chapter 4. Section 11 of the MHSA requires the employer to assess and respond to risk. Once a significant risk has been identified, Section 13 of the Act requires the employer to establish and maintain a system of medical surveillance of employees exposed to health hazards if necessary to do so in terms of a risk assessment, or if required to do so by regulation or notice. The definition of employee in this instance includes the employees of contractors who perform work in a mine.

Benefit examinations, compensation and autopsies in terms of the Occupational Diseases in Mines and Works Act are dealt with in Chapter 14. Similarly, procedures for reporting injuries of the respiratory system not covered by the ODMWA but falling under the COID Act (see Table 5.1) are discussed in Chapter 14.
5.4 Medical surveillance

Medical surveillance is a programme of regular examinations designed to detect disease for early treatment, referral or appropriate placement of employees, as well to collect information for risk assessment and prevention purposes. The legal duties and rights of parties with respect to medical surveillance are summarised in Appendix 5.1.

A medical surveillance programme for occupational lung disease should be initiated if risk assessment indicates that there is significant risk, usually defined in occupational hygiene terms. The occupational medicine practitioner will be required to make decisions or recommendations about employees requiring inclusion in the surveillance programme. In such instances an informed assessment of the accuracy and generalisability of the available hygiene data to different groups of employees must be made. The past history of exposures in these groups and the occurrence of occupational lung diseases should be considered. If there is uncertainty about the presence of significant risk, it is better to conduct additional occupational hygiene measurements and to carry out medical surveillance until a clearer picture of risk is obtained. This policy can then be reviewed at suitable intervals.

In the case of airborne pollutants significant risk is defined as follows:

- If the prevailing hazard exposure concentration as evaluated by the air quality programme is > 50% of the occupational exposure limit (OEL) for that hazard, then a full programme of medical surveillance must be instituted for all employees exposed to the hazard. This programme must include initial, periodic and exit medical examinations according to a programme that is appropriate to the level of risk.
- If employees have previous exposure to mineral dust carrying a significant risk of disease, they must also be included in a medical surveillance programme to monitor possible deterioration or development of disease.
- If the prevailing hazard for mineral dust exposure is > 10% but < 50% of the OEL, a full programme of medical surveillance may not be required. Initial and exit medical examinations are appropriate to this level of risk.

OELs for important airborne pollutants mentioned in this chapter are given in Table 5.9.

Table 5.9: Proposed occupational exposure limits for important airborne pollutants causing occupational lung diseases (DME, 2001)

<table>
<thead>
<tr>
<th>Substance</th>
<th>Exposure Limit (mg/cubic meter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crystalline silica (all forms)</td>
<td>0.1</td>
</tr>
<tr>
<td>Silica, amorphous inhalable</td>
<td>6</td>
</tr>
<tr>
<td>Silica, amorphous respirable</td>
<td>3</td>
</tr>
<tr>
<td>Coal dust (respirable particulates):</td>
<td></td>
</tr>
<tr>
<td>&lt; 5% crystalline silica (quartz)</td>
<td>2</td>
</tr>
<tr>
<td>&gt; 5% crystalline silica (quartz)</td>
<td>As for crystalline silica</td>
</tr>
<tr>
<td>Soluble platinum salts</td>
<td>0.002</td>
</tr>
</tbody>
</table>

5.4.1 Purpose of medical surveillance as mandated by MHSA

The MHSA gives clear guidance on the purpose of a medical surveillance programme, summarised in Table 5.10. If there is a requirement for a medical surveillance programme the employer must draft a Code of Practice for medical surveillance in accordance with the appropriate DME guidelines or regulations, as required by section 9.2 of the Act.

It is clear from the MHS Act that there is an intention that there be a clear communication between the occupational medical practitioner responsible for the medical surveillance programme and the health and safety committee or committees on the mine. A copy of the annual medical report, detailing occupational lung disease statistics for the most recent year must be given to the health and safety committee. This is the minimum requirement, but clearly the occupational medical practitioner can play an active role in health promotion, in conjunction with the health and safety committee.
Table 5.10: Elements and aims of a medical surveillance programme in terms of proposed DME Guidelines.

<table>
<thead>
<tr>
<th>A medical surveillance programme of employees should:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Be appropriate to the health hazard</td>
</tr>
<tr>
<td>• Provide information that the employer can use in determining measures to –</td>
</tr>
<tr>
<td>• Eliminate, control or minimise the health risk and hazards</td>
</tr>
<tr>
<td>• Prevent, or detect and treat occupational diseases at an early stage</td>
</tr>
<tr>
<td>• Consist of an initial medical examination and other medical examinations at appropriate intervals</td>
</tr>
<tr>
<td>• Establish a baseline against which subsequent changes in the health status of employees can be evaluated over time</td>
</tr>
<tr>
<td>• Be designed to identify medical conditions that may render employees temporarily or permanently unable to perform their occupations</td>
</tr>
<tr>
<td>• As far as reasonably practicable ensure that –</td>
</tr>
<tr>
<td>• Employees are fully informed of the health risk and hazards associated with their occupations and of the measures to eliminate, control and minimise the health risk and hazards</td>
</tr>
<tr>
<td>• The health status of employees does not place their health at increased risk in a particular working environment nor place other employees or the public at increased risk</td>
</tr>
</tbody>
</table>

5.4.2 Employee education and medical surveillance

The training and education implied by the requirement that employees be informed about health risks needs to be linked to medical surveillance wherever possible. Medical surveillance is itself an opportunity for education. Further, such surveillance is more likely to be acceptable to employees if they understand its purpose.

There are a variety of media that can be used for employee education. Such media are likely to have the most impact if they carry a simple message and are locally developed with professional assistance. Involving the health and safety committee representatives in the design of the media and programmes to disseminate the message will help to ensure relevance and impact. The various media include formal training sessions, peer education methods, videos, posters and warning signs in the mine. As far as is practicable all vernacular or mother tongue languages in use by miners at a mine should be used.

Educational interventions need to be provided in an appropriate form for both newly engaged miners and with more experienced miners. Such activities could be timed to coincide with medical surveillance, i.e. at 3-year periods. Topics that are of particular relevance to lung disease include: explanations of relevant airborne pollutants, their health effects and preventive measures in place at the mine; symptoms of pulmonary TB to encourage appropriate self-presentation to health services; the hazards of smoking, and HIV/AIDS education.

The interaction of smoking and occupational risk factors for lung disease needs to be emphasised. The combined effect of occupational airborne pollutants and smoking may be more than the sum of the adverse effects of each risk factor alone. Investment in dust control and in smoking cessation programmes to assist workers to avoid or give up smoking will thus both contribute to the reduction of the risk of occupational lung disease.

5.4.3 Medical surveillance for pneumoconiosis and COPD

Recommended current practice for tests and their frequency in workers exposed to > 50% of the OEL of mineral dusts known to cause pneumoconiosis or COPD is summarised in Table 5.11. Each of the tests to be performed will be discussed separately below.
### Table 5.11: Proposed regulations for medical surveillance in the case of exposure to mineral dust (silica, coal, or other mineral dust known to cause pneumoconiosis or COPD)

<table>
<thead>
<tr>
<th>Examination</th>
<th>Tests to be performed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial — carried out on starting or before undertaking work.</td>
<td>Respiratory questionnaire</td>
</tr>
<tr>
<td></td>
<td>Cardiorespiratory examination</td>
</tr>
<tr>
<td></td>
<td>Chest x-ray (large plate)</td>
</tr>
<tr>
<td></td>
<td>Lung function test (spirometry)</td>
</tr>
<tr>
<td>Periodic — every three years</td>
<td>Cardiorespiratory examination</td>
</tr>
<tr>
<td></td>
<td>Chest x-ray (large plate)</td>
</tr>
<tr>
<td></td>
<td>Lung function test (spirometry)</td>
</tr>
<tr>
<td>Exit — when employment terminated for any reason</td>
<td>Cardiorespiratory examination</td>
</tr>
<tr>
<td></td>
<td>Chest x-ray (large plate)</td>
</tr>
<tr>
<td></td>
<td>Lung function test (spirometry)</td>
</tr>
</tbody>
</table>

#### 5.4.4 Medical surveillance for occupational asthma

The problems encountered in platinum refineries or other environments, where sensitising agents are encountered, require specific medical surveillance programmes. Only those for platinum salt exposure will be detailed. At an initial medical examination it is justifiable to exclude persons from such an environment if they already suffer from asthma on the basis that the risk to their health from additional sensitisation to platinum salts is unacceptable. There are arguable grounds for exclusion of current smokers since they are also at increased risk for developing occupational asthma. There is general acceptance that there are no grounds for exclusion of individuals who are atopic (as defined by positive skin prick tests to common non-occupational aeroallergens).

Initial medical examination should include a respiratory symptoms questionnaire, a lung function test and skin prick tests for the occupational sensitising agent that will be encountered in the workplace, if such a test is available. These three examinations should be repeated every six months during the first two years of employment and thereafter annually. They should also be repeated if an exposed individual presents to the occupational medical practitioner with appropriate symptoms. Methods of conducting skin prick tests should follow standard procedures published in the literature (see Merget 1991). If an individual develops appropriate symptoms but has negative specific skin prick tests, a specific bronchial provocation test with platinum salts is justified if it can be carried out under close supervision of a medical practitioner and standard procedures are followed.

#### 5.4.5 Medical surveillance for mesothelioma, lung cancer and Progressive Systemic Sclerosis (PSS)

At the present time there are no screening methods of proven value in the early detection of mesothelioma or lung cancer. There is also no method of proven usefulness for the early detection of individuals at special risk of developing PSS. Early recognition of PSS and removal from further silica exposure could possibly reduce the severity of the PSS. Early diagnosis of this condition is not easy, but mine medical officers should be constantly reminded about the possibility of a diagnosis of PSS.

#### 5.4.6 Data management and reporting responsibilities as part of medical surveillance

**Record maintenance**

The MHSA requires that employee records be kept for 40 years. Preservation of hard copy and software for such a long period requires special expertise. Within the company there must be the allocation of responsibility to ensure that records are kept in the proper manner so as to remain both legible and accessible.

It is not a legal requirement that all records are kept as hard copy/paper, but there should always be at least partial (summary) paper records. Chest x-rays from medical surveillance must be kept and not
sent for recycling for silver. If computerised records are kept it is essential that provision is made for all records to be backed up, and for transfer of old records onto new software systems when systems are changed.

The medical surveillance record system also has to meet the responsibility towards the employees of contractors. A standard operating procedure should be in place on the mine with respect to employees of contractors, to identify those working in risk areas and avoid unnecessary repetition of medical surveillance of short-term employees.

**Reporting**

Section 13 (2)(b) of the MHSA is explicit that one of the most important purposes of a medical surveillance programme is to provide information to assist with the prevention of occupational diseases. The main regular summary of medical surveillance data is the annual medical report. The data relevant to occupational lung disease required for such a report, as mandated by regulation, are summarised in Appendix 5.2.

Occupational medical practitioners have additional statutory reporting duties in terms of the ODMWA, and are required to produce exit medical certificates and to report diagnosed occupational diseases to the DME’s SA Mining Occupational Diseases Database (SAMODD). As is evident from Appendix 5.2 there is a great deal of overlap in the data required for these various responsibilities. It is combinations of these data that will give the most informative reports.

Computerised records will help to meet these various responsibilities, particularly if they are stored in relational databases. Several relational database software programmes are available commercially. An advantage of a relational database in managing a medical surveillance programme is that all data concerning an individual can be interrelated through particular identifiers, such as name or company number. Using a relational database, new data captured in each year’s surveillance can be linked to the results in previous years using these identifiers. Using the same or compatible software it is possible to import or use other data, for example, employee identifiers, past employment record and compensation history from the human resources department.

Most database software enables checks that data are not incorrect by pre-programming plausible values of limits for data being entered. It allows for deviations from baseline measurements to be flagged and drawn to the attention of the occupational health practitioner (such as a 10% or greater decline in lung function). Database programmes can also produce outputs or reports according to any required format for the data contained in them.

An important function of a medical surveillance records system is to link occupational hygiene and medical surveillance information, as required by Section 12 (3) of MHSA. The occupational hygiene database should allocate every person working in the mine to a particular Sample Area for purposes of assigning them to an Activity Area and within that to a Homogeneous Exposure Group (HEG). Within each HEG the hygienist will be sampling the exposure of a 5% proportion of exposed individuals, according to a schedule that is more frequent if there is higher risk. Linkage of exposure and outcome information will enable a more accurate risk assessment of the effects of dust and other exposures in the medium and long term.

**Performance indicators.**

The data captured in Appendices 5.2 to 5.4 can be used to derive a variety of useful measures of the occurrence of occupational lung disease on a mine. Cases should always be expressed per number of employees. These measures can be used to track trends over time, or to compare different parts of a mine characterised by exposure information. Such comparative rates will better serve the functions of risk assessment and prevention.

**Incidence: annual new cases of pneumoconiosis or new certifications**

The minimum requirement for the annual medical report and SAMODD is the crude incidence (number per 1 000 employees) of new ODMWA certifications in the whole mine. A more specific indicator of occurrence would be new certifications per 1 000 employees in a sample area or new
certifications per 1000 employees in an HEG. The most sensitive available indicator would be new cases of pneumoconiosis diagnosed in the radiological surveillance programme for exposed employees, as detailed below. Sample areas or HEGs can be ranked according to the measures of exposure made there and an approximate dose-response relationship can be derived by examining the incidence of certifications at each level. In large mines, where there may be more than one Health and Safety Committee, certifications could be reported according to activity area for which the Committee is responsible.

Pneumoconiosis, COPD and the occupational cancers mentioned are diseases of long latency. In the instance of silicosis, it may take 15 years of underground gold mining before the radiological changes become evident. This means that occurrence rates of these diseases are not particularly useful in indicating areas where engineering control of dust is required. Current environmental measurements are thus a better indicator of risk. In diseases of short latency, such as occupational asthma, the occurrence of cases in a particular area, for example in a section of the platinum refinery, would draw attention to areas in need of control.

**Cumulative incidence: all certifications over a period of years**

Compensation history, or cumulative incidence of previously certified cases of occupational lung diseases over a given period such as five years, is also a potentially useful statistic on disease occurrence. Cumulative incidence, like simple incidence can use as its employee denominator the whole mine, sample or activity area, HEG, or occupation.

**5.4.7 Respiratory questionnaires**

Respiratory questionnaires are required for initial examinations of persons who will be exposed to significant risk from mineral dust.

Although questionnaires are useful for some aspects of a medical surveillance programme, they are not required for periodic or exit examinations of persons exposed to mineral dusts. Use of respiratory questionnaires in periodic or exit examinations is only advocated for circumstances where there is a risk of occupational asthma. Specific questions should then be added to the questionnaire to assist in eliciting appropriate symptoms of asthma.

An example of an abbreviated questionnaire is attached as Appendix 5.3. In using such a questionnaire as a screening tool, any positive response to a question about symptoms should be followed up by additional questions.

Questionnaires should be administered by people who have been specifically trained for the task. The multilingual environment of mines makes use of such questionnaires challenging since some Southern African languages do not have direct translations for terms such as wheezing. One approach is to prepare mother tongue language translations for all languages in use at the mine. This is often feasible since there may be only three or four languages in common usage. Usual practice in preparing the questionnaire is to have the questions translated by a person proficient in the target language, followed by independent back-translation of the questions into English by another person proficient in both languages. Alternatively where the interviewers have multilingual abilities, it is acceptable for the questionnaire to be available only in English and the questions translated appropriately as the interview is conducted.

There can be considerable savings of time and effort if questionnaire administration is computer assisted. Entry of responses to computer prompted questions results in immediate data capture, as well as guiding the interviewer through the process. The interviewer can be prompted if no response is entered or if a response cannot be correct. Epi-Info is an example of free software, available through the Centers for Disease Control (CDC), USA., that can be used for data capture from a questionnaire. (See CDC website under Guide to Resources).

**5.4.8 Chest Radiology**

All of the pneumoconioses (silicosis, asbestosis, coal workers’ pneumoconiosis and others) are best detected by full size postero-anterior (PA)(35 x 43 cm, or 35 x 35 cm) plain chest x-rays of acceptable
technical quality. A large PA film alone is acceptable, although lateral films should be taken if pathology other than pneumoconiosis is suspected. Oblique views of the chest are required for a more sensitive evaluation of asbestos related pleural disease.

Chest x-rays are usually able to detect signs of pneumoconiosis well in advance of the onset of symptoms and abnormal lung function tests. The most important limitations in the use of chest x-rays in medical surveillance are the technical quality of the x-rays and the capabilities of the interpreter of the films.

It is the radiographer’s responsibility to produce a film quality acceptable for detection of pneumoconiosis. It is the film reader’s first decision when looking at the film to judge whether it is acceptable. A close working relationship between radiographer and reader will improve quality and reduce the cost and inconvenience of having to repeat films.

Table 5.12: Features of a technically adequate chest x-ray for detecting pneumoconioses

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labelled with name, date and the location</td>
<td></td>
</tr>
<tr>
<td>Well centered, with apices and costophrenic angles visible</td>
<td></td>
</tr>
<tr>
<td>Full inspiration (such that the sixth rib intersects the shadow of the diaphragm near its dome). (Underinspired films can result in over-reading of pneumoconiotic opacities)</td>
<td></td>
</tr>
<tr>
<td>Scapulae clear of the inner aspect of the chest wall where they may obscure other lesions</td>
<td></td>
</tr>
<tr>
<td>Reasonable contrast, uniform across the film and allowing easy distinction between blood vessels and air-filled parenchyma. Film fogging or poor film-screen contact during developing can result in poor contrast</td>
<td></td>
</tr>
<tr>
<td>Acceptable exposure of the film such that the major pulmonary vessels can be clearly seen behind the heart. Overexposure (film too dark) results in underreading of pneumoconiotic opacities, and conversely under exposure (film too light) can result in overreading</td>
<td></td>
</tr>
<tr>
<td>Avoidance of artefacts such as mottle, which can result in small opacities visible throughout the film including the soft tissues</td>
<td></td>
</tr>
<tr>
<td>For screening radiology, high kV films (125 kV) are recommended</td>
<td></td>
</tr>
</tbody>
</table>

The ILO has established a universally recognised system for grading of the degree of changes on the chest x-ray by comparison of an individual’s chest x-ray with standard films. Although the ILO classification is primarily an epidemiological tool it has also widely used as an aid to medical surveillance programmes and has even been adopted as a grading system by many compensation authorities. Sets of the ILO radiographs are available through the ILO Office in Pretoria or Geneva (cost: approx. US$600).

Appendix 5.4 shows a reading form for use in radiological occupational lung disease surveillance programmes and it incorporates the ILO Short Classification as used at the MBOD. The primary reading form lists seven categories of abnormality that will be encountered by the reader of x-rays in a radiological surveillance programme. The significance of each finding is detailed, together with the recommended plan of action. Information generated by collecting information from use of such a form will provide important information for outcome indicators, e.g. annual incidence of new cases of pneumoconiosis diagnosed.

SIMRAC is currently developing a programme that will make available training materials for distance learning in these skills. Accredited ability to interpret films taken for occupational lung disease surveillance can be expected to become the standard in the mining industry.

Miniature chest x-rays are considered to be less sensitive than large ones in the detection of pneumoconiosis and are not recommended for this purpose.
There is no system analogous to the ILO system to categorise miniature chest x-rays. If previously undiagnosed pneumoconiosis is present on a miniature x-ray, a large film should be obtained to confirm the diagnosis. Use of miniature radiography in active case finding of tuberculosis is dealt with in Chapter 6. There is currently no formal training and accreditation process for skills in the reading of mass miniature radiography for tuberculosis.

The radiation hazard of even repeated full size chest x-rays is very low. Miniature radiography carries a significantly higher radiation dose.

High resolution computerised tomography (CT) scans of the chest offer significant advantages in imaging of the lungs and are useful in diagnostic evaluations of complicated occupational lung disease cases.

5.4.9 Lung function testing

The measurement of lung function by spirometry is now a required part of medical surveillance for workers exposed to mineral dusts or other airborne pollutants. Spirometry consists of a forced expiratory manoeuvre for measurement of Forced Expiratory Volume in one Second (FEV1) and Forced Vital Capacity (FVC). There are a number of spirometers commercially available for use in the occupational setting.

Quality control of spirometry is essential to produce meaningful results. There are many factors such as subject understanding, tester competence and equipment calibration, which affect the reliability of the test.

The DME has recently published a guidance note for occupational medical practitioners to assist in the performance and interpretation of lung function tests that accord with best current practice for this test (See Guide to Resources). This guidance note is to be widely distributed by the DME and mine occupational health services will be expected to use it as a best practice standard.

In pneumoconiosis, lung function abnormalities occur some years after radiological changes have become obvious. It is increasingly being realised that lung changes caused by past, even successfully treated, pulmonary tuberculosis cause significant lung function abnormalities. In these conditions lung function tests are not used for the screening or diagnosis, but rather for the documentation of the degree of abnormality related to the underlying abnormality.

In COPD and asthma, lung function tests serve both as a screening test and as the diagnostic test that, particularly in COPD, give an indication of the degree of severity.

Relational databases are well suited to storage and subsequent analysis of lung function data. A variety of commercial software programmes, sometimes made available with equipment, are available for converting information depicting the full flow-volume curve into a database for storage. The minimum information that must be retained is age, height, FEV1, FVC and the ratio of FEV1/FVC expressed as a percentage.

Reference or predicted values for lung function testing are used to decide whether a single test result falls outside of the normal range or to categorise the degree of abnormality. In response to consistent findings of ethnic variation in FVC and FEV1, international guidelines have recommended that reference equations be derived from healthy non-smoking populations similar in origin to that of the persons tested. In a recent SIMRAC report on reference values for FEV1 and FVC for use in entry medical and medical surveillance examinations in the mining industry, the use of prediction equations derived from a study by Louw (1996) for black male employees in the mining industry, and from a study by Mokoetle (1995) for black female employees, was recommended. European Community for Coal and Steel (ECCS) prediction equations were recommended for white men and women employees in the mining industry. These equations, which can be programmed into spirometers, are contained in the report. A detailed discussion of how these recommendations were arrived at, together with advice on the monitoring of lung function over time, are included in SIMRAC Health 610 report (See Guide to Resources).

Staff properly trained in the performance of lung function tests are essential if reliable results are to be obtained. It has been recognised for some time that provisions in South Africa for training to achieve competency in performing screening spirometry in industry are inadequate. While spirometry
is part of the curriculum of diplomas in occupational health for doctors and nurses, graduation with this qualification does not necessarily carry with it the competence to perform screening spirometry. Medical technologists who specialise in pulmonary technology acquire competence in spirometry in addition to many other skills, but are in fact over-skilled for the performance of screening spirometry. A more limited form of training is required to ensure competency for the performance of screening spirometry in industry. There are currently moves to put in place a curriculum and system of accreditation in screening spirometry, similar to the system in place for training and certification of competency in the performance of screening audiometry.

5.5 Guide to information resources

5.5.1 Official reports


5.5.2 Official regulations and guidelines


Department of Minerals and Energy. Regulations for medical surveillance for exposure to asbestos, silica dust and coal dust. Occupational Health and Safety Inspectorate, DME (in draft).

5.5.3 Further reading

Silicosis


Asbestos

SORDSA

COPD

Progressive Systemic Sclerosis

Medical surveillance
Chest radiography

Lung functions

Allergy testing/platinum

Table 5.13. Websites covering occupational lung disease and medical surveillance.

<table>
<thead>
<tr>
<th>Address</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="http://www.simrac.co.za">www.simrac.co.za</a></td>
<td>Research reports on occupational lung disease and medical surveillance commissioned by SIMRAC.</td>
</tr>
<tr>
<td><a href="http://www.asosh.org">www.asosh.org</a></td>
<td>South African occupational health and safety information, including laws, resources and links to other sites.</td>
</tr>
<tr>
<td><a href="http://www.ohscinfo.tripod.com">www.ohscinfo.tripod.com</a></td>
<td>DME site for occupational hygiene standards, including those in development.</td>
</tr>
<tr>
<td><a href="http://www.cdc.gov/niosh/homepage.htm/">www.cdc.gov/niosh/homepage.htm/</a></td>
<td>National Institute for Occupational Health and Safety, USA. Research and advisory agency. Large database of reports and information on occupational health and safety.</td>
</tr>
</tbody>
</table>
Appendix 5.1: Legal duties and rights with respect to occupational diseases and medical surveillance programmes in terms of the MHSA

<table>
<thead>
<tr>
<th>Employers must</th>
<th>Occupational medical practitioner must</th>
<th>Employee</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 13 (3): engage the services of a full-time or part-time occupational medical practitioner, together with, insofar as is necessary, other appropriately qualified occupational health practitioners</td>
<td>• 13 (5): take every measure that is reasonably practicable to promote the health and safety of employees at the mine and assist employees in matters relating to occupational medicine</td>
<td>• 19 (1) (a)&amp;(b) may request and be provided with a copy of any medical surveillance record or part of it that relates to him/herself</td>
</tr>
<tr>
<td>• 13 (3)(b): provide occupational medical practitioners with the means necessary to perform their functions</td>
<td>• 16 (1 &amp; 2): compile an annual medical report covering employees at that mine, giving an analysis of the employees’ health based on employees’ records of medical surveillance, without disclosing the names of the employees. Copies of the report to be provided to the employer, the health and safety committee and the DME Medical Inspector</td>
<td>• 17 (1)(3): must attend the arranged exit medical examination</td>
</tr>
<tr>
<td>• 18: pay the costs of all clinical examinations and medical tests</td>
<td>• (15) &amp; 13 (2)(a): maintain confidentiality of medical surveillance records, to be stored in a safe place and made available only in accordance with the ethics of medical practice, or if required by law or court order, or if the employee has in writing consented to the release of the information</td>
<td>• 17 (1): (3): may appeal against a decision that he/she is unfit to perform any category of work or any finding contained in an exit medical certificate. The appeal must be lodged with the Medical Inspector within 30 days of the relevant decision</td>
</tr>
<tr>
<td>• 13 (3)(c) &amp; 8 (a)&amp;(b) &amp; 15 (2) (a)&amp;(b): keep a record of medical surveillance for each employee exposed to a health hazard, store it safely and not dispose of it for 40 years or until the mine closes. When the mine closes the records of medical surveillance to be delivered to the Medical Inspector</td>
<td>• 14 (4)(a &amp; b): when conducting an exit medical examination ensure that an exit certificate is produced, indicating the results of all medical surveillance and the presence or absence of any occupational disease. A copy of the exit certificate to be entered into the employees’ record of medical surveillance</td>
<td>• 19 (1)(3): must attend the arranged exit medical examination</td>
</tr>
<tr>
<td>• 12 (3): keep occupational hygiene records in a manner that can be linked as far as practical to each employee’s record of medical surveillance</td>
<td>• 13 (7): inform the employer and employee in the event of the employee being temporarily unfit to perform work as a result of an occupational disease</td>
<td>• 20 (4): in the instance of an appeal against a finding that an employee is unfit to perform any particular category of work, or a finding contained in an exit medical certificate, provide a report to the Medical Inspector</td>
</tr>
<tr>
<td>• 17 (1): if the services of an employee who was subject to medical surveillance are terminated for any reason, arrange for an exit medical examination of the employee</td>
<td>• 14 (4)(b): when conducting an exit medical examination ensure that an exit certificate is produced, indicating the results of all medical surveillance and the presence or absence of any occupational disease. A copy of the exit certificate to be entered into the employees’ record of medical surveillance</td>
<td>• 20 (1) &amp; (2): may appeal against a decision that he/she is unfit to perform any category of work or any finding contained in an exit medical certificate. The appeal must be lodged with the Medical Inspector within 30 days of the relevant decision</td>
</tr>
</tbody>
</table>
Appendix 5.2: Minimum data requirements for various reporting responsibilities of an occupational medicine practitioner in the SA mining industry

<table>
<thead>
<tr>
<th>Name and Surname of individual</th>
<th>Annual Medical Report</th>
<th>SAMODD Input Form</th>
<th>MBOD Benefit Application</th>
<th>Exit Medical Examination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual’s signature</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Gender</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>National ID Number / Passport Number</td>
<td>No</td>
<td>Yes (1)</td>
<td>Yes (1)</td>
<td>Yes (1)</td>
</tr>
<tr>
<td>Industry Employee Number (1)</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes (1)</td>
</tr>
<tr>
<td>Employee Number (1)</td>
<td>No</td>
<td>Yes</td>
<td>Yes (2)</td>
<td>Yes (2)</td>
</tr>
<tr>
<td>Date of birth</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Date of death</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Individual’s address</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Name of mine / employer</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Employee of a contractor</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Type of mine or commodity mined</td>
<td>Yes</td>
<td>No</td>
<td>Yes (2)</td>
<td>Yes</td>
</tr>
<tr>
<td>Total number of employees in the mine</td>
<td>Yes (3)</td>
<td>Yes (4)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Employee job title</td>
<td>No</td>
<td>No</td>
<td>Yes (2)</td>
<td>Yes (2)</td>
</tr>
<tr>
<td>Years of exposure in current job</td>
<td>No</td>
<td>Yes</td>
<td>Yes (2)</td>
<td>Yes (2)</td>
</tr>
<tr>
<td>Hazards exposed to in current job</td>
<td>No</td>
<td>Yes</td>
<td>Yes (2)</td>
<td>Yes (2)</td>
</tr>
<tr>
<td>Previous job titles, years of exposure with current and former employers</td>
<td>No</td>
<td>No</td>
<td>Yes (2)</td>
<td>Yes</td>
</tr>
<tr>
<td>Name, address, telephone number of OMP or other person completing form</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes (5)</td>
<td>Yes (5)</td>
</tr>
<tr>
<td>Submitting party’s case reference number</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Date of initial medical examination</td>
<td>No (6)</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Date of most recent medical examination</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Clinical findings at most recent medical examination</td>
<td>No</td>
<td>No</td>
<td>Yes (7)</td>
<td>No</td>
</tr>
<tr>
<td>Results of lung function tests</td>
<td>Yes (8)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Results of chest radiograph</td>
<td>Yes (8)</td>
<td>Yes (9)</td>
<td>Yes (10)</td>
<td>Yes (9)</td>
</tr>
<tr>
<td>Results of other tests (11)</td>
<td>Yes (8)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Diagnosis</td>
<td>Yes (8)</td>
<td>Yes (12)</td>
<td>Yes</td>
<td>Yes (13)</td>
</tr>
<tr>
<td>ODMWA benefit application made.</td>
<td>No</td>
<td>Yes</td>
<td>—</td>
<td>Yes</td>
</tr>
<tr>
<td>ODMWA compensable disease</td>
<td>Yes</td>
<td>Yes</td>
<td>—</td>
<td>Yes</td>
</tr>
<tr>
<td>Previous compensation history</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>MBOD Reference number</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
### Footnotes:

1. National ID number, Passport number, DME ID number, industry number, company number, 
   TEBA number and MBOD number are optional.
2. The MBOD and exit medical report requires a full occupational exposure history, as well as 
   employee ID numbers with previous employers in the mining industry.
3. The annual report requires that number of employees (including contract workers) subject to 
   medical surveillance in terms of Section 13 be reported, together with the total number of hours 
   worked in the reporting period.
4. SAMODD requires reporting of the employer’s workforce for the previous calendar year, 
   classified into surface, underground, open cast or at sea.
5. Signature also required.
6. The annual medical report requires a summary of the number of initial, periodical and exit 
   examinations performed.
7. MBOD requires past and present medical history, findings of height, weight, blood pressure, 
   general and chest examination.
8. Required to conduct an analysis of employees’ health based on employees’ records of 
   medical surveillance.
9. Use of the ILO Radiological Classification of the Pneumoconioses mentioned.
10. The MBOD radiologists will interpret the films using the ILO Radiological Classification of the 
    Pneumoconioses.
11. Tests include audiometry and other biological monitoring.
12. Diagnoses are entered by disease group (pneumoconiosis, cardiorespiratory tuberculosis, 
    COPD, NIHL, heat disorders and other).
13. Occupational diseases, past or present, including severity.
Appendix 5.3: An abbreviated respiratory symptoms questionnaire

(Also consider which of the data in Appendix 5.2 you require to collect directly from employees)

<table>
<thead>
<tr>
<th>No.</th>
<th>Question</th>
<th>Yes</th>
<th>No</th>
<th>Don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>COUGH: Do you usually have a cough on most days? (Count a cough with first smoke or on first going out doors) (Exclude clearing of throat)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>PHLEGM: Do you usually bring up phlegm from your chest? (Count phlegm with the first smoke or on first going out doors. Exclude phlegm from the nose. Count swallowed phlegm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>WHEEZING: Does your chest ever sound wheezing or whistling?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>CHEST ILLNESS: During the past three years have you had any chest illness that has kept you away from work for as much as a week?</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Has a doctor ever told you that you have?</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>4.1 Heart trouble</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.2 Bronchitis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.3 Asthma</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.4 Pneumonia</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>4.5 Silicosis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.6 Other chest trouble</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.7 If yes to 4.6, please specify other chest trouble (was it confirmed by a doctor &amp; age at start?)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>TUBERCULOSIS: Have you ever had tuberculosis?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>If yes complete the following</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Episode no.</th>
<th>Year</th>
<th>Doctor confirmed?</th>
<th>In lungs?</th>
<th>Affect heart?</th>
<th>Affect any other part of body?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| 6   | MEDICATION: Do you take any medication?                                   |     |    |            |
|     | 6.1 If yes to above, specify condition/disease and medication.           |     |    |            |
| 7   | TOBACCO SMOKING: Have you ever smoked? (Yes = more than 20 packs of tobacco in your life or more than 1 cigarette a day for a year) |     |    |            |
|     | 7.1 If yes, do you smoke now? (Yes = present smoker; No = Ex smoker)     |     |    |            |
| 8   | Present smoker                                                           |     |    |            |
|     | 8.1 What was your age in years when you started smoking?                 |     |    |            |
|     | 8.2 How much do you smoke per day?                                       |     |    |            |
|     | Commercial cigarettes                                                    |     |    |            |
|     | Hand rolled cigarettes                                                   |     |    |            |
|     | Pipes                                                                     |     |    |            |
| 9   | Ex-smoker                                                                |     |    |            |
|     | 9.1 What was your age in years when you started smoking                   |     |    |            |
|     | 9.2 In the past, on average, how much do you smoke per day? (No. of)     |     |    |            |
|     | Commercial cigarettes                                                    |     |    |            |
|     | Hand rolled cigarettes                                                   |     |    |            |
|     | Pipes                                                                     |     |    |            |
|     | 9.3 How old were you when you stopped smoking?                           |     |    |            |

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Appendix 5.4. Reading forms for use in occupational lungs disease surveillance, including a short form for the ILO Radiological Classification of the Pneumoconioses

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.</td>
<td>Technically inadequate film. Repeat film.</td>
</tr>
<tr>
<td>1 NAD</td>
<td>No abnormality detected. No specific action required</td>
</tr>
<tr>
<td>2a Pn new case</td>
<td>Significant pneumoconiosis seen. Review past films for significant interval change. Classify film according to ILO short classification. (see below). Arrange for counseling of employees with new abnormalities. Refer for benefit examination if appropriate and not already done</td>
</tr>
<tr>
<td>2b Pn as before</td>
<td></td>
</tr>
<tr>
<td>2c Pn with progression</td>
<td></td>
</tr>
<tr>
<td>3 TB as before</td>
<td>Signs consistent with tuberculosis seen. Past films show no interval change. No specific action required</td>
</tr>
<tr>
<td>4 TB Current</td>
<td>Signs consistent with tuberculosis seen. Either no past films available or there is significant interval change. Refer for diagnostic evaluation by TB/medical service. Refer for benefit examination if appropriate and not already done</td>
</tr>
<tr>
<td>5 Pn + TB as before</td>
<td>Signs consistent with TB and significant pneumoconiosis. Classify film according to ILO short classification. (see below) Manage as for (2) above</td>
</tr>
<tr>
<td>6 Pn + TB Current</td>
<td>Signs consistent with TB and significant pneumoconiosis. Classify film according to ILO short classification. (see below) Manage as for (4) above Refer for benefit examination if appropriate and not already done</td>
</tr>
<tr>
<td>7 Other</td>
<td>Other significant abnormality seen (e.g. pneumonia, pleural effusion or cardiac enlargement). Review past films for significant interval change. Refer for radiological diagnostic evaluation and/or referral to an appropriate medical service.</td>
</tr>
</tbody>
</table>

Date of X-ray plate:

<table>
<thead>
<tr>
<th>0/0</th>
<th>0/1</th>
<th>p</th>
<th>q</th>
<th>r</th>
<th>s</th>
<th>t</th>
<th>u</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>tha</th>
<th>tbu</th>
<th>cv</th>
<th>hi</th>
<th>es</th>
<th>hv</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
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<td>A</td>
<td>B</td>
<td>C</td>
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<td></td>
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<tr>
<td>1/0</td>
<td>1</td>
<td>2</td>
<td>3</td>
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</tr>
</tbody>
</table>
Symbols in the short ILO Classification

0/0  Pn not present.
0/1  Possibility that Pn present considered but rejected.

p  Small, rounded opacities < 1.5 mm in diameter.
q  Small, rounded opacities 1.5 to 3 mm in diameter.
r  Small, rounded opacities 3 to 10 mm in diameter.
s  Small, irregular opacities < 1.5 mm in width.
t  Small, irregular opacities 1.5 to 3 mm in width.
u  Small, irregular opacities 3 to 10 mm in width.

1/0  Pn present — insufficient small opacities to classify as category 1. Earliest sign of Pn.

1, 2 or 3  Small opacities present (refer to standard films).
A  Large opacity present with greatest diameter between 1 cm and 5 cm.
B  Large opacity or opacities present with combined area < right upper lobe.
C  One or more large opacities with a combined area > right upper lobe.

Abbreviations in the short ILO classification

tba  Active tuberculosis, probably
htub  Tuberculosis — activity uncertain
ch  Cavitation
hi  Enlargement of hilar or mediastinal glands
es  Egg-shell calcification of glands
hv  Heart and vessels
ef  Effusion
pla  Costophrenic angle obliteration
plw  Pleural wall abnormality — diffuse thickening
plc  Pleural calcification (plaque)
em  Emphysema
oth  Any other pathology or abnormality not represented in the table, which should be described in words.
CHAPTER 6

Tuberculosis and Associated Diseases

This chapter outlines the risk factors, natural history and methods for control and treatment of tuberculosis (TB), a disease caused by infection with *mycobacterium tuberculosis*. The close association of Human Immunodeficiency Virus (HIV) and TB is emphasised. The chapter provides detailed best practice guidelines for diagnosing and treating TB in the South African mining industry and designing a comprehensive TB control programme.

The chapter also covers the management of disease due to nontuberculous mycobacteria. This disease is related to TB and currently makes up 10 percent of mycobacterial disease among miners. These are the first published South African guidelines for the management of NTM disease.

Dr. G.J. Churchyard
Specialist physician

Gavin Churchyard holds postgraduate clinical and research qualifications in internal medicine. He is currently Director, Aurum Health Research, Welkom. He has published widely in the areas HIV, tuberculosis and occupational lung disease.

Dr. E.L. Corbett
Infectious diseases specialist

Elisabeth Corbett holds postgraduate qualifications in internal medicine and infectious diseases. She is currently Clinical Research Fellow, Department of Infectious and Tropical Diseases, London School of Hygiene and Tropical Medicine. She has strong links with Southern Africa, where she has conducted research into HIV and tuberculosis.
GLOSSARY

**BCG:** Bacillus Calmette-Guérin. Vaccine against TB, used mainly in children. Does not confer complete protection against TB

**Culture:** Test of sputum or other tissue in laboratory for growth of TB bacilli

**DOTS:** Directly observed therapy, short course. Currently recommended approach to TB treatment

**HAART:** Highly active antiretroviral therapy. Current combination of drugs effective in reducing load of the human immunodeficiency virus in the body

**IPT:** Isoniazid preventive therapy. Single drug treatment given to people at high risk of developing TB as a preventive measure

**Latent TB Infection:** Infection with TB which does not result in clinical disease

**MDR-TB:** Multi-drug resistant tuberculosis. TB caused by bacteria resistant to two or more of the main anti-TB drugs

**NTM:** Non tuberculous mycobacteria. Organisms related to the tuberculosis bacterium capable of causing a similar disease

**PPD:** Purified protein derivative. Material derived from TB bacillus, used in skin testing for past or current infection with TB bacillus

**Reactivation TB:** TB disease, which occurs as a result of flare-up of latent TB infection

**Reinfection TB:** TB disease that results from infection with a new strain rather than reactivation of a latent infection

**Sputum smear:** Examination of specimen of sputum under the microscope for TB bacilli

**Tuberculosis:** Disease of lungs and/or other organs of the body caused by infection with an inhaled bacterium, Mycobacterium Tuberculosis

**VCT:** Voluntary counselling and testing (for HIV)
6.1 Introduction

6.1.1 History of TB on the South African goldmines

Tuberculosis was recognised as an important health hazard shortly after gold mining started in South Africa in the 1890s. Black migrant miners, recruited from rural South Africa and surrounding neighbourhood states, were employed for short contract periods (6 to 9 months) and often stayed home for extended periods between contracts.

The high mortality from TB in black miners in the early 1900s led to an inquiry by the Tuberculosis Commission in 1912. New recruits appeared to be very susceptible, often presenting with TB in the first few months of service. The high mortality from TB was likely to have been underestimated, since mineworkers who developed TB were repatriated. Overcrowding, poor diet and poor working conditions were identified as important factors contributing to the high rate of TB amongst miners. Following the recommendations of the Commission, improvements in diet, living and working conditions were made, and TB rates in black miners declined between 1913 and 1935. The practice of repatriating miners with active TB was discontinued in the early 1980s.

TB was classified as a compensable disease in 1916. Compensation awards were racially based for more than 80 years, with compensation awards to white miners many times the amounts paid to black miners. The Occupational Diseases in Mine and Works Act (ODMWA) was amended in 1994 to remove overt racial discrimination for compensation and to introduce a wage based system.

6.1.2 The current epidemic

TB case rates have risen progressively throughout Africa during the last decade, and have increased by up to fourfold even in countries with well run TB control programmes in which incidence rates had previously been in decline. In recent years, TB cases rates, based on notifications to the Chamber of Mines South Africa, have increased dramatically (Figure 6.1).

![Figure 6.1. TB case rates* 1982-98: gold mining & national RSA rates](image)

USA incidence 1998: 6.8 per 100 000 p.a.

USA general population includes low TB risk groups such as women and children and is unadjusted for age. COM = Chamber of Mines.

Although the increase has occurred among workers on all the main commodity mines, i.e. gold, coal and platinum mines, TB case rates among gold miners are approximately three times higher than those among coal and platinum miners (Figure 6.2).
Among gold miners the increase in TB case notification rates has occurred in parallel with the increasing prevalence of HIV infection, which greatly increases susceptibility to TB (Figure 6.3). Steeply rising TB incidence rates among gold miners from under 1 000 per 100 000 p.a. to over 3 000 per 100 000 have paralleled the rising HIV prevalence in women attending state antenatal clinics, one measure of national prevalence. The proportion of HIV associated TB among miners now exceeds 50% of all TB cases in this group.

In addition to HIV infection, silica inhalation and particular silicosis are potent risk factors for TB. This combination of risk factors places gold miners at very high risk of TB.

TB associated mortality, defined as any cause of death while on TB treatment and including deaths from HIV associated opportunistic infection, exceeded deaths from mine accidents among gold miners for the first time in 1996, and is now the leading cause of death amongst gold miners (Figure 6.4).
The gravity of the threat to TB control posed by the HIV epidemic cannot be overemphasised, and it can be expected that TB incidence rates among miners will continue to increase during the next decade unless effective control methods can be identified and implemented.

Figure 6.4 Mortality rate of gold miners while on TB treatment* and from mine accidents
* (see text)

6.1.3 Legislative framework

Responsibilities regarding medical surveillance of occupational lung disease are detailed in Chapter 5. (See Appendix 5.1). Active TB case detection using radiological screening fulfils the MHSA’s requirement that employers establish medical surveillance to detect occupational diseases.

In addition, in terms of the Occupational Diseases in Mines and Works Act (ODMWA) employers are responsible for covering the reasonable cost of treatment for cardiorespiratory TB for a period of 2 years after the date of diagnosis in employees who have worked more than 200 risk shifts. In excess of 90 percent of TB cases that occur among miners meet this definition of TB in terms of the Act. Under ODMWA employers are also responsible for providing examinations for compensation purposes (benefit medical examinations) to in service workers who may be suffering chronic lung damage due to TB.

The ODMWA requires that employers report cases of TB to the Medical Bureau for Occupational Diseases (MBOD). Additionally and separately, the Health Act 63 of 1977 requires that cases of TB be notified to the Department of Health.

In summary, the provisions of the MHSA, ODMWA and Health Acts together imply that mine owners, and by delegation mine medical officers, are responsible for ensuring TB surveillance, treatment and notification, and in cases of possible chronic lung damage, for the assessment of impairment and submission of cases for compensation.
6.2 Epidemiology of TB

6.2.1 TB infection, latency and disease

TB is caused by *Mycobacterium tuberculosis*, a widespread bacterial pathogen capable of prolonged survival within individuals in a state of latency (inactivity). This leads to an important distinction between latent *TB infection*, a state in which people are well, with normal medical investigations except for a positive skin test reaction to injected TB proteins (tuberculin test), and *TB disease*. Individuals with TB disease usually have symptoms such as cough and weight loss, as well as chest x-ray abnormalities and TB bacilli detectable at the site of tissue damage and disease.

The natural history of TB, as illustrated schematically in Figure 6.5, is the key to understanding the rationale of modern control strategies.

![Figure 6.5 Natural history of TB: infection and disease](image)

TB is transmitted by airborne droplets from person to person, and infection can be acquired only from individuals with active pulmonary TB disease. Transmission is most likely to occur from smear-positive TB individuals, that is, individuals whose sputum contains TB bacilli that can be seen microscopically, implying a high concentration of organisms.

Previous TB infection can be detected in most cases by a skin test reaction to injected purified protein derivatives (the basis of tuberculin tests such as the Mantoux and Heaf tests). Skin tests are currently the only available method of diagnosing previous TB infection. These tests can also be positive, however, in response to previous BCG vaccination and infection with TB-like mycobacteria that are widespread in the environment (non-tuberculous mycobacteria).

The risk of carrying latent TB is particularly high in individuals living in high TB transmission settings, as is the case with South African miners.

Latency complicates both the control and treatment of TB (see Figure 6.5). The risk of developing active TB is increased in latently infected individuals compared to that of infection free individuals. Latent TB bacilli are metabolically inactive and relatively insensitive to anti-tuberculous drugs, so that treatment of infection, as distinct from disease, requires prolonged therapy to avoid a high risk of developing active TB.
6.2.2 Relationship between TB infection and TB disease

Studies among individuals who react to tuberculin skin testing and those with a recent “conversion” to reactivity indicate that most such otherwise fit individuals remain well and have no manifestation of disease. Of those who do go on to have disease, over 90 percent will do so within the first 5 years following infection (progressive primary disease). A small excess risk of reactivation of latent infection, however, persists for many years (see Figure 6.5).

Until recently it was believed that once individuals had been infected with *M. tuberculosis* they had lifetime protection against disease from reinfection. Any subsequent disease would thus be due to reactivation of that initial infecting strain. However, it has become apparent that, although previous infection may provide some protection against being reinfected, reinfection does occur. In the early 1990s, reinfection was identified as a cause of recurrent TB in HIV-positive patients, and more recently, as the major cause of recurrent TB in HIV-positive South African gold miners.

The distinction is important because if most adult disease is in fact due to recently acquired infection, reduction of TB transmission in a community will have a rapid and marked impact on the incidence of TB at all ages. A much slower response to improved control measures would be expected if most adult disease were the result of reactivation of latent TB.

6.2.3 Factors determining the incidence of TB in a community

The most important preventable factors in the mining industry influencing TB transmission and progression to TB disease are illustrated in Figure 6.6.

![Figure 6.6 TB, silicosis, migrancy, and HIV](image)

**Figure 6.6** TB, silicosis, migrancy, and HIV

**Exposure to TB**

The intensity of exposure to TB infection is by far the most important factor affecting TB incidence rates in a community. Estimated transmission rates are usually referred to as a percentage, or “annual risk of infection”, representing the percentage of the population that can be expected to be infected with TB during a one-year period. For example, the population of Cape Town has recently been shown to have an unusually high annual risk of infection of greater than 3 percent.

*The risk of TB infection among gold miners has recently been demonstrated to be at least 10 percent per year.*
TB bacilli are spread primarily by inhalation of airborne droplets from cases of active TB. The risk of transmission is thus increased in crowded living conditions, such as have historically characterised the single sex hostels in which black mineworkers have lived while on contract on the mines. (See section 6.9.2).

**Susceptibility to disease following infection**

The other important factor determining TB incidence rates in a community is the percentage of infected individuals who progress to active TB. For otherwise healthy individuals, the lifetime risk of TB disease following TB infection has been estimated at 10 percent.

A number of factors have been identified that greatly increase this risk, of which the most relevant for mining are age at infection (or reinfection), silica exposure and silicosis, and HIV infection. Alcohol is probably also an important risk factor, but is poorly defined and will not be discussed further. The importance of smoking as a risk factor for TB among miners is unknown but is expected to be small in comparison to the other risk factors.

**Age**

TB incidence in gold miners is strongly age-dependent, with a progressive increase in TB disease rates with increasing age. This is likely to be at least partly due to the effect of silica exposure, since age and length of service are closely related to one another and to cumulative silica exposure.

**Silica dust and silicosis**

Silicosis is dealt with in detail in Chapter 5. The strength of the relationship between silicosis and TB has been recently investigated in two cohort studies in gold miners in Welkom, Free State, summarised in Table 6.1. Both Welkom studies provide estimates of the effect on TB of different grades of silicosis, based on individual chest x-ray readings and follow-up.

<table>
<thead>
<tr>
<th>Author / silicosis category</th>
<th>TB Incidence rate ratio*</th>
<th>TB incidence rate (per 100 000 p.a.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cowie 1994 — South Africa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Older non-silicotics</td>
<td>1</td>
<td>1000</td>
</tr>
<tr>
<td>ILO category 1</td>
<td>2.2</td>
<td>2200</td>
</tr>
<tr>
<td>ILO category 2</td>
<td>2.9</td>
<td>2900</td>
</tr>
<tr>
<td>ILO category 3</td>
<td>6.3</td>
<td>6600</td>
</tr>
<tr>
<td>Corbett 2000 — South Africa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Miners with normal X rays</td>
<td>1</td>
<td>700</td>
</tr>
<tr>
<td>ILO grade 0/1</td>
<td>1.8</td>
<td>1400</td>
</tr>
<tr>
<td>ILO grade 1/0</td>
<td>1.8</td>
<td>1400</td>
</tr>
<tr>
<td>ILO grade 1/1</td>
<td>2.6</td>
<td>1900</td>
</tr>
<tr>
<td>ILO grades 2/2 to 3/3</td>
<td>5.3</td>
<td>4000</td>
</tr>
</tbody>
</table>

* Rate ratios quoted from Cowie and Corbett are unadjusted.

ILO: International Labour Organisation Classification of Radiographs of the Pneumoconioses.

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**Overall, TB rates are approximately 3 times greater in silicotics than in non-silicotics. Workforce TB rates are about 3 to 4 times higher in silica-exposed gold miners than in non-silica exposed platinum miners (see Figure 6.2).**

TB incidence in silica-exposed workers is high even for those with normal chest radiographs. This is likely to be due to an increase in susceptibility to TB due to silica, even in the absence of radiographic silicosis. In addition, high silicosis prevalence will have a secondary impact of increasing TB prevalence and transmission, thus increasing TB incidence in the entire mining workforce.
HIV infection

HIV (human immunodeficiency virus) is a retrovirus that infects blood cells (monocytes and CD4+ lymphocytes, referred to as CD4 cells), resulting in a life-long infection that leads to chronic illness characterised by progressive immunodeficiency and the occurrence of opportunistic infections, including TB. It is primarily a sexually transmitted infection.

The immunosuppression that results from HIV infection leads to a greatly increased risk of TB disease following TB infection, both by increasing the rate of reactivation disease, and by increasing susceptibility to rapidly progressive disease following newly acquired infection. The increased susceptibility to TB is apparent from an early stage of HIV infection, and becomes more pronounced with increasing degree of immunosuppression. Because of the high rate of reactivation disease, latent TB infection (indicated by a positive PPD skin test) is a strong risk factor for TB among HIV-positive individuals. As a consequence, overall TB incidence in HIV-positive patients is higher in communities where TB is endemic than in non-endemic areas.

Combined factors

From the above it is apparent that silica exposure and HIV infection, products of the conditions in which the miners live, work and socialise, contribute to high rates of transmission of TB and the risk of disease in those infected.

The combined effect of silicosis and HIV infection, in particular, is an example of interaction or synergistic risk, in which the two risks do not merely add to each other, but multiply each other. This is illustrated in Figure 6.7. The increasing TB incidence associated with increasing grades of silicosis in the absence of HIV infection is represented by the lightly shaded bars. The TB incidence among HIV positive individuals in the absence of silicosis is represented by the horizontal dotted line. The TB incidence among HIV positive silicotics is indicated by the darkly shaded bars, and is clearly more than the sum of the individual incidence rates for all grades of silicosis.

![Figure 6.7 HIV, silicosis and TB incidence](image)

**Figure 6.7 HIV, silicosis and TB incidence**

(per 100 000 person years)

- Both HIV and silicosis are strong TB risk factors
- Comparison with HIV+ve Ugandans shown by dashed line (Whalen et al 1997)
- Silicosis significantly increases risk of TB in HIV+ve miners – risks multiply

The implication of this interaction is that the incidence of HIV related TB on the mines is strongly influenced by silicosis and silica exposure, and control of both dust and HIV infection is required in order to reduce the incidence of TB.
6.3 TB control in the mining industry: background and principles

6.3.1 Current state of TB control

Control of TB implies stable or declining TB case rates.

The increasing TB case notification rates for the entire mining industry reflect widespread loss of TB control.

The increasing TB case rates may be the result of poorly run TB control programmes or failure of current TB control strategies to contain the TB epidemic. Apart from monitoring TB case rates, the effectiveness of a TB control programme can be determined by monitoring TB treatment outcomes, recurrence rates and prevalence of drug resistance. Apart from a few recent publications on TB treatment outcomes among gold miners there is a paucity of such information for the industry.

TB case-fatality rates for miners are low in comparison to those reported for general populations. However the TB case-fatality rate has increased significantly over the past decade, with the case-fatality rate for HIV-positive patients being at least 10 fold higher than HIV-negative TB patients. The proportion of miners that successfully complete TB treatment is high, with treatment interruption and failure occurring uncommonly. The incidence of recurrent TB following a first episode of TB is low among HIV-negative miners, but HIV-positive miners have an almost 4 fold greater risk of developing recurrent TB.

The prevalence of primary and acquired drug resistance has remained stable over the past two decades, suggesting that the TB control programmes have been effective in preventing drug resistance even if failing to control TB incidence itself. There has been no association between drug resistance and HIV infection.

Although treatment outcomes appear to be good, there may be cause for concern regarding adherence to treatment. Two studies of adherence to treatment among gold miners, based on urine testing for drug metabolites, demonstrated a lower adherence to therapy than was expected among both in-patients and outpatients.

Current TB control programmes have two major objectives: early detection and cure of infectious cases and prevention of drug resistance. In the mining industry, these objectives need to part of a comprehensive strategy to prevent TB transmission and prevent disease among those infected. These elements are discussed in more detail below.

6.3.2 Prompt diagnosis and treatment of infectious cases

Patients with pulmonary TB have the potential to infect others until they are cured or die. Infectivity varies greatly: patients who are smear positive are considerably more infectious than those who are smear negative, and other factors, such as strain virulence, may also affect infectivity. Patients with chronic disease are an important source of transmission to other members of their community.

It has been estimated that an average of 10 to 20 people are infected with TB by each smear positive case in typical endemic settings.

Treatment of TB disease, caused by drug sensitive strains, results in a rapid decline in infectivity but treatment has to be continued for prolonged periods to avoid a high risk of relapse to active disease and renewed infectivity.

The TB control strategy currently promoted by the World Health Organisation (WHO) is based on the principle of interrupting TB transmission through (1) the diagnosis of smear positive patients who self present with symptoms (passive case finding), and (2) cure by ensuring completion of TB treatment. This strategy, referred to as directly observed treatment, short course (DOTS) has been estimated to be among the most cost-effective health interventions.
6.3.3 Preventing the emergence of drug resistant TB

Drug resistance can be acquired during the course of TB if patients are treated with a single drug, or with combination therapy if the patient’s strain already has resistance to all but one of the drugs in the combination. Acquired drug resistance can occur due to prescribing errors, patient non-adherence, or if the initial infecting strain is already resistant to some drugs.

Standard DOTS is unable to contain highly resistant strains of TB once they have become established at high prevalence, so that prevention of drug resistance is an essential component of DOTS and TB control programmes. Even in specialist units, treatment outcomes are poor for patients with TB caused by strains resistant to both rifampicin and isoniazid (the standard definition of multidrug resistant TB [MDR TB]). Smear conversion from positive to negative may not be possible, and patients remain infectious to others for prolonged periods. Mortality and relapse rates are high even among HIV-negative patients, and mortality among HIV-positive patients during outbreaks of MDR TB can be extremely high.

DOTS alone does not appear to be able to reduce, or even contain, TB incidence rates when drug resistance rates to rifampicin and isoniazid are already high, HIV/TB co-infection is prevalent, and in institutional settings where TB transmission rates are high. Under such circumstances it is clear that additional measures such as increased case finding or use of preventive therapy will be required to reduce TB incidence.

6.3.4 Comprehensive preventive strategy

The guidelines for a TB control programme in the mining industry are discussed in detail below. In addition to DOTS, there are a number of other interventions that are needed to control TB on the mines. These are summarised in Figure 6.8. These include reduction in silicosis through dust control, reduction of transmission of TB by improvements in housing, preventive therapy against TB in high-risk miners and reduction of the prevalence of HIV infection. These are covered later in the chapter.

![Figure 6.8 Potential interventions to reduce TB incidence](image)

VCT = Voluntary counselling and testing
HAART = Highly active antiretroviral therapy
6.3.5 Guidelines for a TB control programme

National guidelines for TB control were introduced in 1996 and are based on the DOTS strategy. The main elements are:

- Commitment to ensuring sustained TB control activities
- Diagnosis of infectious TB cases based on smear microscopy among those individuals who self present with symptoms, particularly a cough of greater than 3 weeks duration
- Standardised short course anti-TB treatment administered under direct observation
- An uninterrupted supply of drugs
- A standardised recording and reporting system that allows assessment of treatment results

Other key elements of the national TB control programme are:

- Use of combination tablets given 5 days a week to ensure adherence, and to prevent selective omission of tablets that may predispose to the development of resistance
- Use of treatment supporters other than health care professionals for the administration of directly observed therapy

This and the following sections provide recommendations for optimal TB control in the mining industry. These guidelines are evidence based as far as possible or based on best practice in the industry.

The recommendations provided in this chapter are in addition to those provided in the National TB Control Programme guidelines, and are based on the assumption that the mining company has adopted the National TB Control Programme guidelines as the minimum standard required for TB control (see Appendix 6.1 and Guide to Resources). The recommendations are generally in line with guidelines developed by the Chamber of Mines in its document, Practice Standards for the Management of Patients with Pulmonary TB on Mines (Chamber of Mines, 2000).

The rationale for an expanded DOTS programme is that miners represent a group highly susceptible to TB and that current TB control programmes have failed to control TB case rates. Differences between the National and authors’ guidelines are outlined in Appendix 6.1.

6.3.5.1 Objectives of the TB control programme

The overall objectives of the TB control programme should be to:

- Reduce morbidity and mortality attributable to TB
- Prevent development of resistance to anti-TB drugs
- Ensure accurate and ongoing evaluation of the programme performance

Specific objectives should include:

- Bacteriological evaluation of all pulmonary TB cases
- Directly observed therapy for all TB cases
- Cure of at least 85% of new smear positive cases using standard short course chemotherapy

6.3.5.2 The company’s TB policy and procedures

Commitment from senior management and policy makers has been shown to be of the utmost importance in TB control in a workforce. Written policies and procedures should be in place commensurate with the TB risk in the company and the current TB control programme performance. Policies and procedures should be in line with national best practice guidelines and reviewed annually in light of recent programme performance.

The tuberculosis programme and its performance should be a standing item on the agenda of the Health and Safety Committee and its statistics discussed regularly at management meetings.
6.3.5.3 Structure and staffing

A programme manager should be made responsible for the implementation, running, monitoring and evaluation of the TB control programme. Ideally the programme manager should be a medical officer with experience in TB control. The level of staffing of the various services, i.e. medical, nursing, pharmacy, radiology, and laboratory, should be appropriate to the TB case load, so as to be able to meet the objectives of the TB control programme.

The programme manager should establish a TB control programme committee to ensure integration of all aspects of TB control. All of the services listed above should be represented on the committee. The committee should be responsible for programme evaluation and for making the results available to all stakeholders, such as mine management and health and safety committees. The committee should also communicate with the appropriate community TB control programmes in order to share experiences and provide support where required.

6.3.5.4 Passive case detection

Passive detection of TB cases is the reliance on the self-presentation of individuals with symptoms to health care facilities and is the only method of case detection advocated by the national TB guidelines. Delays in self-presentation with symptoms, particularly from cough, may occur, as cough is a common symptom among miners. Significant delays may occur in the diagnosis of TB if health care staff do not have a high index of suspicion for TB and initiate investigations for TB timeously. The following is recommended:

- Promotion of self-presentation of employees through regular educational campaigns or use of peer educators
- Staff training, to heighten awareness of TB so as to minimise delays caused by the health service in the diagnosis of TB among patients who self present

6.3.5.5 Active case detection

Active case finding uses systematic screening with radiography and/or sputum to identify cases of active TB disease that have not been detected on symptoms. Active case finding may be conducted either to estimate TB prevalence, as part of contact tracing in close contacts of patients with active TB, or to intensify control measures in communities or individuals with a high risk of TB. Active case finding is expensive, and requires access to an efficient TB treatment programme in order to be effective. Apart from prevalence estimation, the aims are to limit transmission to others and reduce morbidity by detecting disease at a relatively early stage.

Because of the expense, active case finding other than household contact screening is not recommended as a core part of TB control in most settings. South African miners are one of the few communities in the world in which routine radiography is practised.

The proportion of TB cases detected by the radiological screening programme has declined because miners with HIV associated TB are more likely to self present than be picked up in routine screening. Nevertheless, a substantial number of TB cases are still detected by this programme (Figure 6.9).

Those cases detected by the radiological screening programme are more likely to be HIV-negative, to have limited disease extent, be smear negative and to survive their illness than miners who self-present. The optimal frequency of radiological screening is currently under investigation.

Symptom screening is less effective than radiological screening in detecting undiagnosed cases of active TB among asymptomatic employees. Other methods of active case detection such as sputum screening and weighing have not yet been validated. Contact tracing of hostel roommates is of uncertain benefit, but if resources permit may be used as an additional case finding method.
The following is recommended:

- Active case detection using a radiological screening programme at least annually
- Miniature or large chest radiographs may be used for radiological screening. Miniature chest radiographs are cheaper than standard size chest radiographs but are associated with a significantly higher radiation dose
- Chest radiographs should be read by trained readers
- A quality assurance programme to ensure acceptable quality of chest radiographs, evaluation of the screening programme’s performance and appropriate referral for further investigation of miners with suspected TB
- High-risk groups, such as silicotics, HIV-positive miners and room contacts may be considered for more frequent screening

6.4 Diagnosis of TB

Algorithms for the management of both new and retreatment TB are presented in Appendices 6.2 and 6.3.

Investigations for TB are initiated once a patient is suspected of having TB. Within the mining industry a more extensive TB investigation is warranted. The justification for this is:

- A greater proportion of the TB is smear negative owing to the active radiological screening programme
- Disease from non-tuberculous mycobacteria occurs relatively commonly
- Radiological diagnosis of TB in the presence of silicosis may be more difficult owing to similarities in radiological presentation. However, the microbiological diagnosis of TB remains unaltered in the presence of silicosis

> A diagnosis of TB should be based on strict criteria and a presumptive diagnosis of TB, particularly pulmonary TB, is discouraged. (See Appendices 6.2 and 6.3).

6.4.1 Symptoms

The presence of TB should be suspected in any individual who presents with one or more of the following symptoms:
• Persistent cough of 3 weeks or more
• Sputum production, particularly if blood stained
• Chest pain, shortness of breath
• Loss of appetite and loss of weight
• Night sweats and fever
• Malaise (general fatigue and weakness)

Cough is a common symptom among miners and cough alone is less likely to result in presentation to the health service. Studies have shown that miners are more likely to self present to the health service if they have symptoms such as chest pain, shortness of breath, fever, loss of weight and coughing up blood. Nursing staff should be trained to recognise these symptoms and investigate promptly for TB.

Extrapulmonary TB (TB outside the lungs) occurs relatively commonly in miners. TB may occur as TB pleurisy (infection of the lining of the lungs), pericarditis (infection of the outer heart lining) and lymphadenitis (infection of the lymph glands). Staff should therefore also be familiar with symptoms and signs suggestive of extrapulmonary TB. Central chest pain that is relieved by sitting forward, tachycardia and low blood pressure suggests TB pericarditis. Pleuritic chest pain (sharp pain made worse by deep breathing) is suggestive of TB pleurisy. Lymphadenopathy on the chest x-ray, particularly if asymmetrical in an HIV-positive individual, warrants investigations for TB.

6.4.2 Bacteriology

For miners with suspected TB the following investigations are recommended.

6.4.2.1 Sputum microscopy

All patients with suspected pulmonary TB should have three sputum smears done over 2 days.

• It is recommended that a spot specimen be collected at the clinic and the patient instructed on how to produce and adequate specimen
• The patient should be provided with an empty specimen jar and instructed to collect another sputum sample the next morning and to take it to the clinic at which time another spot specimen should be collected
• The specimen should be clearly labelled and sent to the laboratory with in 24 hours
• All smear results should be obtained within 48 hours

Owing to the high volume of specimens processed by laboratories serving the mining industry, smear examination using an auramine stain and fluorescent microscopy may be used as an alternative to Ziehl-Neelsen staining, without a loss in sensitivity, in order to reduce the time taken to examine a smear. If auramine staining is used, scanty smear positives should be confirmed by Ziehl-Neelsen staining.

6.4.2.2 Sputum culture and organism identification

One sputum specimen should be collected for culture and organism identification. If the Ziehl-Neelsen method is used for smear microscopy a separate specimen will be required for culture. If the auramine method is used then the same sputum sample can be used for culture. Available resources would determine the culture medium used. Culture using Lowenstein Jensen medium is cheap and reliable but is rarely offered by private laboratories. Alternative culturing systems provide reliable results more rapidly but are more expensive. Each TB programme should review with their TB laboratory the most appropriate TB culture to use.

All positive culture should have the organism identified. The reason for this is that NTM disease occurs commonly among miners, is indistinguishable clinically from TB and is treated differently from TB. Failure to diagnose NTM disease would result in inappropriate therapy, progression of disease and worse treatment outcomes. This is discussed further in the last section of the chapter.
6.4.2.3 TB drug susceptibility testing

Routine drug susceptibility testing is not recommended. The same indications, as in the National TB guidelines, are used for drug susceptibility testing. These are:

- Failure of new smear positive cases to convert their sputum smears from positive to negative after two months of TB treatment
- All retreatment cases at diagnosis (See section 3.2.7 for definition of retreatment cases)

In addition, patients who have had previous TB preventive therapy who are diagnosed with TB should have drug susceptibility testing requested at the time of TB diagnosis.

Ideally, drug susceptibility testing should be done for the primary anti-TB drugs, i.e., isoniazid, rifampicin, ethambutol and streptomycin. Testing against pyrazinamide can be done using specific liquid culture techniques such as Bactec. Some laboratories offer a testing algorithm, starting with tests against rifampicin or rifampicin and isoniazid, and test against other drugs only if there is resistance to these two drugs, in order to reduce costs. Susceptibility testing against the second line drugs should be done only if there is multiple drug resistance, particularly against isoniazid and rifampicin.

6.4.2.4 Laboratory quality assurance

The programme manager should ensure that the TB laboratory has both internal and external quality assurance programmes linked to an accredited TB reference laboratory. The results of the quality assurance programme should be made available to the programme manager on a quarterly basis for review.

6.4.3 Chest radiography

A chest radiograph is indicated in patients with suspected pulmonary TB. The justification for this is:

- Almost half of all pulmonary TB cases are detected by the miniature radiographic screening programme and would require confirmation with a large plate chest x-ray
- Improvement in the chest radiograph following TB treatment provides supportive evidence of a diagnosis of TB in patients with smear negative, pleural and pericardial TB
- Non-tuberculous chest pathology occurs commonly among miners
- A chest radiograph is required at diagnosis and following completion of treatment for notification to and compensation assessment by the MBOD

The diagnosis of pulmonary TB should not be based on the chest radiograph alone.

It should also be noted that the radiographic pictures of silicosis and TB may be similar. TB should be suspected in silicotics who become symptomatic or develop new or changing radiological lesions (see 5.2.3).

The chest radiographic picture of TB in HIV-positive patients is often atypical. A diagnosis of TB therefore should not be excluded in HIV-positive patients on the basis of the chest radiograph alone.

6.4.4 Criteria for diagnosis and classification of TB

6.4.4.1 Diagnostic criteria

The following criteria are recommended for diagnosis of pulmonary TB.

- 2 positive sputum smears
- 1 positive sputum smear and a compatible clinical and / or radiological picture
- A positive sputum culture
- 3 negative sputum smears, a compatible clinical and / or radiological picture and no response to a course of broad-spectrum antibiotics. Response to TB treatment provides supportive evidence for the diagnosis of TB

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Patients who do not meet these criteria should not be treated for TB but should be investigated for other conditions.

6.4.4.2 Classification according to site of disease

TB cases should be classified as pulmonary or extrapulmonary TB. Patients who have both extrapulmonary and pulmonary TB should always be classified as pulmonary TB.

Patients diagnosed with pulmonary TB should be classified as:

- Smear positive if 1 or more smears are positive, including scanty positives
- Smear negative if 3 sputum smears are negative

Classifying TB cases as smear positive or negative is required to create cohorts to determine treatment outcomes.

6.4.5 Clinical and radiological features of HIV associated TB

In addition to increasing the risk of disease, HIV infection alters the clinical and radiological presentation of TB. Most, but not all, case series have shown that a lower proportion of HIV-positive TB patients have smear positive disease, and that a higher proportion have extrapulmonary and disseminated disease than do HIV-negative TB patients.

HIV infection also affects the radiological manifestations of pulmonary TB, so that patients with HIV-associated TB more commonly have hilar adenopathy and/or pleural effusions and a lower prevalence of cavitation than HIV-negative TB patients. The impact of HIV infection on clinical and radiological features is related to the degree of immunosuppression, being more marked in those with low CD4+ T-lymphocyte counts (CD4 counts). The lobar distribution of radiological abnormalities also differs between HIV-positive and HIV-negative TB patients. TB in HIV-negative adults usually has a “reactivation” pattern, with the disease process starting either in one of the apical segments, or in one of the apical segments of the lower lobes. A “progressive primary” type of radiological appearance with lobar consolidation and hilar adenopathy rather than cavitation is much more common in HIV-positive than HIV-negative adults, and is associated with lower CD4 counts and more advanced immunosuppression.

Mortality during TB treatment is higher in HIV-positive than HIV-negative patients but, this seems to be mainly due to a high incidence of other opportunistic infections in patients with HIV-associated TB. A diagnosis of HIV-associated TB has been associated with an increased mortality rate when TB patients are compared to other HIV-positive individuals who have similar CD4 counts but do not have TB. Among HIV-positive TB patients, survival is shorter in those with extrapulmonary and disseminated disease than those with pulmonary disease alone, and is adversely affected by a low CD4 count.

In non-mining patients, both the risk of treatment failure and recurrence rates after treatment with rifampicin-based regimens are similar for HIV-positive and HIV-negative patients. In contrast, two studies in South African miners have shown a significantly increased rate of recurrence in HIV-positive compared to HIV-negative miners following treatment for TB. In such a high transmission setting, there is now good justification for using secondary isoniazid prophylaxis after TB treatment (see 6.8.3).

6.5 Treatment of TB

6.5.1 Case definitions

Treatment regimens vary according to treatment category and site of disease. The following case definitions should be used for treatment category.
• New cases are patients who have not previously been treated for TB for more than one month
• Retreatment cases are patients who have previously had more than 1 month of TB treatment and now require retreatment. Retreatment for TB may be required for relapse following previous cure, interruption of treatment or treatment failure

6.5.2 Treatment regimens
The treatment regimens for new and retreatment cases recommended by the National TB Control Programme should be used. All treatment should be given as a fixed dose combination treatment. Single drugs should never be used unless indicated, e.g. individualising treatment for multi-drug resistant TB or following a severe adverse drug reaction. Some patients with severe forms of extra-pulmonary TB (meningitis, miliary TB, pericarditis, peritonitis, bilateral or extensive pleural effusions, spinal or genito-urinary TB) may require prolongation of the continuation phase of TB treatment from 4 months to 7 months.

6.5.3 In-patient and ambulatory care
All patients that are infectious (smear positive) or clinically ill should be admitted to a TB facility for initial care. Once patients are clinically well and uninfectious, i.e., converted from sputum smear positive to negative, they may be discharged from the in-patient facility.

Patients may return to work on treatment if clinically fit to do so.

These individuals are uninfectious and would not pose a threat to other employees. Cure rates of miners who return to work while taking TB treatment are good. The WHO supports the return to work of TB patients as soon as possible. This also applies to underground mining work.

6.5.4 Adherence to therapy
• All treatment must be administered under direct observation
• Trained treatment supporters, other than health care workers, may by used
• Adherence to therapy can further be improved if the directly observed therapy is provided in a patient centred manner by providing TB treatment at a time and place convenient to the patient by treatment supporters who are sympathetic to the cultural and economic needs of the patient
• Treatment dispensed under directly observed therapy should be recorded on a TB treatment record card
• The TB record cards should be reviewed at least weekly. Patients who have missed treatment should be traced and encouraged to continue treatment

6.5.5 Missed treatment
During the intensive phase: if no more than 10 doses were missed these should be added onto the end of the intensive phase. If more than 10 doses were missed then the patient should be registered and managed as a standard retreatment case.

During the continuation phase: if more than 40 doses were missed and the patient is sputum smear negative then the continuation phase should be completed. If the patient is sputum smear positive the patient should be commenced on a retreatment regimen.

6.5.6 Monitoring response to treatment
Monitoring response to treatment among patients with new and retreatment TB is outlined in appendices 6.2 and 6.3 respectively.

6.5.6.1 New cases
Two sputum smears should be examined at the end of the intensive phase (after 2 months) and in the last month of treatment. If smears are negative at the end of 2 months of treatment the patient can be
changed to the continuation phase of treatment. If one or more smears are positive then an additional month of intensive phase treatment should be given. Sputum smears should then be repeated at the end of the third month of treatment and the patient changed to the continuation phase of treatment. If smears are positive then a specimen should be obtained for drug susceptibility testing. Treatment should not be altered unless resistance to anti TB drugs is demonstrated.

6.5.6.2 Retreatment cases

Two sputum smears should be examined at the end of the intensive phase (after 3 months) and in the last month of therapy. If the sputum smears are positive at the end of the intensive phase and if drug susceptibility testing was not done at diagnosis or the culture was contaminated then a repeat sputum specimen should be obtained for drug susceptibility testing. Treatment should only be altered according to drug susceptibility testing.

6.5.7 Treatment outcomes

6.5.7.1 Case definitions

The following case definitions are used for treatment outcomes in accordance with the National TB Control Programme guidelines.

Cure The patient is smear negative within the last month of treatment and on at least one previous occasion.

Treatment completion The patient completed treatment without bacteriological confirmation of cure.

Treatment failure The patient has positive sputum smears or cultures within the last month of treatment.

Died The patient died for any reason during the course of treatment.

Treatment interrupted The patient interrupted treatment after a month of treatment for more than 10 days during the intensive phase of treatment or more than 40 days during the continuation phase of treatment.

Transfer out The patient was transferred out to another clinic for treatment.

6.5.7.2 Cohort analysis

Response to treatment is evaluated by creating cohorts of smear positive pulmonary TB cases over a specified period of time. Treatment outcomes are defined according to the above case definitions and expressed as a percentage of total known outcomes. Confirmed cases of NTM disease should be excluded from the cohort of patients when determining treatment outcomes.

The National TB Control Programme register should be used for reporting treatment outcomes. Evaluation of treatment outcomes should be done separately for new and retreatment smear positive pulmonary TB cases. If a significant proportion of patients are transferred out on treatment due to retrenchment the cohort analysis should be repeated after excluding these patients from the cohort in order to obtain an accurate cure rate of miners treated in service.

The following treatment outcome targets are recommended for smear positive pulmonary TB cases that were not transferred out while on treatment.

- Cure > 85% in accordance with WHO guidelines
- Treatment failure <5%
- Treatment interruption <5%
6.5.8 Special treatment situations

6.5.8.1 Smear negative disease

The first priority of any TB control programme is to stop the transmission of TB by curing new infectious smear positive patients. However, smear negative disease occurs commonly among miners owing to the earlier detection of TB by the radiological screening programme. The treatment regimes are the same as for smear positive cases. The National TB Control Programme does not require documentation of treatment outcomes for smear negative pulmonary TB cases. However, the mining industry is encouraged to determine treatment outcomes for smear negative TB cases. The monitoring of response to therapy by repeating sputum smear examination at the end of the intensive phase and end of treatment is not required. For these cases cure can be defined as a good clinical response to treatment and the completion of treatment.

6.5.8.2 HIV associated TB

HIV testing

As more than 50% of all TB in the industry is HIV associated, voluntary HIV testing should be offered routinely to all miners with suspected TB. Voluntary HIV testing should only be undertaken if individual pre and post test counselling are provided by trained counsellors, with consent and if confidentiality of results can be assured.

Voluntary counselling and testing have a number of benefits for the HIV positive patient. The patient has the opportunity to receive emotional support, to be able to plan for the future and to protect sexual partners. Health care providers can offer preventive therapy (and HAART when it becomes available), enabling reduction of opportunistic infections while on TB treatment and of recurrence of TB once completed.

Treatment of HIV positive cases of TB

The same treatment regimens are used as for HIV-negative individuals. The case fatality rate is higher among HIV-positive compared to HIV-negative patients. Cure rates among HIV-positive TB patients who survive to the end of treatment are similar to those in HIV-negative TB patients.

Morbidity and mortality due to opportunistic infections occur commonly among HIV-positive patients. Use of cotrimoxazole in HIV-positive TB patients has been associated with reduced morbidity and mortality from opportunistic infections, particularly due to bacterial infections. Cotrimoxazole chemoprophylaxis may be of limited value among HIV-positive miners owing to a high level of cotrimoxazole resistance among commonly occurring bacterial pathogens and a high prevalence of opportunistic infections that are not preventable with cotrimoxazole, such as cryptococcal disease.

6.5.8.3 Silicotuberculosis

The same treatment regimens as for TB are used to treat silicotuberculosis, and similar outcomes can be expected among those who survive to completion of treatment. However, silicotuberculosis may be associated with an increased mortality compared to TB patients without silicosis.

6.5.8.4 Extrapulmonary TB

Pleural and pericardial TB are the commonest forms of extrapulmonary TB among miners. The diagnosis of pleural TB should be confirmed by histology or bacteriology. Sputum microscopy and culture should be requested as a significant number of cases may have positive smears. Culture of the pleural fluid or tissue has a high diagnostic yield particularly in HIV-positive individuals.

A diagnosis of TB pericarditis should be presumptive, based on the presence of a fibrinous pericardial effusion on echocardiography in the absence of another cause. Sputum microscopy and culture should also be requested. Response to therapy provides supportive evidence of the diagnosis. The treatment of pleural and pericardial TB is the same as for other TB cases.
### 6.5.8.5 Multi-drug resistant TB

Multi-drug resistant TB is defined as resistance of *M. tuberculosis* to isoniazid and rifampicin with or without resistance to other TB drugs.

In order to minimise the risk of drug resistance, initial therapy should follow established guidelines, and should be with 4 drugs, preferably given as combination tablets, or 5 drugs if the patient has had TB treatment before.

The treatment of multi-drug resistant TB should only be undertaken in specialised centres by experienced clinicians. It is therefore strongly recommended that unless facilities for in-patient isolation exist and experienced clinicians supervise treatment, that these patients be referred to an appropriate centre.

Once MDR TB is diagnosed, the patient should be isolated and the regimen changed to include at least 2, and preferably 3 or 4 drugs to which the isolate is sensitive. Single new drugs should never be added to a failing regimen: it is better to wait for the laboratory sensitivity patterns before making changes. Surgery to remove or close cavities should be considered if second-line medical therapy fails.


### 6.5.9 Notification to the Department of Health

Notification of TB cases at diagnosis (new and retreatment), or death from confirmed or suspected TB, is required to be sent to the Department of Health (Form GW17/5).

Quarterly reports for case rates and treatment outcomes should be submitted to the local health authority (GW 10/16).

### 6.6 Occupational issues

#### 6.6.1 Reporting

All cases of suspected or confirmed cardio-respiratory TB in employees who have performed 200 or more risk shifts and who have developed TB within one year of performing such work, must be reported to the Medical Bureau for Occupational Disease (MBOD) at the time of diagnosis. Risk shifts are ill defined in the ODMWA but generally refer to silica dust exposure. Cardio-respiratory TB includes pulmonary, pleural, pericardial and miliary TB.

In addition, it is recommended that the following be reported to mine managers and mine health and safety committees on a quarterly basis:

- The number and proportion of employees with medical incapacitation (i.e., unable to perform their particular job) and fatalities due to cardio-respiratory TB
- The number and proportion of lost shifts due to cardio-respiratory TB
- The number of cases of cardio-respiratory TB submitted to the MBOD alone or in combination with other occupational lung diseases
- The number of cases of cardio-respiratory TB, alone or in combination with other occupational lung diseases, certified by the MBOD, and the degree of impairment

Data from these reports can be incorporated into the annual medical report required by the MHSA.

#### 6.6.2 Sick leave and compensation

Miners on sick leave for TB receive their normal salary for 42 days if they have worked for the company for one year, and up to 82 days if they have worked for more than 2 years. (Certain Chamber of Mines companies have had agreements with employee groups for employees to receive 100% payment for six months while on sick leave for an occupational disease or injury.)
Most miners with cardio-respiratory TB do not suffer loss of earnings as few exceed their sick leave allowance. However, under the ODMWA, employees who suffer loss of earnings as a result of being off work with cardio-respiratory TB, are eligible for compensation for loss of earnings to the value of 75% of the earnings lost for a maximum of 6 months. These monies are payable to the employee retrospectively by the Compensation Commissioner for Occupational Diseases.

It is the medical practitioner’s duty to ensure that all cases of cardio-respiratory TB are reported to the MBOD, even if they have previously been compensated for first-degree disability for occupational lung disease. (See Chapter 14). (Once a second-degree award has been paid, no further compensation in any form is due, and the certificate of fitness to perform risk work should be withdrawn).

Miners who successfully complete treatment for cardio-respiratory TB must undergo a benefit medical examination under ODMWA one year after completion of TB treatment. Those patients who are considered to fall into a compensable category should have a full benefit examination, which includes a medical report, a current full sized chest radiograph and lung function tests, and the case forwarded to the MBOD for assessment for compensation. The responsibility for notification and assessment of impairment rests with the attending medical practitioner, usually the mine medical officer. See Chapter 14 for further details on compensation.

6.6.3 Leave

There are no current guidelines or legislation regarding annual or other non-sick leave while on TB treatment. Owing to the magnitude of the TB problem in mines and the importance of ensuring smear conversion and cure we would strongly recommend that miners be advised not to take leave during the intensive phase of TB treatment, other than for compassionate reasons. Similarly miners should be advised to defer leave while on the continuation phase of TB treatment other than for compassionate reasons and for renewal of contract.

6.6.4 Termination of employment contract

| Under ODMWA, employers are responsible for covering the reasonable cost of treatment for cardio-respiratory TB for a period of 2 years after the date of diagnosis in current employees who have worked more than 200 risk shifts. If the employee leaves the service of the mining company, the state becomes responsible for TB treatment and costs. |

Where possible, termination of the contract of employment of miners while on the intensive phase of treatment should be avoided.

Miners whose contract of employment is terminated, for whatever reason, while on TB treatment should undergo an exit examination prior to leaving. The patient should be classified as a transfer out in the TB register and a referral letter given to the patient detailing how the TB diagnosis was made, current treatment and if the patient has completed the intensive phase, whether smear conversion has been documented. Sufficient TB treatment should be provided to the patient to tide the patient over until the care is taken over by another TB clinic. Arrangements should be made for a follow up benefit examination to be done one year following completion of treatment.

Cardio-respiratory TB is considered an occupational disease for up to 12 months after leaving risk work. Former miners who develop cardio-respiratory TB during this time and who have worked more than 200 risk shifts are eligible for a benefit examination and submission for compensation (See Chapter 14).

6.6.5 Nosocomial ("hospital acquired") TB

Transmission of TB may occur within health care facilities to patients and health care workers alike. Policies and procedures that ensure a safe environment for health care workers and patient should be in place. Measures to reduce the nosocomial transmission of TB include administrative and environmental controls and personal respiratory protection.
Administrative controls should take precedence over all other measures to reduce nosocomial transmission of TB. Without effective administrative controls, environmental and personal respiratory protection are of limited value. Administrative controls should include policies and procedures for the identification and isolation of patients with suspected infectious TB, both as out- and in-patients, and early diagnosis and treatment. Known infectious TB patients leaving isolation areas for further investigations should be required to wear a disposable surgical mask.

Environmental controls aim to reduce the concentration of infectious droplet nuclei in high-risk areas in which health care workers or patients may be exposed. Natural ventilation should be maximised by keeping windows open and doors closed. Exhaust ventilation systems may be used in isolation rooms or wards to produce negative pressure that minimises the escape of contaminated air into hallways and surrounding areas. Patients should be encouraged to cough into tissues. Ultraviolet irradiation, although effective, requires proper installation and careful ongoing maintenance.

Personal respiratory protection masks are expensive and not generally available. The use of such masks by health care workers may be considered when performing cough-inducing procedures or when caring for MDR TB patients.

HIV-positive health care workers are at increased risk of acquiring TB. They should thus be offered jobs in low TB risk areas (such as surgical and orthopaedic wards and clinics), screened frequently for TB and offered isoniazid preventive therapy.

6.7 TB control programme evaluation

Each mining company should evaluate its TB control programme performance annually. The TB control programme can be evaluated by monitoring trends for case rates, treatment outcomes, relapse rates and prevalence of drug resistance.

If treatment outcome targets are not being met, the TB control programme should be audited to determine possible reasons for not meeting these targets.

Process measures that should be audited include:

- Proportion of TB cases treated under DOTS
- Adherence to treatment determined by reviewing treatment record cards
- Bacteriological coverage of pulmonary cases started on treatment
- Proportion of smear positive cases that have sputum collected at the end of the intensive phase and end of treatment

The effectiveness of the TB control programme can further be determined by the relapse rate among cohorts of patients with new smear positive pulmonary TB. The relapse rate should be < 5% over 2 years for HIV-negative patients.

The prevalence of drug resistance, particularly primary drug resistance, is a good indicator of the overall success of the TB control programme. Surveillance of drug resistance should be conducted every 3 to 5 years.

6.8 Other interventions to reduce the incidence of TB

Potential interventions are summarised in Figure 6.8.

6.8.1 Dust control

As most of the workforce is occupationally exposed to dust and is at risk of developing silicosis, improved dust control is of critical importance in improving TB control.

Strategies to improve dust control are discussed in Chapter 4. However, it should be borne in mind that even if sustained dust exposures well below the occupational exposure limit were achieved with
immediate effect, the prevalence of silicosis would decline only over decades as employees leave the industry. As a result, the impact of improved dust control on TB case rates would become evident only in the long term.

6.8.2 Housing

The 1995 Report of the Commission of Enquiry into Occupational Health and Safety in the Mining Industry, known as the Leon Commission, identified unacceptable housing conditions on some mines. They noted the long historical association between mining, the migrant labour system and single sex hostels and the likely negative effects on health of this type of mine accommodation.

Modelling of the factors associated with TB incidence now being done for SIMRAC indicates a lower risk for TB among miners in non-hostel single partner or family accommodation.

The conditions needed for adequate respiratory health generally, including reduction of the risk of TB transmission, include uncrowded sleeping and living quarters, good ventilation and the minimum of pollution from indoor fuels. The upgrading of accommodation on mines, as recommended by the Leon Commission, should thus be regarded as part of a TB control strategy.

6.8.3 Isoniazid preventive therapy (IPT) for TB

Preventive therapy is an under-utilised, but highly effective, method of reducing an individual’s risk of TB by eradicating recently acquired or latent TB infection (Figure 6.5). Isoniazid has been used since the 1950s to reduce the risk of active TB in asymptomatic individuals shown to be infected with *M. tuberculosis* on the basis of skin test reactivity.

When taken for between 6 and 12 months, IPT has been shown to significantly reduce the subsequent incidence of TB in a variety of high risk groups, including children with recent skin test conversions, adults living in or emigrating from high TB prevalence areas, individuals with radiological evidence of self healed TB, silicotics, and HIV-positive individuals.

Six months of IPT has been the recommended standard, considered to maximise cost-effectiveness. This recommendation has recently been changed to 9 months in the US.

6.8.3.1 IPT and HIV infection

A clear benefit in reduced TB incidence in the short term has been shown when six months of IPT is taken by tuberculin skin test (PPD) positive individuals who are also HIV-infected. The long-term effectiveness is less certain, since incidence begins to rises again soon after the end of treatment. It is also not yet clear to what extent medium term mortality is reduced. The benefit of treating individuals who are PPD negative or too immunosuppressed to make any skin response (anergic) is smaller, and was not significant in a recent meta-analysis. Trials comparing 6 months of IPT with indefinite IPT are underway, but no firm recommendations can be made until results are available.

6.8.3.2 Preventive therapy for silicotics

There have been two placebo-controlled trials of preventive therapy in presumed HIV-negative silicotics; one in South African miners and one in granite workers living in Hong Kong.

The Hong Kong study compared placebo with 6 months of isoniazid, 3 months of rifampicin alone and 3 months of isoniazid plus rifampicin. Each of the three active regimens led to a significant reduction in TB incidence compared to placebo, and was of equivalent efficacy (estimated reduction in TB incidence of 48%, 63% and 41% respectively at 5 years). The South African trial compared 3 months of rifampicin, isoniazid and pyrazinamide with placebo and found no significant difference, with an annual TB incidence in the order of 1.5 per 100 person-years during the 4 years of follow-up in both groups. The lack of efficacy was probably the result of outside reinfection.

The current American Thoracic Society (ATS) guidelines recommend that silicotics be offered 12 months of isoniazid therapy.
6.8.3.3 Isoniazid toxicity and resistance

The serious side effects of isoniazid are peripheral neuropathy (nerve damage), which can be treated or prevented by the vitamin pyridoxine, and hepatitis (liver damage), which is occasionally severe and fatal.

Risk factors for isoniazid-induced hepatitis include older age and heavy alcohol consumption. The risk of mild biochemical hepatitis is under 1%. The fatality rate has been estimated to be about 1 in 10 000, or even below. Studies of IPT in HIV-positive Africans have found clinically significant hepatitis to be rare. However, hepatitis remains a concern and IPT should only be offered to individuals at high risk of TB.

A further potential hazard of IPT is that subjects with minimally symptomatic active TB may be inadvertently given isoniazid monotherapy, creating a risk of inducing isoniazid resistance. This appears to be a rare event in practice, provided that patients are screened to exclude active TB before starting IPT. Screening can be based on history, examination and chest radiography, with bacteriological examination of sputum only when one or more abnormalities are found.

6.8.3.4 Adherence and alternative short course combination regimens

Adherence to preventive therapy has been shown to be poor in all studies where this question has been specifically addressed. Because adherence with shorter regimens is better, alternative short course preventive therapy regimens (i.e. for 2 to 3 months) based on rifampicin plus one or two additional drugs have been tested. Short-term efficacy has generally been shown to be equivalent to that of 6 months of isoniazid, although most studies have not been large enough to detect all but a major difference in effectiveness.

Alternative regimens are discussed in the American Thoracic Society/Centres for Disease Control and Prevention recommendations (See “Targeted tuberculin testing and treatment of latent tuberculosis infection” under Guide to resources).

6.8.3.5 Recommendations for preventive therapy in miners

See Appendix 6.4 for summary recommendations.

Since miners can receive therapy under directly observed conditions, and because of the concerns about introducing rifampicin resistance, the opinion of the authors is that isoniazid prophylaxis should be offered to all HIV-positive and high risk HIV-negative miners.

High-risk HIV-negative miners include those with radiological silicosis. Other miners with an intermediate risk include older or heavily dust-exposed men, and those with lesser risk factors such as diabetics or patients taking corticosteroid therapy.

IPT should be used for at least 6, and preferably the 9, months duration considered standard care for miners in a high-risk group. Given the high TB transmission rates, the likelihood of anergy, and high likely benefit from IPT, a tuberculin test is not part of the recommended work-up for high-risk miners, summarised in Appendix 6.4.

Tuberculin testing of HIV-negative men at intermediate risk should, however, be carried out, and IPT limited to those with reactions of 10 mm or more using the standard intradermal Mantoux technique and 5 units of PPD equivalent.

Patients receiving IPT should receive counselling on side-effects and then be followed-up monthly with clinical assessment for symptoms or signs of hepatotoxicity, peripheral neuropathy or TB. At each visit patients should be instructed to interrupt treatment and present to the health care service immediately following the onset of symptoms of potential toxicity, such as nausea, vomiting, dark urine or jaundice.

Pyridoxine should be offered to those with symptoms of neuropathy. IPT should be terminated if the patients develop hepatitis or active TB.
6.8.4 HIV prevention and care

HIV prevention needs to be seen as an essential component of TB control (See Figure 6.8). National control programmes in high HIV prevalence areas are moving towards an integrated approach to the control of HIV and TB.

证据显示，HIV预防计划可以对行为产生重大影响，HIV发病率和 prevalence。Evidence from individual trials and whole countries have shown that HIV prevention programmes can have a major impact on behaviour, HIV incidence and prevalence.

Also included in Figure 6.8 is treatment of HIV itself. The use of highly active antiretroviral therapy (HAART) has been shown to reduce the incidence of HIV-associated TB by restoring immune function and so reducing susceptibility to disease following infection. At the time of writing, HAART is not being offered to HIV-positive employees by mining companies in South Africa. However, some companies are investigating the provision of anti-retroviral therapy to their employees, and a number of antiretroviral therapy studies are currently in the planning phase. Such studies will test the feasibility of introducing such treatment as well as questions such as when to initiate treatment, the role of viral load monitoring and the best method of delivering the treatment to ensure a high level of adherence.

Widespread uptake of voluntary counselling and testing (VCT), linked to targeted education and counselling for those found to be HIV-negative, and IPT and HAART for those found to be HIV-positive, offer the best potential for rapidly reversing the current epidemic of HIV-associated TB.

As HIV infection is currently the most powerful risk factor for TB within the workforce, intensification of HIV prevention programmes is urgently required. Concerns among workers regarding confidentiality and the judgmental attitude of health personnel appear to be a major barrier to their seeking care.

An HIV prevention programme needs many parts, such as health education, syndromic STD management, partner notification, peer education, community interventions and voluntary counselling and testing.

6.8.4.1 Syndromic management of sexually transmitted diseases (STD)

Syndromic management is the management of STDs according to the presenting clinical syndrome, e.g., ulcers or discharge, rather than according to the specific cause of the disease, e.g., syphilis or gonorrhoea. Although syndromic STD management has been available from mine health services, the use of this service by miners has been poor. Use may be improved through education and training of caregivers, with a specific emphasis on the importance of a non-judgemental and confidential approach to STD management. Partner notification should be an integral part of the STD care provided by the mine health service. Syndromic STD management should be in line with national guidelines (see Guide to Resources).

6.8.4.2 Voluntary counselling and testing

The vast majority of HIV-positive individuals are unaware of their HIV status. As a result they may continue to transmit HIV infection to sexual partners and would lose the opportunity to receive preventive or antiretroviral therapy if available.

HIV-negative individuals who are unaware of their status may continue to be vulnerable to HIV infection through continued high-risk sexual behaviour. HIV-negative individuals identified through voluntary counselling and testing can be persuaded through education to reduce their risk of acquiring HIV infection.

HIV-positive individuals should be counselled in order to promote safe sex and reduce the risk of HIV transmission to both casual and stable sexual partners. Support groups (i.e., post-test clubs) for individuals who have had VCT can provide counselling and support to participants.
6.8.4.3 Peer educators

The use of workplace peer educators should be extended as they provide education widely and direct individuals into HIV prevention or care programmes. Continued education of men by peer educators is vital given the control men typically exercise over sexual relationships. Potential peer educators can be recruited for training through post-test clubs.

6.8.4.4 Community interventions

It is important that the mining industry become involved in community interventions, in collaboration with state, community and other non-governmental organisations, donor agencies and broader industry. Community interventions may be general, targeted or both.

Targeted interventions focus on people at high risk, which includes commercial sex workers and their clients, and individuals with multiple partners or STDs. General interventions focus on the community at large and include education, particularly in schools, STD programmes and social development programmes. In communities with mature HIV epidemics, transmission of HIV infection occurs among high-risk groups and the larger community. In this setting strategies aimed at both high risk groups and the general community will be required in order to have a significant impact on the HIV epidemic.

6.8.4.5 Integrated HIV prevention, care and support

HIV positive individuals and their families require sustained psychosocial support and medical care in order to cope with the burden of their illness. Uptake of VCT is improved when offered as part of a comprehensive package of prevention and care. Individuals are more likely to present for voluntary HIV testing if they have access to preventive therapy, antiretroviral therapy and palliative care and treatment. The package of prevention and care, outlined below, can be tailored to available resources and finances, but should include as a minimum all elements of the essential package (See Table 6.2.)

<table>
<thead>
<tr>
<th>Table 6.2 Integrated HIV prevention, care and support, as defined by UNAIDS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Essential package</strong></td>
</tr>
<tr>
<td>• Syndromic STD care</td>
</tr>
<tr>
<td>• Voluntary HIV counselling and testing</td>
</tr>
<tr>
<td>• Psychosocial support for HIV-positive individuals and their families</td>
</tr>
<tr>
<td>• TB treatment</td>
</tr>
<tr>
<td>• Treatment of common conditions e.g., pneumonia and thrush</td>
</tr>
<tr>
<td>• Prevention of opportunistic infection with cotrimoxazole among symptomatic individuals</td>
</tr>
<tr>
<td>• Cooperation with community activities that reduce the impact of HIV infection</td>
</tr>
<tr>
<td><strong>Intermediate package</strong></td>
</tr>
<tr>
<td>All of the above PLUS one or more of the following:</td>
</tr>
<tr>
<td>• Active case-detection of TB</td>
</tr>
<tr>
<td>• TB preventive therapy</td>
</tr>
<tr>
<td>• Treatment of systemic antifungal infections</td>
</tr>
<tr>
<td>• Treatment of Kaposi sarcoma with essential drugs</td>
</tr>
<tr>
<td>• Treatment of extensive herpes with acyclovir</td>
</tr>
<tr>
<td>• Funding community interventions that reduce the impact of HIV infection</td>
</tr>
<tr>
<td><strong>Advanced package</strong></td>
</tr>
<tr>
<td>All of the above PLUS:</td>
</tr>
<tr>
<td>• Highly active antiretroviral therapy</td>
</tr>
<tr>
<td>• Diagnosis and treatment of opportunistic infections and HIV associated cancers that are difficult to diagnose and/or treat</td>
</tr>
<tr>
<td>• Targeted and general community interventions that reduce the social and economic impact of HIV infection, e.g. providing a sexual health service to woman at high risk of acquiring STDs</td>
</tr>
</tbody>
</table>

UNAIDS: United Nations AIDS organisation
6.8.5 Vaccination

BCG remains the only TB vaccine available and the world’s most widely used vaccine, despite widely discrepant results from studies of efficacy. While protection against progressive primary forms of TB, such as childhood meningitis, is good, protection against reactivation disease appears to be incomplete, varies between populations and wanes with passing time since vaccination. HIV infection and silica exposure are considered to be relative contraindications to BCG vaccination.

*BCG revaccination has no place in prevention of endemic TB in adult populations such as South African miners.*

A vaccine against HIV is under intensive research, and trials in South Africa and elsewhere are being planned.

6.9 Nontuberculous mycobacterial (NTM) disease

6.9.1 Causes and incidence of NTM disease

NTM disease is included in this chapter because it is an important and growing problem in the South African mining industry. The disease resembles TB, is caused by closely related mycobacteria, and is relatively common among gold miners because it shares occupational risk factors with TB such as silica dust exposure, silicosis and past TB.

Estimates of NTM disease incidence vary from 1.8 per 100 000 per year in the US general population to approximately 100 per 100 000 per year among South African mineworkers. The most common NTM species in miners is *M. kansasii*, one of the most pathogenic NTM species.

NTM species are free-living environmental organisms that vary widely in their pathogenic potential. The more common NTM species are listed, together with an indication of their likely clinical significance in Appendix 6.5. The main forms of NTM disease in adults are:

- Pulmonary disease resembling TB
- Soft tissue infections following trauma or surgery
- Disseminated disease associated with immunosuppression, including HIV infection

The differences between NTM organisms and TB can be summarised as follows:

- NTM infection and disease do not appear to be the result of person-to-person transmission. Instead, infection is thought to be environmentally acquired
- NTM disease occurs with a much lower incidence than TB in most populations
- NTM disease diagnosis and treatment are more complex than for TB. Ideal treatment regimens and durations have not been established by clinical trials, and there is considerable disagreement between experts on both topics. Opinion on appropriate diagnostic criteria also varies
- Many of the NTM species have intrinsic drug resistance: all are resistant to pyrazinamide, and *M. kansasii* has resistance to isoniazid

With the exception of HIV-associated disease, NTM disease incidence is extremely low considering the widespread environmental exposure to these organisms. In keeping with lower pathogenicity, host factors appear to be much more important in NTM disease than in TB. In the majority of patients, NTM disease occurs in association with either pre-existing pulmonary disease (including post-tuberculous scarring and silicosis), or factors likely to be associated with poor immune function (HIV infection, corticosteroid use, alcoholism and extremes of age), as summarised in Table 6.3.
Table 6.3 Risk factors for NTM disease in South African gold miners

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Comments</th>
</tr>
</thead>
</table>
| HIV infection | • NTM patients significantly more likely to be HIV-positive than control without NTM  
• HIV testing should be offered to all  
• No impact of HIV on NTM species distribution as yet  
• Pulmonary disease remains the common presentation  
• CD4 counts higher than reported elsewhere  
• Good response to standard treatment |
| Silicosis | • *M. kansasii*, *M. scrofulaceum*, *M. avium complex* all strongly associated with previous chest radiograph abnormalities and/or past history of TB. High dust exposure the most important at population level |
| Ongoing high dust exposure | |
| Past history of TB | |
| Post-tuberculous lung disease | |
| Increasing age/employment duration | • May be a true age effect, as exists in the general population. Also likely to be due to association with increasing risk of silicosis and cumulative dust exposure |
| Alcoholism | • *M. avium complex* (shown in other settings) |

In addition to their direct effects, both silicosis and HIV infection have the potential to indirectly lead to an increased risk of NTM disease, because both predispose to TB, itself a strong NTM disease risk factor. The interrelationship among NTM disease risk factors is illustrated in Figure 6.10. Dust exposure may result in occupational bronchitis, which in turn is a risk factor for NTM disease. In addition there may be a general effect of intra-pulmonary silica on mycobacterial disease susceptibility.

![Diagram](image)

**Figure 6.10 Nontuberculous mycobacterial disease risk factors in miners**

It is also possible that the association with dust is due to the extensive use of aerosolised water for dust control on the mines, since piped water systems are often highly colonised with NTM organisms.

Two studies have recently investigated water systems in South African mines. NTM organisms were cultured from half of the water bodies and outlets sampled, with the most commonly identified species being *M. scrofulaceum*. Although such a high prevalence of NTM colonisation is not unusual in water systems, the species distribution is of interest in that *M. scrofulaceum* is the second most common cause of pulmonary NTM disease in the mining workforce in Welkom, but is a rare cause of pulmonary disease elsewhere. *M. kansasii* was not isolated, but is difficult to isolate even in high incidence areas.
Failure to identify a source does not therefore rule out a link to occupational exposure, but may simply be a consequence of an insufficient number of sites sampled, or organism concentrations below the threshold for detection with the methods used. Despite the lack of environmental isolates and the high prevalence of smear positive disease there have been no indications of person-to-person transmission of \textit{M. kansasii}.

6.9.2 HIV-associated NTM disease

Disseminated \textit{M. avium} complex disease has been diagnosed in AIDS patients from several African countries, but with a much lower prevalence than in the US, both in life and at autopsy.

The effect of HIV infection on NTM disease in South African miners differs from that elsewhere in that the predominant cause is still \textit{M. kansasii}, and miners present at a much earlier stage of their HIV infection than is the case in the US or Europe.

NTM disease occurs with a higher incidence in HIV-positive than HIV-negative miners, but disease is mainly limited to lungs and responds well to treatment. This unique picture is probably because of an interaction with mining-associated pulmonary risk factors such as silicosis and post-tuberculous lung disease. At present, because of the similar presentation and outcomes, our recommendations are that HIV status should not affect the approach to diagnosis and treatment of NTM disease in miners.

6.9.3 Diagnostic criteria (case definitions)

The clinical significance of NTM isolates from individual patients is less certain than for \textit{M. tuberculosis}, since isolates may be the result of non-pathogenic respiratory tract colonisation or specimen contamination rather than disease (Appendix 6.5). For pulmonary NTM disease, the potential for non-invasive colonisation and specimen contamination has led to diagnostic criteria that are based on demonstrating multiple isolates from sputum specimens taken at different times before NTM disease can be considered confirmed.

The most commonly used diagnostic criteria are those defined by the American Thoracic Society (ATS), initially designed for use in the US, but since globally adopted. However, they are based on expert opinion, rather than being evidence-based and in the authors’ opinion are not appropriate for the diagnosis of NTM disease in the South African mining industry. Our recommendations are given in Appendix 6.6. This is based on a prospective evaluation of the ATS criteria that demonstrated under-diagnosis of \textit{M. kansasii} disease due to the logistical barrier presented by the requirement for multiple sputum isolates.

6.9.4 Treatment

Suggested treatment regimens are given in Appendix 6.7. Treatment regimens for pulmonary NTM disease are based on case series rather than clinical trial data, although there have been clinical trials of treating disseminated HIV-associated \textit{M. avium} disease that have demonstrated clarithromycin, rifabutin and ethambutol to be considerably more effective than previously recommended streptomycin based regimens. There are also a limited number of case series from the US reporting pulmonary \textit{M. avium} disease in HIV-negative individuals to have a better than expected response to treatment with clarithromycin containing regimens compared to historical experience with other regimens. Our recommendations are based on these observations and the authors’ good experience over several years of using clarithromycin to treat \textit{M. scrofulaceum} and \textit{M. avium} disease. The recommendations of the American and British Thoracic Societies differ considerably, both from one another and from the recommendations given here, and are not further detailed.

Since treatment failure and relapse rates tend to be higher in NTM disease than TB, patients should be followed up with sputum smears and cultures every 3 months, and treatment prolonged on the basis of those results to at least 6 months of culture negativity. Follow up after treatment should also be three monthly for the first year, with sputum smears and cultures.
6.9.5 Control measures

Improved control of dust and reduction of TB and HIV incidence would be the most satisfactory methods of reducing NTM disease incidence, as can be deduced from Figure 6.10. At present, the links between occupational water exposure and NTM disease are not sufficiently strong to recommend any change in practice.

6.9.6 Legal considerations

Under ODMWA compensation for NTM disease is not specifically mentioned. However, as NTM disease is strongly associated with occupational silica dust exposure, silicosis and past history of TB, the authors’ recommend that miners with NTM disease should be assessed and referred for compensation as for TB patients.

6.9.7 Overview of best practice

The initial work-up will be that of patients with TB, since the two diseases are indistinguishable clinically. Correct diagnosis is important, since misdiagnosis of NTM disease from contaminated culture will expose the patient with a non-significant isolate to lengthy and potentially toxic courses of treatment. Conversely, dismissing the significance of NTM isolates from patients with true NTM disease will lead to delayed or inadequate treatment. An approach to the diagnosis and management of a miner with suspected or confirmed NTM disease is given in Appendix 6.8.

6.10 Guide to information resources

6.10.1 Reading

Epidemiology


Control


Drug resistance


Preventive therapy


HIV


NTM disease


6.10.2 Internet resources

<table>
<thead>
<tr>
<th>Institution</th>
<th>Web address</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety in Mines Research Advisory Committee</td>
<td><a href="http://www.simrac.co.za">http://www.simrac.co.za</a></td>
<td>Reports of past occupational health research.</td>
</tr>
<tr>
<td>World Health Organisation</td>
<td><a href="http://www.who.org">http://www.who.org</a></td>
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</table>
### Appendix 6.1 Differences between the National TB Control Programme guidelines and those recommended in this chapter

<table>
<thead>
<tr>
<th>Case finding:</th>
<th>National</th>
<th>Mining industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>RSP</td>
<td>No</td>
<td>Yes (at least annually)</td>
</tr>
<tr>
<td>Passive</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Contact tracing</td>
<td>No (except for children)</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Diagnosis**

<table>
<thead>
<tr>
<th>Sputum smear</th>
<th>National</th>
<th>Mining industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes (2 smears)</td>
<td>sputum smear if smear negative at diagnosis and unresponsive to a course of antibiotics. Failure to convert smear.</td>
<td>All patients with suspected pulmonary TB should have sputum specimen submitted for culture. Failure to convert smear.</td>
</tr>
<tr>
<td>Sputum Culture</td>
<td>1 sputum for culture if smear negative at diagnosis and unresponsive to a course of antibiotics. Failure to convert smear.</td>
<td>Same</td>
</tr>
</tbody>
</table>

**Identification**

<table>
<thead>
<tr>
<th>Drug susceptibility testing</th>
<th>National</th>
<th>Mining industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Failure to convert smears and for all retreatment cases at diagnosis</td>
<td>Same</td>
<td></td>
</tr>
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</table>

**Admission criteria**

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<thead>
<tr>
<th>Smear Positive</th>
<th>National</th>
<th>Mining industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>Yes</td>
<td></td>
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</table>

**Clinically indicated**

<table>
<thead>
<tr>
<th>National</th>
<th>Mining industry</th>
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<tbody>
<tr>
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**Re-treatment TB**

<table>
<thead>
<tr>
<th>National</th>
<th>Mining industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes (Initial phase)</td>
<td>Yes (NTM speciated)</td>
</tr>
</tbody>
</table>

**Treatment§**

<table>
<thead>
<tr>
<th>New TB</th>
<th>National</th>
<th>Mining industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>2RHZE / 4RH</td>
<td>Same</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Retreatment TB</th>
<th>National</th>
<th>Mining industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>2RHZES / 1RHZE / 5RHE</td>
<td>Same</td>
<td></td>
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<table>
<thead>
<tr>
<th>Treatment frequency</th>
<th>National</th>
<th>Mining industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 days/week (initial)</td>
<td>5 days/week (initial)</td>
<td></td>
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<table>
<thead>
<tr>
<th>Smear negative TB</th>
<th>National</th>
<th>Mining industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes, if no response to broad-spectrum antibiotics and CXR compatible.</td>
<td>Same</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DOTS (Intensive phase)</th>
<th>National</th>
<th>Mining industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DOTS (Continuation phase)</th>
<th>National</th>
<th>Mining industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>If possible</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Multi —drug resistant TB</th>
<th>National</th>
<th>Mining industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individualised / standard</td>
<td>Same</td>
<td></td>
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<table>
<thead>
<tr>
<th>CXR</th>
<th>National</th>
<th>Mining industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>At diagnosis</td>
<td>Yes, if ≥ 1 smear is negative</td>
<td>Yes, on all patients.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Follow up</th>
<th>National</th>
<th>Mining industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

**Treatment outcomes:**

<table>
<thead>
<tr>
<th>National</th>
<th>Mining industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>As per definitions</td>
<td>Same</td>
</tr>
</tbody>
</table>


§ Fixed dose combination tablets should be used for RHZE, RHE and RH.
Appendix 6.2 Management of new pulmonary TB patients (never had more than 4 weeks of previous TB treatment.

**DIAGNOSIS**

Day 1 – One sputum for microscopy. One sputum for culture & organism identification.

Day 2 – One sputum for microscopy early in the morning & one sputum for microscopy at the close.

- **Two smears positive**
  - Review chest X-ray
  - Compatible with TB
  - Smear positive
  - Repeat AFB microscopy
  - Smear negative
  - Repeat chest X-ray and review culture result

- **Three smears negative**
  - Broad spectrum antibiotics for at least 7 days
  - Improvement
  - Improvement

- **One smear positive**
  - Review chest X-ray
  - Normal / Not compatible

- **Three smear negative**
  - Improvement

**TREAT AS NEW PATIENT**

**FOLLOW UP**

- 2 months – take 2 spots
  - Both negative
  - One or both positive
  - Susceptible
  - Resistant
  - Refer to MDR TB unit

- Start with Continuation phase treatment
  - 3 months – take 2 spots
  - Both negative

- 6 months – stop treatment and register as cured
  - Chest X-ray

- Treatment should be stopped for 48 hours before taking a sputum for culture and susceptibility test during treatment.

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Appendix 6.3 Management of retreatment pulmonary TB patients (have had more than 4 weeks of previous TB treatment)

**DIAGNOSIS**

Day 1 – One sputum for microscopy.
One sputum for culture, organism identification & drug susceptibility testing.

**FOLLOW UP**
Review organism identification & drug susceptibility: if NTM manage as per protocol.

- Susceptible
  - 3 months - take 2 sputa
  - Both negative
    - Susceptible
      - Start with continuation phase treatment
        - 7 months - take 2 sputa
        - Both negative
          - 8 months - stop treatment and register as cured
          - Chest X-ray
    - Repeated culture and susceptibility and start continuation phase treatment

- Resistant
  - Refer to MDR TB unit
  - One or both positive
    - Repeated culture and susceptibility and start continuation phase treatment
    - Resistant
      - Refer to MDR TB unit
      - One or both positive
        - Register as failure and refer to MDR TB Unit

- Treatment should be stopped for 48 hours before taking a sputum for culture and susceptibility test during treatment.
### Appendix 6.4 Recommendations for TB preventive therapy

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Regimen — IPT</strong></td>
<td></td>
</tr>
</tbody>
</table>
Isoniazid at 5 mg/kg to maximum of 300mg 5times weekly for 9 months | Some experts recommend 6 months |

<table>
<thead>
<tr>
<th>Suitable recipient groups</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High risk</strong></td>
<td>Very high TB incidence. Offer IPT without skin testing</td>
</tr>
</tbody>
</table>
- HIV +ve |
- silicotics |
- chronic corticosteroids use |

<table>
<thead>
<tr>
<th>Intermediate risk</th>
<th></th>
</tr>
</thead>
</table>
HIV-ve plus: Untreated annual TB incidence ≥ 1 000 per 100 000 Offer IPT if skin test positive |
- employed in dusty job for 10 years or more |
- dusty job and aged over 40 years |
- diabetic |

<table>
<thead>
<tr>
<th>Recruitment</th>
<th></th>
</tr>
</thead>
</table>
**Link to STD and medical clinics** | Give priority to those with symptomatic HIV — a high TB risk group |
- Promote voluntary HIV counselling and testing |
- Offer IPT to all known HIV-positive patients |

**Link to annual fitness examination** | Give prioritise to more advanced disease |
- Offer IPT to all silicotics |
- Offer VCT with rapid result |

<table>
<thead>
<tr>
<th>Screening for active TB prior to IPT</th>
<th>See above for skin testing</th>
</tr>
</thead>
</table>
**Mandatory** | |
- CXR |
- clinical examination |
- symptomatic screen (esp. weight loss) |
- smear and culture x 3 if any suggestion of TB |

**Optional** | Creates a delay |
- routine smear and culture x 2 |

<table>
<thead>
<tr>
<th>Other action before starting IPT</th>
<th></th>
</tr>
</thead>
</table>
- Provide health information on TB and HIV |
- Provide information about side-effects, and instructions to stop treatment and report symptoms of hepatitis |

<table>
<thead>
<tr>
<th>Follow-up</th>
<th></th>
</tr>
</thead>
</table>
- Dispense tablets weekly through primary health clinics |
- See monthly for symptom check Check for signs and symptoms of drug side effects and TB |
- Liver function tests only if symptomatic |

**IPT** = isoniazid preventive therapy, **VCT** = voluntary counselling and testing
## Appendix 6.5 NTM species, and likely clinical significance

<table>
<thead>
<tr>
<th>Pathogenicity</th>
<th>Comments on suggested management</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High</strong></td>
<td></td>
</tr>
<tr>
<td><em>M. kansasii</em></td>
<td>Strong association with occupational lung disease especially mining. Rarely a contaminant. Most frequent cause of pulmonary NTM disease in miners, and the majority of isolates represent disease. Response to treatment is good. Regimen relatively cheap and non-toxic. Should have a low threshold for treatment and a single available isolate associated with compatible pulmonary disease should be treated as pathogenic.</td>
</tr>
<tr>
<td><strong>Moderate</strong></td>
<td></td>
</tr>
<tr>
<td><em>M. avium complex</em> (includes <em>M. intracellulare</em>, <em>M. scrofulaceum</em>)</td>
<td>Pulmonary isolates from underground workers are likely to be clinically significant, but do not treat as such unless 2 identifications are made because a) the treatment course is prolonged and expensive and b) harmless transient sputum carriage or contamination is also possible. Try to obtain multiple isolates from fresh sputum or the TB laboratory — use bactec (liquid media) cultures if the patient is not already on TB treatment since these species grow poorly on solid TB culture media. Return to clinic 2 monthly while waiting.</td>
</tr>
<tr>
<td><em>M. szulgai</em></td>
<td>Rare but often clinically significant; need 2 separate identifications before treating as NTM disease.</td>
</tr>
<tr>
<td><em>M. malmoense</em></td>
<td></td>
</tr>
<tr>
<td><em>M. abscessus</em></td>
<td></td>
</tr>
<tr>
<td><strong>Intermediate</strong></td>
<td></td>
</tr>
<tr>
<td><em>M. fortuitum</em> and <em>M. chelonae</em></td>
<td>Commonly isolated from hospital environment, giving rise to pseudo-epidemics as the result of laboratory/specimen contamination. Can cause true nosocomial disease (usually post-surgical soft tissue infections) and non-significant sputum colonisation. Rapid growers resistant to first line TB treatment. Treat as pulmonary NTM disease only if multiple identifications are obtained and the patient is failing standard TB treatment.</td>
</tr>
<tr>
<td><em>M. xenopi</em></td>
<td>Uncommon pulmonary pathogen. Can grow in hospital hot water systems resulting in pseudo-epidemics, true nosocomial disease (pulmonary) and non-significant sputum colonisation. Treat as NTM disease only if multiple identifications are obtained.</td>
</tr>
<tr>
<td><strong>Minimal</strong></td>
<td></td>
</tr>
<tr>
<td><em>M. gordonae</em></td>
<td>These species are essentially non-pathogenic, and unless multiple identifications are obtained they should be considered to be specimen contaminants regardless of the clinical presentation. There are occasional reports of apparent disease in patients with advanced HIV-infection.</td>
</tr>
<tr>
<td><em>M. flavescens</em></td>
<td></td>
</tr>
<tr>
<td><em>M. gastri</em></td>
<td></td>
</tr>
<tr>
<td><em>M. terrae</em></td>
<td></td>
</tr>
<tr>
<td><em>M. triviale</em></td>
<td></td>
</tr>
</tbody>
</table>
Appendix 6.6 Suggested adaptation of ATS diagnostic criteria for pulmonary NTM disease for South African mining industry

- Compatible signs/symptoms and reasonable exclusion of other disease to explain condition (including *M. tuberculosis* disease)
- Pulmonary changes compatible with pulmonary NTM disease
- Plus any one of:
  a) 2 NTM isolates from separate sputum or bronchoalveolar lavage (BAL) specimens*
  b) Heavy growth and numerous AFB** isolated for a single available BAL specimen
  c) Single NTM isolate grown from lung biopsy tissue
  d) Single available sputum isolate identified as *M. kansasii***
  e) Single available sputum isolate identified as an NTM species associated with a previous episode of mycobacterial disease (potential relapse)

**Case definitions not met:**
- Take more cultures and consider bronchoscopy
- If already on presumptive TB treatment — treat as if culture-negative TB, but continue ethambutol throughout
- Consider other pathology e.g. malignancy or silicosis with progressive massive fibrosis

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* ATS recommendations are that 3 isolates are required to confirm smear negative disease.
** AFB. Acid-fast bacilli.
*** ATS recommendations do not distinguish between species with different intrinsic pathogenesis, and do not recommend treating on a single sputum or BAL NTM isolate unless the diagnosis is supported by granulomas or AFB on lung biopsy tissue.

Appendix 6.7 Suggested NTM treatment regimens

<table>
<thead>
<tr>
<th>Presumptive TB&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Intensive phase&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Continuation phase</th>
<th>Duration (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>New case</td>
<td>RHZE&lt;sup&gt;c&lt;/sup&gt;</td>
<td>RHE</td>
<td>6</td>
</tr>
<tr>
<td>Retreatment case</td>
<td>RHZES&lt;sup&gt;d&lt;/sup&gt;</td>
<td>RHE</td>
<td>8</td>
</tr>
<tr>
<td><em>M. kansasii</em>&lt;sup&gt;a&lt;/sup&gt;</td>
<td>RHE</td>
<td>RHE</td>
<td>12</td>
</tr>
<tr>
<td><em>M. avium and M.</em>&lt;sup&gt;c&lt;/sup&gt; <em>scrofulaceum</em></td>
<td>RHE Clarithromycin&lt;sup&gt;f&lt;/sup&gt;</td>
<td>RHE Clarithromycin&lt;sup&gt;f&lt;/sup&gt;</td>
<td>15-18g</td>
</tr>
<tr>
<td>Other slowly growing</td>
<td>RHE Clarithromycin&lt;sup&gt;f&lt;/sup&gt;</td>
<td>RHE Clarithromycin&lt;sup&gt;f&lt;/sup&gt;</td>
<td>15-18g</td>
</tr>
<tr>
<td>NTM spp.</td>
<td>As directed by sensitivity testing&lt;sup&gt;h&lt;/sup&gt;</td>
<td>As directed by sensitivity testing&lt;sup&gt;h&lt;/sup&gt;</td>
<td>12</td>
</tr>
<tr>
<td>Rapid growers</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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* a. First 2 months of presumptive TB regimen.
* b. Regimen used to treat patients with mixed *M. tuberculosis* and NTM isolates and also those with non-*kansasii* NTM isolates not meeting case-definitions for NTM disease, but considered to have mycobacterial disease on clinical and radiological grounds.
* c. Drug abbreviations: R = rifampicin, H = isoniazid, Z = pyrazinamide, E = ethambutol, S = streptomycin. Fixed combination RHE tablets can be used (e.g. 150 mg of rifampicin, 75 mg of isoniazid and 300 mg of ethambutol. Daily dose: 4 tablets if above 50 kg, 3 tablets if below 50 kg).
* d. Omit streptomycin if HIV-positive.
* e. Regimen used for all patients with *M. kansasii* isolates and clinical / radiological disease. Isoniazid probably adds little and may be omitted, but allows use of combination tablets and will treat any underlying *M. tuberculosis* disease more effectively. British Thoracic Society recommends 9 months of rifampicin and ethambutol.
* f. Clarithromycin 750 mg daily (some experts would recommend a higher dose up to 1g bd).
* g. Treatment to be continued to 12 months of culture-negativity.
* h. Not responsive to *any first line* TB drugs. Seek expert advice. Drugs to consider testing for susceptibility include doxycycline, cotrimoxazole, clarithromycin, ciprofloxacin, amikacin and cephalosporins.
Appendix 6.8 Guidelines for clinicians assessing patients with NTM isolates

1. What does it mean when a positive sputum culture is identified as a NTM?

In many instances receiving a report of a NTM isolate from a patient will be an unexpected event, the original request for mycobacterial culture having been prompted by suspicion of *M. tuberculosis* disease.

- It is important to realise that a NTM isolate does not necessarily imply NTM disease
- For these reasons, the diagnosis of NTM disease should be based on repeated identification of the *same NTM organism* from more than one specimen whenever possible

2. How likely is it that the culture either represents disease or is not significant?

NTM disease is more likely if:

*The patient*
- has new chest radiograph changes that look like TB
- is also smear positive
- has risk factors in addition to dust exposure that predispose them to NTM disease (see Table 6.3)
- has no other cause identified for their illness

*The organism*
- is a relatively pathogenic one known to cause lung disease (see Appendix 6.5)
- is present as a heavy growth on culture
- is isolated more than once from sputum samples taken on separate occasions (see below and Appendix 6.6)
- is isolated from lung lavage or biopsy tissue (see below and Appendix 6.6)

Pulmonary NTM disease is unlikely if:

*The patient*
- has a normal chest radiograph
- has no other risk factors for NTM disease
- is culture negative on repeat sputum culture (unless TB treatment has already been started, see section below)

*The organism*
- is a non-pathogenic one (see Appendix 6.5)

3. How should I investigate further?

- Diagnostic criteria based on those set by the American Thoracic Society (ATS) are shown in Appendix 6.6, and whenever possible all efforts should be made to meet them before starting treatment, even if this results in a delay and/or invasive investigations
- Patients who do not meet the diagnostic criteria for pulmonary NTM disease should not initially be treated, but should be followed up with repeat cultures
- HIV testing with pre- and post-test counselling should be offered to all patients diagnosed with NTM disease

In all patients: (since multiple identifications are desirable)
- Ask the TB laboratory to send any spare positive sputum cultures for full identification. (*The TB clinic should provide a dedicated form for this purpose*)
- If further sputum cultures are required, ask the TB laboratory to use a liquid culture medium such as Bactec since NTMs grow poorly on Lowenstein-Jensen slopes
- Look for radiological progression with repeat chest radiography
- Where uncertainty remains, patients should be referred for consideration of more invasive and expensive investigations such as bronchoscopy and / or CT scanning
For patients already being treated with TB drugs

(This section does not apply to isolates of M. fortuitum, M. chelonae or M. abscessus).

Confirming the diagnosis with multiple identifications should still be attempted, but many NTM patients become culture negative within a few weeks of starting standard TB treatment.

Because of this:

• Further sputum cultures are less likely to confirm the diagnosis in patients who do have NTM disease
• Negative sputum cultures will not help to exclude NTM disease
• It is especially important to contact the TB laboratory so that any spare positive sputum cultures can be found and sent for full identification

The initial response to standard TB treatment should not be used as a diagnostic guide because many NTM infections will initially respond to standard TB treatment, but with a high risk of relapse and/or acquired drug resistance.

Other considerations before starting treatment or changing from TB to NTM treatment

• Unfortunately, occasions will arise where it is impossible either to confidently confirm or to exclude NTM disease, especially in patients started on empirical TB treatment before identification of the isolate. The clinician will then have to use his or her judgement as to whether the patient should be treated for NTM disease or not. This decision should take into account the points outlined above
• The long-term response of NTM disease to standard TB drugs is disappointing for all but M. kansasii disease
• Clarithromycin has greatly improved the treatment response to M. avium disease, and shows promise with other NTM species, but it is expensive

4. How should NTM disease be treated?

The recommended treatment regimens for the more common causes of NTM disease, expected treatment outcome and notes are given in Appendix 6.6.

However:

• In general the correlation between in vitro drug sensitivity and in vivo response is sufficiently poor to mean that NTM species should be treated with standard NTM regimens without modification even if sensitivity testing shows resistance. The exception to this is when NTMs acquire drug resistance during the course of treatment. This has been shown to be associated with a poor outcome for rifampicin resistant M. kansasii, and clarithromycin resistant M. avium, and M. scrofulaceum
• Surgery should also be considered in any patient with localised pulmonary NTM disease that does not respond to drug treatment (remains culture positive)
• Isolation of patients and directly observed therapy are not necessary, since NTM disease is not a public health threat in the same way that a highly communicable disease like TB is

5. How often and for how long should patients be followed up?

Warn patients on ethambutol to report visual symptoms promptly.

Monitor response with repeat sputum cultures and radiograph 3 monthly during treatment and for at least 1 year after apparent cure.
CHAPTER 7

Noise and Vibration

This chapter covers best practice regarding the hazards of noise and vibration. It is intended as a practical guide and reference document, as well as a tool for audits/assessments and prioritising sources of risk for appropriate interventions. The chapter also serves as an informational and educational tool for persons unfamiliar with these two important health hazards. References to sources of additional information and the appendices facilitate access to more specific details.

R M Franz
Project Manager

Mike Franz currently works for CSIR: Division of Mining Technology. He has worked since 1982 in the field of noise risk assessment and hearing conservation for the mining and other industries. He has conducted several SIMRAC research projects and provided input to the formulation of standards and legislation relating to noise control and compensation for noise-induced hearing loss.

J I Phillips
Natural Scientist

Dr Jim Phillips works for the National Centre for Occupational Health. He has extensive experience in basic and applied biological research in many fields and has focussed on occupational health problems in South African Industry. Jim has been involved in the SIMRAC research project on vibration in collaboration with the Health and Safety Laboratories in the United Kingdom.
Glossary

**ADBA** audiometric database analysis  
**dB** decibel  
**Hz** hertz (cycles per second)  
**HAVS** hand arm vibration syndrome  
**HCP** hearing conservation programme  
**HPD** hearing protection device  
**HTL** hearing threshold level  
**NCE** noise control engineering  
**NIHL** noise-induced hearing loss  
**NRR** noise reduction rating (for HPDs)  
**Pa** pascal  
**µPa** micropascal  
**PTS** permanent threshold shift (see HTL)  
**RBME** risk-based medical examinations  
**RRN** risk rating for noise  
**SLM** sound level meter  
**TTS** temporary threshold shift (see HTL)  
**WBV** whole body vibration
7.1 Introduction

Sound and vibration both originate in the mechanical movement or excitation of machinery, its sub-assemblies and components. Movement or excitation of these objects causes their repetitive displacement and, thus, the transmission of energy into surrounding air or structures. If the level of energy is sufficient to excite a structure or the ground and the frequency of propagation is relatively low (generally below 20 Hz), the result is vibration perceptible through the tactile sense (touch). When the energy is directly or indirectly transmitted to surrounding air at a propagation frequency of 20 to 20 000 Hz, it is perceptible via the hearing sense as sound. Sound is regarded as noise if it has the potential to interfere with communication or damage people’s hearing.

Noise and vibration are also similar in that workers’ exposure to them can be detrimental to health and safety, as well as to productivity and profitability. This chapter addresses the two hazards separately, as their effects on exposed persons and the means to control risks are hazard-specific.

7.2 Noise

7.2.1 Extent of problem

Noise has been increasingly recognised as a significant health hazard for workers and a serious financial threat to many industries. The South African mining industry introduced hearing conservation programmes (HCP) in 1988 (COMRO User Guide No. 11). HCPs subsequently became compulsory, since labour-intensive methods common to many mineral extraction and processing operations were resulting in large numbers of people being routinely exposed to noise beyond the legally recognised safe limit of 85 dB. Research indicated that time-weighted average (TWA) equivalent exposure levels normalised to an 8-h duration are generally between 90 and 100 dB, depending on occupation. Corresponding values for operators of certain production machinery and for personnel in close proximity were found to range between 95 and 110 dB (Franz et al. 1997). It has subsequently been estimated that between 68 and 80 per cent of mineworkers are exposed at a TWA of 85 dB or greater, indicating a significant risk of hearing loss for the majority of the industry’s personnel.

The increased financial impact of noise-induced hearing loss (NIHL) on South African mining operations can be partially attributed to changes in the criteria for assessing compensation claims (Workmen’s Compensation Commissioner Internal Instruction No. 168, 1995). The revised criteria reduced the threshold (or “fence”) for compensation from 42 to 26 dB average hearing loss, including losses at 3 000 Hz. Since the implementation of WCC II 168, the proportion of compensation claims for hearing loss in the mining industry has escalated from eight per cent of all claims to approximately 14 per cent. Amounts paid have increased by an even greater margin, due to more substantial settlements for any given level of impairment.

The subsequent replacement of II 168 with Instruction 171 (WCC 2001) is not expected to reduce the overall financial impact of compensation claims, but will provide for apportioning them among claimants’ current and previous employers.

7.2.2 Legal responsibilities of employers and workers

In terms of the Mine Health and Safety Act (MHSA, Act 29 of 1996), employers’ obligations specific to noise are:

- Risk assessment, noise control engineering, noise monitoring and medical surveillance
- Hearing and safety training for noise-exposed persons to reduce the risk of NIHL
- Provision of appropriate hearing protective devices (HPD) to noise-exposed persons; and
- Compilation of a code of practice for controlling noise and managing the risk of NIHL

Workers’ obligations specific to the noise hazard are:

- The proper use and care of HPDs
- Reporting problems that may preclude or limit their use of HPDs; and
- Reporting noise sources, communication problems or perceived lack of protection
In cases where risk control measures ultimately fail to prevent NIHL, affected persons may be eligible for compensation. In terms of the Compensation for Occupational Injuries and Diseases Act (COIDA), the employer is obliged to report such cases to the Compensation Commissioner or to the relevant mutual association, even if in dispute of their merit [COIDA 68(2)].

7.2.3 Quantifying noise and exposure levels for risk assessment and occupational hygiene monitoring

Although details of the physical properties of noise and relevant measurement techniques are beyond the scope of this handbook, basic concepts are included. These include sound pressure, the decibel and A-scale frequency weighting within the text. Sound pressure level, sound power/sound power level and various parameters for quantifying noise exposure are beyond the scope of this handbook, and should be explored by consulting other sources, including some of those listed as references.

It is important to note that every 3-dB increase in the level of workplace noise beyond the 85 dB limit requires a 50 per cent reduction in exposure time for unprotected workers if the legal limit to be adhered to. For example, unprotected exposure to an equivalent continuous noise level of 88 dB would be permissible for 4 h per day, or for 2 h per day in the case of a level of 91 dB.

7.2.3.1 Sound pressure

Sound can be propagated in any elastic medium, but ultimately reaches the ear via the air. Most measurement parameters are based on the variations in air pressure that sound produces. The human ear is sensitive to a large range of sound pressures and responds to pressure differences in a logarithmic rather than a linear manner. This makes a logarithmic scale useful for characterising the “loudness” (magnitude or intensity) of sound. Sound is normally quantified on the logarithmic decibel scale, relative to the normal ear’s hearing threshold of 20 micropascals (µPa) at 1 000 Hz. As the threshold for normal hearing, 20 µPa has been adopted as the reference level for sound pressure, and is assigned a value of 0 dB. The 20-Pa (20 000 000 µPa) threshold of pain for normal ears has a decibel value of 120.

7.2.3.2 A-scale frequency weighting

The human ear is most sensitive to sounds at or near the centre of its frequency range (in octave terms). This provides the basis for A-scale frequency weighting to assess the impact of noise on people. Sound generated at frequencies to which the ear is less sensitive has less impact on exposed persons, and A-weighting devalues the contribution of such noise to the overall level determined. A-weighting is in accordance with the 40-phon (perceived) equal loudness curve (ISO 226: 1987, Annex A). A-weighted levels are quantified in dB (A), sometimes noted as dBA, but the normal convention is to omit the “A” once it has been stated that decibel values are A-weighted. Decibel values for noise level and noise exposure level in this chapter are A-weighted, unless otherwise noted.

7.2.3.3 Exposure level

Workers’ exposure to noise can be quantified by means of several parameters, but regulatory requirements and practical considerations generally determine the parameter of choice. SABS 083: 1996 stipulates rating level, \( L_{Ar,T} \) as the basis for determining exposure level. \( L_{Ar,T} \) is derived from sound level meter (SLM) measurements, which imposes practical difficulties for assessing risk. When the noise level varies during the working day, SLM-based measurements require the observer to “shadow” workers and either manually integrate results or use an integrating instrument to combine results from multiple measurement intervals. This reduces the number of samples that can be obtained from SLM-based monitoring and may also affect the representativeness of results if the observer elects to sample for less than a full shift.
Reasons for stipulating the use of $L_{eq}$ mainly relate to the SABS 083 requirement for Type-1 instrument precision (typically ±0.7 dB). Personal noise dosimeters, which quantify exposure in terms of other but generally equivalent parameters, normally provide only Type-2 accuracy (typically ±1.0 dB). (Instrument precision is determined in accordance with SABS-IEC 60651: 1998 for SLMs, and SABS-IEC 60804: 1998 for integrating SLMs.) In practice, the intrinsic variability of noise in the workplace (commonly ±2 dB or more) makes the number of samples obtained and validity of the sampling strategy the most crucial factors in accurately quantifying workers’ exposure and risk. Acceptance of Type-2 precision would allow the deployment of more (less costly) instruments and, hence, the accumulation of greater numbers of samples to better inform the risk assessment process.

The potential for personal noise dosimetry to facilitate larger sample sizes and application of a rational sampling strategy makes it the preferred method of exposure assessment (ISO 1999: 1990 and ISO 9612: 1997). Furthermore, dosimetry is particularly useful when workers do not have fixed workplaces, or they are subjected to significant sources of exposure outside their normal workplaces.

The mining industry should regard noise exposure level normalised to a nominal 8-h working day ($L_{EX, 8h}$) and time-weighted average 8-h equivalent noise exposure ($N_{eq}$) as the preferred parameters for quantifying exposure, for both risk assessment and occupational hygiene monitoring purposes. These two parameters, measured in decibels by means of personal dosimetry, can be regarded as numerically equivalent. Only when significant exposure is confined to continuous and unvarying noise at fixed workstations, can SLM-based measurements readily provide a representative quantification of exposure level and risk.

7.2.4 Risk management for the noise hazard

Figure 7.1 illustrates a risk management system for occupational noise. Linkages in the figure indicate relationships and information flow between elements, which should be considered during the Hearing Conservation Programme (HCP) review process (Section 7.2.4.7). The preferred order of implementation for risk management strategies is, firstly, noise control engineering (NCE), followed by administrative control measures and, lastly, personal protection. Despite this ranking of risk control strategies, the significance of the noise hazard and practical constraints generally necessitate a combination of two or more of these, particularly in the short-term.

7.2.4.1 Risk assessment and occupational hygiene monitoring

Risk assessment and occupational hygiene monitoring for the noise hazard should be based on a rational sampling strategy, using personal noise dosimetry as the principal source of data. Sampling must include all occupations, activities/processes and workplaces, as well as known sources of noise. To ensure accuracy of measurements and appropriateness of risk control measures, instruments should be electro-acoustically calibrated at 12-month intervals by a laboratory meeting the requirements of SABS 0259: 1990 and traceable to the National acoustics standard (National Measuring Units and National Measuring Standards Act 76 of 1973).

For practicability, observed exposure levels should be classified in accordance with Table 7.1 [adapted from Royster, Berger and Doswell-Royster (2000, 171) and the Occupational Hygiene Regulations: 9.1(f)(iii)]. Classification is based on the level of risk imposed (ISO 1999: 1990).
Risk Assessment by Occupational Hygienist [MHSA 11(1)(a)-(c) & 12(2)(b)]

If Risk is Significant:

Education & Training in Hazard Awareness and Risk Control Measures [MHSA 10(1)-(3)]

Implement/revise HCP under authority of H&S Committee [MHSA 11 (2)(a)-(d)], Involving H&S Reps [MHSA 11(7)(a)] and employees [MHSA 11(7)(b)]

Evaluate interventions through:
Medical Surveillance [MHSA 13(1)-(3)], viz. Audiometry and Re-assessment of Risk by OH measurements [MHSA 12(1)-(3)]
Use findings to optimise interventions

Issue PPE/HPDs [MHSA 11(2)(d)] and Monitor worker compliance [MHSA 22(a)(c)&(f)]

Instruction in use & care of HPDs during Hazard Awareness/Risk Control Training [MHSA 10(1)-(3)] and during RBME

If Risk is Significant:

Risk-based Medical Exams (RBME) [MHSA 13(2)(c)]

Individual fitment of HPDs by Occ. Health Practitioner [MHSA 13(5)(a)&(b)]

Implement elements of HCP in order of descending preference

NCE by Eng. Dept. [MHSA 11(2)(a)&(b)]

Administrative Control [MHSA 11(2)(c)]

Personal Protection [MHSA 11(2)(d)]

Figure 7.1 Functional structure of a risk management system for occupational noise
Table 7.1 Classification and required action for various levels of noise exposure

<table>
<thead>
<tr>
<th>TWA (dB)</th>
<th>Exposure classification according to:</th>
<th>OH Regs.</th>
<th>Risk factor (n), with significance of risk and required action</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 82</td>
<td>—</td>
<td>0: Insignificant risk of NIHL. No action required.</td>
<td></td>
</tr>
<tr>
<td>83-85</td>
<td>C</td>
<td>1: Potential risk of NIHL. OH monitoring of exposure levels.</td>
<td></td>
</tr>
<tr>
<td>86-90</td>
<td>B</td>
<td>2: Moderate risk of NIHL. Intervene and re-evaluate risk.</td>
<td></td>
</tr>
<tr>
<td>91-95</td>
<td>B</td>
<td>3: Significant risk. Priority intervention, followed by re-evaluation of risk.</td>
<td></td>
</tr>
<tr>
<td>96-105</td>
<td>B</td>
<td>4: Unacceptable risk. Immediate intervention and re-evaluation of risk.</td>
<td></td>
</tr>
<tr>
<td>≥ 106</td>
<td>A</td>
<td>5: Extreme risk. Urgent intervention and ongoing re-evaluation of risk.</td>
<td></td>
</tr>
</tbody>
</table>

*Observed values to be rounded to nearest decibel

The risk assessment process should result in the prioritisation of all sources of worker exposure, based on a risk rating for noise (RRN) defined as:

RRN = Exposure classification factor x Percentage or number of workers affected

Note: For full-time exposure to a given source, the exposure classification factor is taken directly from Table 7.1. For part-time/intermittent exposure, the exposure classification factor is the product of the applicable factor from Table 7.1 and the source’s percentage contribution to total exposure.

RRN should serve as the basis for prioritising all sources of exposure (machinery and operations) for interventions formulated in accordance with the order of preference shown in Figure 7.1.

Occupational hygiene measurements should be used to evaluate the control measures implemented, and monitor any remaining risks to workers. With regard to the latter, results should also be incorporated or linked with employee records of medical surveillance (Section 7.2.4.6).

7.2.4.2 Education, motivation and training

If significant risks exist, the employer is obliged to provide appropriate health and safety training for exposed persons. Education, motivation and training, fundamental prerequisites to the success of a hearing conservation programme, must be addressed at all levels in the organisation, not only among noise-exposed workers. The essential purpose is to:

• Instil an awareness of the noise hazard, and to
• Inform and instruct workers regarding risk control measures (e.g. the use of HPDs, undergoing routine medical surveillance and reporting any concerns related to the noise hazard)

Educational/motivational and training materials are available from a number of sources, including manufacturers and suppliers of HPDs and certain machinery, as well as from SIMRAC, through the CSIR Division of Mining Technology (SIMRAC Project GEN 011). Materials should contribute to:

• A comprehensive understanding of the noise hazard and motivation to prevent hearing loss
• A positive attitude towards implementation of hearing conservation/risk control measures, and
• Increased participation and contribution to the success of risk control measures, e.g. modified work practices and the proper use/care of HPDs

Officials responsible for formulating or implementing hearing conservation/risk control measures should receive training in a number of aspects additional to those aimed at workers. Essential learning topics are summarised in Table 7.2.
Table 7.2 Learning topics for all workers and responsible officials

<table>
<thead>
<tr>
<th>All workers</th>
<th>Responsible officials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nature, mechanisms and consequences of noise-induced deafness; Risk factors in the occurrence of NIHL and its potential impact on work, family and social life</td>
<td>Requirements for effective health &amp; safety training; Communication/consulting strategies to facilitate implementation of health and safety training and ensure effectiveness</td>
</tr>
<tr>
<td>Recognising dangerous noise in the workplace</td>
<td>Development of hazard identification and risk assessment procedures</td>
</tr>
<tr>
<td>Means to actively prevent NIHL; Benefits, use and care of HPDs</td>
<td>Formulation of strategies and workplace procedures for effective risk management; Requirements for an effective personal protection strategy and HPD selection criteria</td>
</tr>
<tr>
<td>Legislated requirements; Employer’s code of practice and risk management system; Employer’s responsibilities; Workers’ responsibilities</td>
<td>Employers’ and manufacturers/suppliers’ responsibilities; Incorporation of noise emission limits into procurement criteria; Formulating codes of practice and risk control measures; Communicating requirements for compliance</td>
</tr>
<tr>
<td>Modified workplace procedures to reduce the risk of NIHL; Workers’ role and responsibilities in controlling risks</td>
<td>Consultation strategies during the development of risk control measures and revised workplace procedures; Communication strategies to facilitate implementation</td>
</tr>
<tr>
<td>Purpose of occupational hygiene monitoring and medical surveillance; Workers’ role and responsibilities in monitoring hazards and controlling risks</td>
<td>Design of occupational hygiene monitoring and medical surveillance programmes; Record-keeping systems, administrative and legal requirements</td>
</tr>
</tbody>
</table>

A number of learning outcomes can be identified as potential contributors to a successful HCP. Appendix 7.N.1 provides an example of risk management-related learning outcomes (adapted from Worksafe Australia 1993a, 1993b, 1994).

- Developers or providers of training courses should formalise all expected learning outcomes, with due consideration to other requirements, e.g. those prescribed by the Mine Qualifications Authority
- On completion of their training, learners should be able to demonstrate the required competencies
- Educational, motivational and training programmes should be evaluated and revised on an ongoing basis, e.g. by comparing the results of pre- and post-tests based on expected learning outcomes, and by considering the findings of HPD compliance monitoring (Section 7.2.4.5.3)
- Reinforcement and retention training are also important aspects that should be appropriately addressed and regularly evaluated

7.2.4.3 Noise control engineering

An HCP must incorporate the element of noise control engineering (NCE) as a fundamental strategy to address the source of risk. NCE is the direct responsibility of engineering personnel, and should include at-source noise reduction, controlling noise transmission through the workplace and improving machinery maintenance procedures. Machine maintenance should incorporate noise emission measurements as a quality control check for significant noise sources.

Source control measures must be specific to the machinery and work situation and often require specialised input from suitably qualified and experienced individuals, such as the designers and manufacturers of the equipment and acoustics engineering consultants. Where practicable control measures are individually inadequate, appropriate combinations of the following strategies should be considered:
Adopting alternative methods or processes where suitable technologies are available
Installing quieter machinery at the time of replacement or plant expansion
Modifying existing machinery to incorporate noise reduction features of current models
Implementing measures to control the transmission of noise through the workplace, e.g. use of enclosures and absorbent interfaces, reflective or absorbent barriers, as well as specialised installation techniques for machinery and reticulation components, and
Re-locating major noise sources away from workers, or isolating/enclosing sources or workers

NCE is the preferred strategy, but is initially expensive. It should address the priorities determined during the risk assessment process and confirmed by occupational hygiene monitoring. NCE initiatives must also incorporate noise standards and emission limits for machinery that are enforced through the employer’s procurement and maintenance policies. Finally, engineering personnel must keep abreast of new developments in technology and machinery design, to ensure ongoing reductions in noise at or near the source. Examples of engineering-based noise control treatments are summarised in Appendix 7.N.2. For a comprehensive presentation of the principles and application of noise and vibration control measures, refer to Beranek and Vér (1992).

7.2.4.4 Administrative measures to control risk
The Mine Health and Safety Act implies that where elimination or control is not possible or practicable, minimisation is an acceptable course of action. Despite their limited practicability, administrative measures to change the organisation of work offer some potential to reduce individual exposure. Examples include revised working procedures, such as the relocation or alternative scheduling of noisy operations performed in the same or adjacent areas, and rotation of workers out of noisy areas to quieter activities. The latter requires workers to be competent in multiple tasks and sufficient work in quieter areas to accommodate individuals approaching their exposure limit. Worker rotation may be limited by its likely impact on productivity and by the potential safety and productivity implications of workers being less familiar with certain tasks.

Use of worker rotation would also impose the additional administrative burden of quantifying and documenting individual workers’ exposure, based on noise levels and exposure durations in each of their workplaces. The potential contribution of administrative measures to successful risk management should be evaluated but is likely to be restricted to changes in work organisation, e.g. staggered scheduling and/or the relocation of noisy tasks.

7.2.4.5 Personal protection
Where NCE and administrative measures fail to reduce risks sufficiently, a personal protection strategy based on the use of HPDs is indicated. However, this approach should be regarded as a last resort, and as a temporary supplement to the preferred elements of risk management. The essential prerequisites of education, motivation and training, as well as risk-based medical examinations (RBME, below), must be in place before reasonable benefits can be derived from a personal protection strategy.

7.2.4.5.1 Risk-based medical examinations
The risk-based medical examination (RBME) should be incorporated into existing medical examination procedures for all individuals who will be exposed to hazardous noise. The RBME is intended to identify:

- any contraindication for an employee or prospective employee to work in noisy areas, including safety issues (e.g. an inability to hear warning signals while wearing HPDs) or health concerns (e.g. an abnormal susceptibility to hearing loss, or to external ear infection that could be exacerbated by insertable HPDs), and
- any anatomical abnormality or temporary medical condition that could negatively influence the appropriateness or effectiveness of HPDs, or the validity of an audiometric examination about to be performed

An occupational health practitioner should perform RBMEs as part of routine periodic examinations and re-examinations (e.g. cases of re-allocation involving a change for the worse in workplace noise levels). The RBME for noise exposure should consist of the following four elements:
• Confirmation of current eligibility for audiometry, by examining the external ear canals and middle ears for possible pathology, i.e. a pre-audiometric medical examination
• HPD compatibility assessment, i.e. an examination of the external ear canals to confirm their compatibility with HPDs, particularly where insertable types may be used, and identification of any limitations imposed by external ear anatomy
• Special needs assessment where the results of previous audiometry indicate significant hearing loss, to consider the use of low-attenuation HPDs for enhancing communication and perception of warning signals in noise, and
• A participative decision regarding allocation to noisy areas where current and previous audiometry indicate an abnormal susceptibility to NIHL.

In order to inform and facilitate the HPD selection process (Section 7.2.4.5.2), the HPD compatibility and special needs assessments should result in classification according to Table 7.3.

Table 7.3 Classification from HPD compatibility and special needs assessments

<table>
<thead>
<tr>
<th>Employee classification</th>
<th>Interpretation/additional information required</th>
</tr>
</thead>
<tbody>
<tr>
<td>No restriction</td>
<td>No medical/anatomical contraindications for any HPD type</td>
</tr>
<tr>
<td>Restricted use of HPDs, either: Permanent restriction, or Temporary restriction</td>
<td>Details of restriction imposed, in accordance with underlying reasons; Indication of temporary restriction’s likely duration or criteria for removal of restriction</td>
</tr>
<tr>
<td>Change from current HPDs recommended</td>
<td>Reasons for recommended change in HPDs; Selection criteria for alternative devices</td>
</tr>
<tr>
<td>Exclude insertable HPDs</td>
<td>Reasons for restriction, and criteria for alternative devices</td>
</tr>
<tr>
<td>Issue custom-moulded HPDs</td>
<td>Reasons/motivation for classification and selection criteria</td>
</tr>
<tr>
<td>Issue low-attenuation HPDs</td>
<td>Attenuation criteria, relative to audio frequency</td>
</tr>
<tr>
<td>Any other classification deemed appropriate by examiner</td>
<td>Reasons for classification; Recommended course of action</td>
</tr>
</tbody>
</table>

7.2.4.5.2 Selection of hearing protection devices

Selection, fitment and hands-on instruction in the application of HPDs should be conducted during or immediately after the RBME, under the direct supervision of an occupational health practitioner.

Conventional HPDs are classified according to their manner of application, as indicated in Table 7.4.

Table 7.4 Conventional HPD types

<table>
<thead>
<tr>
<th>Type of HPD</th>
<th>Description/example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circum-aural</td>
<td>Enclose or surround the ears, i.e. earmuffs</td>
</tr>
<tr>
<td>Extra-aural</td>
<td>Seal the entrance to ear canal, i.e. ear caps</td>
</tr>
<tr>
<td>Intra-aural, either: Disposable, or Reusable, either: Custom-moulded, or Universal-fit, but commonly available in a range of sizes</td>
<td>Inserted into ear canal, i.e. earplugs, including: Unmoulded or formable earplugs, and Pre-moulded, either: Moulded for a specific individual, or Compliant with all normal ear canals, provided correct size earplug is supplied</td>
</tr>
</tbody>
</table>

SABS 083: 1996 stipulates that HPDs issued in terms of an HCP must comply with the requirements of SABS 1451-I: 1988 (ear-muffs), II: 1988 (ear-plugs) or III: 1998 (helmet-mounted ear-muffs), as relevant. The employer should provide only HPDs found to comply with that standard and, similarly, HPD vendors should supply only such devices.
The Noise Reduction Rating (NRR) cited by some manufacturers should be used only for comparative purposes. Its use for predicting effective (with protection) exposure levels requires C-weighted measurements for workplace noise, and many employers do not have access to the necessary instrumentation. Also, the NRR is determined under controlled laboratory conditions that are not representative of the workplace. Thus, a 50 per cent de-rating is commonly recommended to compensate for the optimistic protection levels indicated by NRR, but only after an initial 7-dB reduction in rating for cases where A-weighted workplace measurements are used. For example, a device having a NRR of 22 should be de-rated to 11 for C-weighted workplace measurements, and the lesser value used to calculate effective exposure level. If A-weighted workplace measurements are used, the NRR should first be reduced by 7 dB to 15, and then de-rated by 50 per cent to 7.5 dB. Berger (2000, 434) states emphatically that, “Under no circumstances should labelled NRRs be used as is for making predictions for groups of wearers”.

Some HPD manufacturers use the octave-band (long-method computation), REAT (real-ear attenuation at threshold) or HML (high, medium, low) methods to characterise their products’ protection levels. Details of these and other methods are provided in Berger’s discussion of the topic (2000, 427-434). The octave-band method is preferred because it facilitates the matching of HPD attenuation with the noise environment (see tabulated example in Appendix 7.N.3).

The selection process must consider the findings of individuals’ HPD compatibility and special needs assessments, as well as workplace ergonomics and environmental conditions. Factors to be considered during the HPD selection process are summarised in the points below.

- The level and nature (relative to frequency) of protection provided by HPDs must be matched with the noise environment. Excessive attenuation causes sensory deprivation and interference with communication, to the potential detriment of safety and productivity. Individuals with significant pre-existing hearing loss may require specially selected low-attenuation HPDs. In addition, any anatomical abnormalities of the external ear must be accommodated.
- Environmental/physical conditions and work rates may render some HPDs unsuitable for certain situations, despite their other attributes (e.g. earmuffs would be inappropriate for hot and humid conditions, and where heavy physical exertion or confined workspaces are a factor).
- HPDs must be compatible with other PPE that will be used, e.g. hardhat, safety glasses/goggles or respiratory equipment.

It is important that workers can choose from a reasonable selection of HPDs that are both appropriate for the intended application and compatible with individual requirements. Initial fitting by individual users should be supervised and facilitated by the occupational health practitioner.

7.2.4.5.3 Compliance monitoring

HPD usage should be monitored as a measure of the personal protection strategy’s effectiveness. Quarterly monitoring by trained personnel using random sampling (COMRO 1988, 31-33) should be conducted and documented to assess the appropriateness, acceptability and availability of devices being issued, as well as to provide input to the review of education, motivation and training, RBMEs, HPD selection/procurement criteria and distribution methods. Findings should be considered during the HCP review, to formulate appropriate revisions.

7.2.4.6 Medical surveillance

Medical surveillance is the direct responsibility of occupational health and occupational medical practitioners. Audiometry is used to monitor the impact of noise on workers’ hearing and evaluate measures aimed at controlling NIHL.

7.2.4.6.1 Legal basis

Noise is regarded as a “significant hazard” where workers’ TWA equivalent exposure levels exceed 50 per cent of the occupational exposure limit (i.e. >82 dB, in accordance with the 85-dB rating limit and 3-dB exchange/doubling rate stipulated by SABS 083: 1996). In such cases, the MHSA and the Occupational Hygiene Regulations oblige the employer to implement a mandatory code of practice.
and occupational hygiene monitoring. When persons are subjected to an occupational health hazard, i.e. an equivalent exposure level exceeding the exposure limit of 85 dB, Section 13(1) of the MHSA requires the employer to establish and maintain an appropriate system of medical surveillance (as defined in Section 102 of the Act).

The MHSA further requires that medical surveillance programmes be designed to provide the employer with information that enables the elimination, control or minimisation of the hazard and associated risks. This indicates that linkages must be established between the results of noise exposure determinations (i.e. occupational hygiene and risk assessment measurements) and records of medical surveillance. Where such linkage is not possible on an individual basis, it should be based on occupation, activity and/or workplace.

7.2.4.6.2 Application and frequency of audiometric testing

Audiometry is the process where an individual’s hearing threshold levels are determined over a specified range of audio frequencies. As a minimum requirement, these should comprise 500; 1 000; 2 000; 3 000; 4 000; 6 000 Hz and 8 000 Hz, but may also include 125 and 250 Hz. Routine screening audiometry employs basic air-conduction techniques to record baseline, periodic screening, monitoring and exit audiograms. Diagnostic audiometry for specialist medical evaluations incorporates additional techniques such as bone-conduction, speech recognition and/or oto-acoustic emission audiometry. The application, purpose and procedural requirements for the various types of audiometry are summarised in Table 7.5.

<table>
<thead>
<tr>
<th>Type of audiometry</th>
<th>Application</th>
<th>Purpose</th>
<th>Procedural requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>Before allocation to work in a noise zone (TWA ≥ 85 dB) or within 30 days of commencing such work</td>
<td>To provide a reference for evaluating any future changes in hearing status</td>
<td>Before testing, a 16-h period with no exposure to noise &gt;85 dB (use of HPDs complying with SABS 1451-I, II or III is NOT acceptable); Use better of two audiograms that are within 10 dB at 0.5; 1; 2; 3 and 4 kHz; Where consistency is not possible or pathology is suspected, refer for medical opinion to consider possible audiologist or specialist evaluation; Incorporate results into medical surveillance records</td>
</tr>
<tr>
<td>Periodic screening</td>
<td>Annually for noise-exposed individuals (TWA ≥ 85 dB)</td>
<td>To quantify any permanent hearing loss that results from exposure to noise</td>
<td>Before testing, a 16-h period with no exposure to noise &gt;85 dB (use of HPDs complying with SABS 1451-I, II or III, as appropriate, is acceptable); Incorporate results into medical surveillance records</td>
</tr>
<tr>
<td>Monitoring</td>
<td>6-monthly for high-risk exposure (TWA &gt;105 dB), subject to employer’s code of practice</td>
<td>To identify temporary threshold shifts and enable the prevention of permanent hearing loss; To evaluate the efficacy of HPDs</td>
<td>Conduct testing as soon as possible after exposure to noise, i.e. at the end of the working shift</td>
</tr>
</tbody>
</table>
On conclusion of employment in a noise zone (TWA ≥ 85 dB) or on employee’s termination, To provide a record of hearing levels on conclusion of employment in a noise zone. Before testing, a 16-h period with no exposure to noise >85 dB (use of HPDs complying with SABS 1451-I, II or III, as appropriate, is acceptable). Incorporate results into medical surveillance records.

When medical opinion recommends a specialist evaluation for purpose of investigating ear pathology, inconsistent baseline results or a potential compensation claim for NIHL, To enable a specialist evaluation of hearing status as required; To support a possible compensation claim, where indicated. Before testing, a 16-h period with no exposure to noise >85 dB: N.B. Use of HPDs to limit noise immission during this period is NOT ACCEPTABLE; To determine eligibility for compensation, two audiograms must be recorded during two different sittings (both may be on same day). If the two differ by more than 10 dB for either ear at any mandatory test frequency (0.5; 1; 2; 3; 4; 6 or 8 kHz), a third audiogram must be recorded during a third sitting. Where third audiogram also indicates inconsistencies >10 dB, subject should be re-evaluated in six-months’ time. Thereafter, if consistent results are still not obtainable, subject may be referred for further specialist evaluation of hearing loss; Incorporate results into medical surveillance records.

### 7.2.4.6.3 Equipment requirements

The requirements for screening and diagnostic audiometers are summarised in Table 7.6a.

#### Table 7.6a Audiometer requirements

<table>
<thead>
<tr>
<th>Type of audiometer</th>
<th>Test frequencies</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screening</td>
<td>0.5; 1; 2; 3; 4; 6 and 8 kHz</td>
<td>Type 4 (IEC 60645-1)</td>
</tr>
<tr>
<td>Diagnostic</td>
<td>0.25; 0.5; 1; 2; 3; 4; 6 and 8 kHz</td>
<td>Type 3 (IEC 60645-1)</td>
</tr>
</tbody>
</table>

Acoustic enclosures or “soundproof” rooms for screening or diagnostic audiometry must comply with the relevant requirements for background noise and environmental conditions stipulated in SABS 0182: 1998. This standard provides background noise limits (in unweighted decibels) for air-conduction, bone-conduction and sound field audiometry, as listed in Table 7.6b.

#### Table 7.6b Background noise limits for audiometry

<table>
<thead>
<tr>
<th>Type of audiometry</th>
<th>Maximum unweighted sound pressure level (dB) at given centre frequency (Hz): SABS 0182: 1998</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>125</td>
</tr>
<tr>
<td><em>Screening</em></td>
<td>52.0</td>
</tr>
<tr>
<td>Diagnostic:</td>
<td></td>
</tr>
<tr>
<td>Air-conduction</td>
<td>29.0</td>
</tr>
<tr>
<td>Bone-conduction</td>
<td>22.5</td>
</tr>
<tr>
<td>Sound field</td>
<td>19.0</td>
</tr>
</tbody>
</table>

*Baseline, periodic screening, monitoring and exit audiometry using air-conduction methods

#### 7.2.4.6.4 Audiometer calibration and verification

Screening and diagnostic audiometers should have a valid calibration certificate at the time of commissioning. The supplier normally provides an initial certificate after on site calibration, and, thereafter, on site electro-acoustic calibrations must be performed annually in accordance with SABS 0154: 1996. Calibration service providers should have the necessary training and equipment, and demonstrate traceability to the National acoustics standard (National Measuring Units and
National Measuring Standards Act 1973). Calibration details for the service provider’s instruments must appear on the audiometer’s calibration certificate. Audiometer calibration certificates should be retained for record keeping and inspection purposes, as well as for validating audiometric test results in cases of dispute.

Personnel conducting audiometry should confirm the accuracy and calibration continuity of screening and diagnostic audiometers on a weekly basis, by means of subjective or biological calibration checks. These procedures involve the recording of a calibration reference audiogram using a calibration subject with known and stable hearing threshold levels (i.e. calibration subjects must not have hearing threshold levels exceeding 25 dB at any test frequency, or be routinely exposed to excessive noise). The subject’s weekly audiogram from a given audiometer is compared with the calibration reference audiogram. Where the two values differ by 10 dB or more, the audiometer should be immediately withdrawn from service for repair and electro-acoustic re-calibration. Thereafter, a new calibration reference audiogram must be recorded before the instrument is returned to service.

Records of all subjective or biological calibrations, including calibration reference audiograms, should be retained for record keeping and inspection purposes, as well as for validating audiometric test results in cases of dispute.

Each day, prior to testing, personnel conducting audiometry should:

- confirm correct function of the audiometer
- inspect all cables and connections
- confirm proper function of the patient response button, and
- perform listening checks to ensure the absence of unwanted or extraneous sounds, e.g. hums, clicks or distortion [at a minimum of three hearing level (HL) or loudness settings for each test frequency]

If unwanted or extraneous sounds occur, the audiometer should be withdrawn from service for inspection and possible repair, after which an electro-acoustic calibration should be performed and a new calibration reference audiogram recorded.

### 7.2.4.6.5 Qualifications and registration of personnel conducting audiometry

Qualification and registration requirements for personnel conducting audiometric tests are summarised in Table 7.7.

<table>
<thead>
<tr>
<th>Requirements for personnel conducting:</th>
<th>Screening audiometry (Baseline, periodic screening, monitoring and exit)</th>
<th>Diagnostic audiometry (Specialist evaluations)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Audiometrist registered with the Health Professions Council as an audiometrist or hearing aid acoustician, or holding a certificate in audiometry issued by an institution recognised and approved by the DME;</td>
<td>Audiologist, i.e. a graduate in speech therapy and audiology registered with the Health Professions Council;</td>
<td>Medical practitioner specialising in otorhinolaryngology (ENT) and registered with the Health Professions Council</td>
</tr>
<tr>
<td>Occupational medical practitioner registered with the Health Professions Council;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Audiologist, i.e. a graduate in speech therapy and audiology registered with the Health Professions Council;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medical practitioner specialising in otorhinolaryngology and registered with the Health Professions Council</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
7.2.4.6.6 Medical opinion in cases of hearing loss

In complex cases, or where permanent disability is likely to exceed 15 per cent (i.e. impairment >30 per cent) or a cumulative shift in percentage loss of hearing (PLH, Section 7.2.4.6.9) equalling or exceeding 10 per cent is apparent, the opinion of an otorhinolaryngologist (ENT specialist) should be obtained. In all other instances where the hearing loss is judged to be noise-related, the medical opinion should be that of an occupational medical practitioner.

7.2.4.6.7 Audiometric testing procedures

Audiometric testing should be preceded by instruction in the procedures and a familiarisation phase to confirm subject competence, by observing responses to preliminary test signals. The test phase follows, during which hearing threshold levels are measured and recorded. According to ISO 6189 one of two methods may be used, either the ascending or the bracketing method. Given its simplicity, the ascending method is recommended. The order of test frequencies and procedures for determining threshold at each are listed in Sections 7.N.4.1 and 7.N.4.2, respectively (Appendix 7.N.4).

7.2.4.6.8 Information to be recorded

Information to be recorded in audiometry records and incorporated into medical surveillance records is summarised in Table 7.8.

<table>
<thead>
<tr>
<th>Information to be included in records of audiometry</th>
<th>Type of audiometry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name, identity number, company number and age</td>
<td>X</td>
</tr>
<tr>
<td>Method used for positive identification, i.e. identity document, ID card or similar with photograph</td>
<td></td>
</tr>
<tr>
<td>Occupation, details of work, date of employment</td>
<td>X</td>
</tr>
<tr>
<td>Noise and exposure levels from OH monitoring as relevant to individual, occupation or workplace, including levels for previous allocations and period of previous allocations</td>
<td>X</td>
</tr>
<tr>
<td>Name, address, qualifications and registration number of person conducting audiometry</td>
<td>X</td>
</tr>
<tr>
<td>Relevant medical history, e.g. medication, colds, allergies, excessive ear wax, ear pathology, etc.</td>
<td>X</td>
</tr>
<tr>
<td>Baseline audiometric data and corresponding PLH (Section 2.4.6.9)</td>
<td>X</td>
</tr>
<tr>
<td>Current air-conduction hearing threshold levels and PLH Routine: 0,5; 1; 2; 3; 4 and 6 kHz; Diagnostic: 0,25; 0,5; 1; 2; 3; 4; 6 and 8 kHz</td>
<td>X</td>
</tr>
<tr>
<td>Current bone-conduction hearing threshold levels (0,25; 0,5; 1; 2; 3; 4; 6 and 8 kHz) and PLH</td>
<td>X</td>
</tr>
<tr>
<td>Current hearing threshold levels derived from speech discrimination or any other audiometric techniques applied</td>
<td>X</td>
</tr>
<tr>
<td>Relevant comments regarding response to testing</td>
<td>X</td>
</tr>
<tr>
<td>Details of any differences between the current and baseline audiograms and corresponding values for PLH</td>
<td>X</td>
</tr>
<tr>
<td>Details of any actions taken/recommended on basis of results</td>
<td>X</td>
</tr>
<tr>
<td>Copies of any medical opinions obtained, with names and addresses of individuals providing them</td>
<td>X</td>
</tr>
<tr>
<td>Assessment of possibility of a causal relationship between any abnormalities/threshold shifts and occupational (or other) noise exposure, or of a link with any other cause(s)</td>
<td>X</td>
</tr>
<tr>
<td>Signature of audiologist or medical specialist</td>
<td>X</td>
</tr>
</tbody>
</table>

*Baseline, periodic screening, monitoring and exit audiometry
Records of all audiometry, diagnostic or routine, must be maintained in accordance with legal requirements [MHSA 15(1) & (2)]. Thus, computer-based systems should have adequate, regular backup to ensure that data are not lost.

7.2.4.6.9 Evaluation of hearing status and criteria for compensation claims

The principal criterion for assessing hearing status is percentage loss of hearing (PLH). Shifts in PLH are identified by comparing the current value with that from the baseline audiogram (for cumulative shifts) or previous audiograms (for interim shifts). PLH is derived from combining the individual’s hearing threshold levels (i.e. hearing losses) at 0.5; 1; 2; 3 and 4 kHz, using tables available from the Compensation Commissioner. A shift of 10 per cent or more in PLH, as compared with the baseline audiogram, has been accepted as the level at which a compensation claim may exist (Workmen’s Compensation Commissioner Instruction 171 2001, superseding WCC I 168 1995). In such instances, the employer is obliged to make a submission to the Compensation Commissioner or relevant mutual association within 14 days of becoming aware of the shift in PLH, irrespective of any agreement or dispute with the case’s merits or validity.

7.2.4.7 Review of the hearing conservation programme

The various elements of a hearing conservation programme require regular review, the interval being dependent on their nature and role within the overall programme. Evaluations for individual aspects should be reported on completion, with interim findings being incorporated into a comprehensive report on HCP effectiveness.

7.2.4.7.1 Risk assessment and occupational hygiene monitoring

The quantification and monitoring of noise emission and exposure levels, as well as the prioritisation of noise sources for possible intervention, are normally performed by the occupational hygienist with input from the risk assessment process. In terms of SABS 083: 1996, noise measurements and confirmation of noise zoning should be performed at least every two years, but immediately where changes are made. Changes include the replacement, major overhaul, upgrading or expansion of noisy plant or machinery, the implementation of noise reduction or control measures, as well as the addition/removal of walls, partitions, doors, windows, etc. Exposure levels are best determined by ongoing personal noise dosimetry.

Findings should be reviewed and evaluated quarterly or at six-month intervals (as appropriate), in terms of previous results and targets or key performance indicators (KPI) adopted by the HCP Management or Health and Safety Committee, and agreed to in advance of their application. Where the review process indicates an unfavourable trend or failure to achieve an agreed target, the relevant personnel should take appropriate action.

7.2.4.7.2 Education, motivation and training

Although HPD usage provides some measure of effectiveness, other forms of evaluation such as pre- and post-training knowledge checks can identify outstanding training needs and revisions required for training subsequent groups. Training personnel or health and safety representatives should evaluate reinforcement and retention training, by means of workplace interviews and questionnaires. Appropriate KPIs would include shifts in workers’ attitudes towards hearing conservation and compliance with risk control measures. Review and evaluation of education/motivation/training initiatives should be conducted on a quarterly to six-monthly basis, with revisions implemented as soon as the need becomes apparent.

7.2.4.7.3 Engineering-based source and transmission control

Measures to reduce noise at source and control its transmission through the workplace would normally be evaluated by considering emission and exposure levels. The nature of significant noise sources and their risk-based prioritisation determine what control measures should be applied. A review of the NCE strategy includes measurement-based evaluations of steps already taken, with pre-implementation levels and agreed targets serving as the basis for key performance indicators.
The NCE review should also examine plans for future interventions to ensure their appropriateness, feasibility and compliance with priorities established during risk assessments and confirmed by occupational hygiene monitoring. Ultimately, audiometric testing will provide a measure of NCE effectiveness, but such trends will only emerge after hearing losses have already occurred.

The review interval depends on the number of significant noise sources and the complexity of corrective measures, but should be not longer than one year nor less than three months. Standards, limits, targets and KPIs for noise emission and exposure levels should be reviewed and revised annually.

7.2.4.7.4 Administrative control measures

Evaluation of administrative control measures rely mainly on results of personal noise dosimetry (as a prospective indication) and medical surveillance/audiometry (retrospective), both compared with previously set KPIs. Given the need for a reasonable number of samples to demonstrate trends, a review period of three to six months would be required for dosimetry based evaluations, while those based on audiometry would normally require a 12-month review period.

7.2.4.7.5 Personal protection

A comprehensive review of the personal protection strategy is relatively complex. Workers’ use of HPDs provides an immediate indication of the strategy’s efficacy and, accordingly, compliance should be monitored on an ongoing basis with results reviewed at quarterly intervals. Poor compliance levels may indicate inadequacies in the range of HPDs offered (including their appropriateness with regard to attenuation and individual/workplace ergonomics), the application of RBME procedures, as well as the effectiveness of education/motivation/training initiatives and HPD distribution procedures.

Audiometric trends are the definitive measure of a personal protection strategy’s effectiveness. Combined with the findings of HPD compliance and occupational hygiene monitoring, they can be used to evaluate the appropriateness of HPD attenuation and certain aspects of the RBME. A 12-month period is normally required for audiometric trends useful to the review process to emerge.

Key performance indicators for the personal protection strategy should provide a measure of the extent to which worker compliance is maintained or improved, and shifts in hearing threshold levels. Both require the comparison of current and previous results and agreed targets.

7.2.4.7.6 Medical surveillance/audiometry

Audiometry for noise exposed workers remains the ultimate indicator of HCP effectiveness, as it measures hearing losses that the programme should prevent. Shifts and trends for the entire workforce and subgroups are vital for HCP evaluation. Identifying those occupations, workplaces and activities where hearing loss is progressing most rapidly, particularly in the case of a large workforce, normally requires the use of audiometric database (ADBA) techniques (Doswell-Royster and Royster 2000, 517-548). To ensure their validity, ADBA based assessments must control for the effects of workforce turnover. The workforce is divided on the basis of occupation, activity and/or workplace, as appropriate, to evaluate the relative influence of noise on collective hearing status in these categories. This involves the use of average values, distributions of values or prevalence of critical shifts for one or more of the following parameters:

- Audiometric category (COMRO 1988, 107-109), particularly with respect to the higher test frequencies of 3, 4 and 6 kHz, which are most susceptible to the effects of noise exposure
- Average or total threshold shift at 3, 4 and 6 kHz
- Threshold shift at 4 kHz only, and/or
- Percentage loss of hearing (PLH)

The choice of parameter(s) and means of analysis depend on the audiometric test system’s data management capabilities, and suppliers should be asked to provide enhancements where required. This should not pose a serious constraint in the case of locally developed software, particularly if consensus on requirements can be reached at Group level or on an industry-wide basis.
Noise-exposed workers should undergo audiometric testing annually but, depending on the employer’s code of practice, those performing high-risk work (8-h TWA equivalent noise exposure >105 dB) may be tested every six months. Accordingly, the results of medical surveillance should be reviewed at similar intervals, i.e. annually or six-monthly, as applicable. Reports for medical surveillance should include current and previous results, as well as KPIs set by the HCP Management or Health and Safety Committee and an analysis of the comparisons. Occupations, activities and workplaces where the greatest prevalence and extent of hearing loss are apparent should be highlighted and prioritised for risk control interventions.

7.2.4.7.7 Overall review of the HCP

A comprehensive review of the HCP should be compiled annually and incorporate, at least in summary form, interim findings for various elements and sub-elements of the programme. The review should present actual and targeted values for key performance indicators, and prioritise areas for intervention. It should also incorporate action plans, with clearly defined evaluation criteria and assignments of responsibility. Critical aspects of the HCP review process are summarised in Table 7.9.

Table 7.9 Summary of HCP review requirements

<table>
<thead>
<tr>
<th>Programme element</th>
<th>Evaluation parameters/indicators</th>
<th>Review period</th>
<th>Basis of KPIs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk assessment &amp; OH monitoring</td>
<td>Emission and exposure levels; Number/percentage of workers affected</td>
<td>Quarterly/6-monthly</td>
<td>Variance with previous findings and with agreed targets</td>
</tr>
<tr>
<td>Education, motivation and training (EMT)</td>
<td>Level of knowledge and skills measured by pre- and post-EMT tests</td>
<td>Quarterly/6-monthly</td>
<td>Collective variance between pre- and post-EMT results;</td>
</tr>
<tr>
<td></td>
<td>Employee attitudes and behaviour determined by workplace interviews/questionnaires/observations; HPD compliance level; Audiometric trends</td>
<td></td>
<td>Shifts in employee attitude or behaviour;</td>
</tr>
<tr>
<td>Noise control engineering (NCE)</td>
<td>Noise emission and exposure levels; Audiometric trends</td>
<td>Quarterly to annually</td>
<td>Variance with previous findings and with agreed targets</td>
</tr>
<tr>
<td>Administrative control measures</td>
<td>Individual exposure levels</td>
<td>Quarterly/6-monthly</td>
<td>Variance with previous findings and with agreed targets</td>
</tr>
<tr>
<td></td>
<td>Individual audiometry results; Audiometric trends</td>
<td>Annually</td>
<td></td>
</tr>
<tr>
<td>Personal protection</td>
<td>HPD compliance level</td>
<td>Quarterly</td>
<td>Variance with previous findings and with agreed targets</td>
</tr>
<tr>
<td></td>
<td>Audiometric trends</td>
<td>Annually</td>
<td></td>
</tr>
<tr>
<td>Medical surveillance/audiometry</td>
<td>Average values, distributions or prevalence of critical variance in: Audiometric category, particularly with regard to 3, 4 and 6 kHz; Threshold shifts at 3, 4 and 6 kHz; Threshold shift at 4 kHz only; Percentage loss of hearing.</td>
<td>Annually or 6-monthly, as appropriate</td>
<td>Variance with previous findings and with agreed targets</td>
</tr>
</tbody>
</table>
7.2.4.8 HCP coordination and management

Implementing, monitoring and reviewing a hearing conservation programme require close co-ordination and effective management by a suitably qualified and experienced HCP co-ordinator. The HCP coordinator should command sufficient authority and possess the requisite leadership skills for managing the activities of a multidisciplinary team of specialists.

The Hearing Conservation Management Committee should liaise with the Health and Safety Committee and include, in addition to the HCP coordinator, senior personnel from the following departments or disciplines:

- Senior Management (Chair)
- Environmental Safety/Occupational Hygiene/Ventilation or equivalent
- Risk Management/Loss Control or equivalent
- Engineering
- Mining
- Metallurgy/Plant/Refinery
- Occupational Health/Medical Services
- Human Resources/Personnel
- Training and Development
- Services, e.g. Transport, Procurement

Members of the HCP management committee should assume primary responsibility for aspects/elements of the HCP, according to their function in the organisation. This responsibility cannot be delegated.

7.3 Vibration

7.3.1 Extent of problem

Exposure to vibration can lead to physical injury the severity of which is dependent upon duration of exposure and the type of vibration emitted by the tool or machinery. Consequences of vibration induced injury include poor job performance, reduced efficiency, poorer quality of life and disability.

Vibration induced disease is recognised and well documented from many parts of the world. Although there has been no overt evidence of vibration induced disease in the South African mining industry, exposure and potential disease exist. COMRO (1987) and SIMRAC (GEN 503) reports highlighted the potential for vibration induced disease in South African mines (Appendix 7.V.1). The likelihood of disease is increased by the more stable work force and bonus remuneration schemes which both tend to increase the working time and hence exposure to vibration.

Vibration induced disease can be divided into two main areas: whole body vibration (WBV) and vibration affecting the upper limbs or hand arm vibration syndrome (HA VS). In the mining industry of other countries, WBV is usually associated with operators of transport equipment such as trucks and locomotives. HA VS is usually associated with hand held or hand controlled tools such as rock drills. Adverse health effects attributable to WBV are less well defined than those ascribed to HA VS. Evidence on disease caused by WBV comes from epidemiological studies, while for HA VS, there are clinical and objective tests available.

Problems in defining vibration induced disease include relating vibration exposure to health effects, the latent period before onset of symptoms, the lack of simple diagnostic tests, distinguishing vibration induced disease from other disease processes, and confounding factors such as posture and temperature. Two SIMRAC studies, Health 703 and 702 are currently investigating HAVS, WBV and musculoskeletal disorders in the South African mining industry.

7.3.2 Definitions

Vibration is oscillatory motion occurring when there is an alternating movement or velocity in one direction and then a velocity in the opposite direction.
Whole body vibration (WBV) occurs when a human body is supported on a surface, which is vibrating, and causes the body to vibrate.

Acceleration — Vibration can be measured as a rate of change of velocity or acceleration, measured in metres per second, per second (ms\(^{-2}\)).

Accelerometers measure acceleration and commercial models can be fitted on to vibrating surfaces such as the seat of a truck.

Vibration frequency is the number of oscillations in a given time.

Hertz — The units of frequency are Hertz (Hz). Frequency analysers are commercially available.

Low frequency vibration — Frequencies less than 20 Hz.

7.3.3 Whole body vibration (WBV)

7.3.3.1 Scope of problem

Large numbers of workers in the South African mining industry are exposed to WBV with unknown consequences. Delivery vehicles, forklift trucks, lorries, tractors, buses and loaders are the most frequently reported sources of WBV. The most prevalent vibration is found in the frequency range 2-80Hz, and the whole range has an effect on the body.

In the United Kingdom (UK), it is estimated that 9 million people are exposed to WBV in the course of their work but the health effects of such exposures are largely unknown. In a systematic literature review, Lings and Leboeuf reported back pain to be more frequent in workers exposed to WBV and one study showed an increased frequency in lumbar prolapse. At low vibration frequencies of less than 20Hz, symptoms of motion sickness have been reported along with general symptoms of discomfort. This type of vibration can also impair visual perception and the ability to control a vehicle.

The most common self reported symptom associated with WBV exposure is lower back pain. Less well documented is sciatic pain, gastrointestinal tract disturbances and dizziness. In female workers, disturbances of the urogenital tract have been reported, with menstrual disorders and spontaneous abortion being the most common. The clinical findings associated with WBV are degenerative changes in the spine and intervertebral disc disorders. There are, however, no signs and symptoms that are specific to WBV.

As lower back pain is a common complaint, many factors have to be considered before ascribing symptoms to WBV. These include:

- Posture of the worker
- Force needed to perform tasks
- Repetitiveness of tasks, and
- Duration of exposure

Workers often have additional tasks to perform. For example, a vehicle driver may also be involved in loading the vehicle or maintaining it. Repeated climbing in and out of large vehicles and other activities related to the work of drivers may lead to back pain which cannot be distinguished from the effects of vibration. Individual characteristics such as gender, age, strength and health status may also have a bearing on susceptibility to back pain along with anthropometric factors such as the height, weight and length of limbs of the driver or operator.

7.3.3.2 Sources of exposure

WBV is usually associated with the driving or operation of transportation equipment. Vibration can be due to the machinery itself or the road surface. The following values give approximate indications to likely reactions to various magnitudes of vibration from vehicles.
Less than 0.315 m/s² Not uncomfortable
0.315 to 0.63 m/s² A little uncomfortable
0.5 to 1 m/s² Fairly uncomfortable
0.8 to 1.6 m/s² Uncomfortable
1.25 to 2.5 m/s² Very uncomfortable
Greater than 2 m/s² Extremely uncomfortable

In the mining industry, equipment has been categorised in terms of risk according to levels of vibration.

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Articulated dump trucks</td>
<td>High</td>
</tr>
<tr>
<td>Bulldozers</td>
<td>High</td>
</tr>
<tr>
<td>Front end loaders</td>
<td>High</td>
</tr>
<tr>
<td>Hydraulic shovels</td>
<td>High</td>
</tr>
<tr>
<td>Tractor tippers</td>
<td>High</td>
</tr>
<tr>
<td>Underground locomotives</td>
<td>Moderate</td>
</tr>
<tr>
<td>Load haul dumpers</td>
<td>Moderate</td>
</tr>
<tr>
<td>Shuttle cars</td>
<td>Low</td>
</tr>
<tr>
<td>Draglines</td>
<td>Low</td>
</tr>
</tbody>
</table>

The risk rating should be used as a general guide since machinery may cause different vibrations under different operating conditions. For example, if not properly maintained, an engine may vibrate excessively. Poor or worn suspension systems and the condition of the road will influence the vibration transmitted to the vehicle driver. Therefore, all vehicles are a potential source of WBV.

7.3.3.3 Standards
In South Africa, no cases of occupational disease have as yet been attributed to WBV. There are no South African standards governing exposure limits to whole body vibration and there is no defined limit for vibration for vehicle operators. Currently, the European Parliament is considering a daily exposure limit value of 1.15 m/s² and a daily exposure action level of 0.6 m/s².

The SABS has adopted ISO 2631 as SABS ISO 2631 as the standard for measuring whole body vibration. Guidelines can also be found in BS 6841, (Appendix 7.V.1)

7.3.3.4 Monitoring
Monitoring for WBV takes the form of measuring vibration by placing accelerometers under the seats of vehicles. The standards for measuring equipment are covered in ISO 8041 (Appendix 7.V.1). Measurements may vary with different operating conditions (see Sources of exposure above).

7.3.3.5 Control
Vibration characteristics should be a consideration when purchasing new equipment. The best and most practical approach is to reduce exposure. This can be achieved by good maintenance, improving vehicle suspensions and damping seats. To reduce low frequency vibration, road surfaces can be smoothed.

7.3.3.6 Treatment
There are no treatments specifically for the effects of WBV. The effects are treated symptomatically. The best strategy is prevention.
7.3.3 Compensation

The Compensation for Occupational Injuries and Diseases Act (COID) refers to HAVS in schedule 3; however, it does not refer to WBV specifically (appendix 7.V.1). The Act does refer to work involving exposure to vibrating equipment.

7.3.4 Hand arm vibration (HAV)

7.3.4.1 Definitions

Since 1983, hand arm vibration syndrome (HAVS), has been used as a collective term for various forms of damage to the hands and arms suffered by workers who have worked regularly and for prolonged periods with vibrating, hand held, tools and equipment. Disease of the upper limbs associated with the use of hand held vibrating tools has been recognised for nearly a century. The many terms used for the condition include traumatic vasospastic disease, dead man’s hand, Raynaud’s phenomenon of occupational origin and vibration induced white finger. The latter is descriptive of one of the symptoms of HAVS.

7.3.4.2 Scope of potential problem

HAVS has been described in several countries in a variety of industries, including mining and quarrying, where vibrating, hand held, power tools are used. In the UK, HAVS is the most common of all industrial diseases reported to the Department of Social Security under the Industrial Injuries Benefit Scheme, with over 3,000 new cases of HAVS recorded in the year 1995 to 1996. In South African mines, tools are used which have the potential to produce HAVS. However, to date, the syndrome has not been diagnosed nor reported in a South African mine worker. SIMRAC researchers (GEN 503) measured the vibration emitted by various types of hand held tools and machinery in the mining industry and concurred with a COMRO report (433 of 1987) in recommending a survey to establish the prevalence of HAVS in the mining industry. SIMRAC researchers (Health 703) are currently investigating the presence and prevalence of HAVS in gold miners. Theoretically, using a rock drill, pavement breaker or jackhammer for four hours a day would cause 50% of the machine tool operators to develop symptoms of HAVS within five years (GEN 503). It is estimated that the hands of drill operators may only be in full contact with a vibrating drill for as little as two hours a day. At such an exposure level, 50% of the machine tool operators would be expected to have symptoms of HAVS within nine years.

It is postulated that the high temperatures prevalent in South African gold mines may prevent the occurrence or presentation of HAVS. However, there are indications that problems may exist since some machine tool operators do complain about symptoms caused on exposure to the cold water that is used to control dust.

7.3.4.3 Sources of exposure

The following tools used in mining were identified as being potentially hazardous (GEN 503); grinders, impact hammers, jack hammers, pavement breakers, pneumatic tools, rock breakers and rock drills. In addition, it was thought that the vibrations emitted by compactors, drilling machines, impact wrenches and rotary hammers drills were a potential hazard.

7.3.4.4 Standards

There are no statutory limits for vibration in South Africa but there are international standards that address specific aspects of vibration and its measurement, including ISO 5349, BS 6842 and ISO 8662-4 (appendix 7.V.1). The SABS has adopted ISO 2631-1: 1997, which does not set limits but gives guidelines for measuring vibration on which limits can be based. The dose of vibration received by a worker depends on the magnitude of the vibration and the duration of the exposure. For comparative purposes, exposure patterns are adjusted to a standard 8 hour day. In the UK, it is recommended that vibration levels over an 8 hour working period should not exceed 2.8 ms⁻². The European Parliament is currently considering legislation that sets a daily exposure limit of 5ms⁻² and an action level of 2.5ms⁻².
Average vibration levels equivalent to an exposure of 2.8ms\(^{-2}\) over an 8 Hour working day

<table>
<thead>
<tr>
<th>Working day, hours</th>
<th>16</th>
<th>8</th>
<th>4</th>
<th>2</th>
<th>1</th>
<th>0.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vibration level that gives the equivalent to 2.8ms(^{-2}) over 8hrs</td>
<td>2</td>
<td>2.8</td>
<td>4</td>
<td>5.6</td>
<td>8</td>
<td>11.2</td>
</tr>
</tbody>
</table>

In practice, hand held tools such as rock drills can exceed 2.5ms\(^{-2}\) by an order of magnitude.

7.3.4.5 Aetiology

The primary cause of HAVS is working with a hand held vibrating tool with a frequency between 2 and 1500 Hz. Frequencies in the 5 to 20 Hz range appear to be the most damaging (HSL, 1994). Prolonged exposure to vibration through the use of hand held power tools and equipment leads to damage in several organ systems of the upper limb. Blood vessels, nerves, muscles, bones and joints can all be affected. Damage to the vascular system is thought to be due to a direct effect of the vibration on the blood vessels themselves. Such damage can cause impairment to the circulation. Damage to the nerves is also thought to be a direct result of vibration, although the swelling of adjacent tissues due to the trauma of vibration may play a role in compressing nerves. Muscular damage may be the result of nerve injury or a direct effect of the vibration. The damage to bones and joints is not well understood. Osteoarthritis and bone cysts occur in workers who are exposed to vibration from hand held tools but the evidence that bone and joint problems are specifically caused by vibration is inconclusive. Workers who use hand held power tools are subject to other ergonomic risks factors such as awkward postures, exertion of force and repetitive procedures.

7.3.4.6 Symptoms

Impaired circulation gives rise to the symptoms of blanching of the fingers or parts of the hand, hence the term vibration induced white finger. Neurological and muscular damage cause numbness and tingling in the fingers and hands. Neurological damage also causes a reduction in sensation to touch and temperature, as well as reducing grip strength and manual dexterity. The symptoms experienced from bone and joint damage are pain and stiffness in the hand, joints of the wrist, elbow and shoulder.

There is a latent period between exposure to vibration and onset of symptoms. This period is variable and, while there are reports of symptoms occurring within a year, the latent period is typically several years. This variation is to be expected as, in addition to the varying susceptibility of individual workers, exposure will differ with occupation and the type of tool used. Factors that vary include the frequency of vibration and the time a worker is exposed on a daily basis.

The first symptom of HAVS is usually a tingling sensation in the fingers. It is often more noticeable after work has finished. Numbness may accompany the tingling. In the early stages, if the worker is removed from the source of vibration, the symptoms may improve. As exposure continues, the symptoms are more likely to be permanent. In the next stage of the syndrome, the worker experiences periodic attacks during which the fingers blanch or become white on exposure to cold. Initially, the blanching may be confined to the tips of the fingers but this may progress to involve the whole finger. These attacks can last up to an hour. When the circulation returns to the fingers, there is an intense red flush to the fingers accompanied by uncomfortable and sometimes painful throbbing. As the condition progresses, attacks can become more frequent and may occur even in warm surroundings. The attacks themselves can be painful. There is a gradual loss of manual dexterity and grip strength. In the most severe cases, blood circulation is permanently impaired and the fingers may become dark and blue-black in appearance. In extreme cases, the fingers can become ulcerated and even gangrenous due to inadequate circulation.
Effects of hand held vibrating tools.

<table>
<thead>
<tr>
<th>Affected tissues</th>
<th>Effect of vibration</th>
<th>Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood vessels</td>
<td>Direct</td>
<td>Blanching (white fingers), pain and throbbing, Ulcers and gangrene in advanced cases</td>
</tr>
<tr>
<td>Peripheral nerves</td>
<td>Direct and indirect</td>
<td>Tingling, numbness, reduced sensation and pain.</td>
</tr>
<tr>
<td>Muscles bones and joints</td>
<td>Direct and indirect</td>
<td>Pain, stiffness and weakness</td>
</tr>
</tbody>
</table>

7.3.4.7 Diagnosis

The diagnosis of HAVS can be established by taking a detailed occupational and medical history, performing a physical examination and conducting objective tests. The occupational history should put emphasis on the nature and length of past and present vibration exposure. The medical history and physical examination are crucial in the differential diagnosis of HAVS (appendix 7.V.4). Other conditions that can produce similar symptoms include intoxication, obstructive arterial disease, connective tissue diseases, hypersensitivity reactions, neurogenic disease, side effects of drug therapy (e.g. tuberculosis drugs) and trauma to the hands. During the physical examination, measurements can be made of grip strength using a dynamometer and manual dexterity using a peg board test (e.g. Purdue). In the UK, three standardised tests are employed to objectively assess HAVS for compensation purposes. Thermal aesthesiometry and vibrotactile thresholds are used to assess the neurological component and a cold provocation test is used for the vascular component (appendix 7.V.4).

7.3.4.8 Staging

In 1975, Taylor and Pelmear classified the different stages of HAVS. More recently, the Stockholm Workshop scale has replaced the Taylor-Pelmear classification scheme. The Taylor-Pelmear classification combines the vascular and neurological symptoms while The Stockholm Workshop scales take into account the fact that the vascular and neurological component of HAVS may progress independently (appendix 7.V.3). In the Stockholm scale, grade 0 is symptomless, grade 1 is mild, grade 2 is moderate and grade 3 is severe disease. Control measures and monitoring should prevent workers from progressing to grade 3.

7.3.4.9 Monitoring

In order to carry out surveillance or monitor the situation in South African mines, there has to be a reliable method for diagnosing and staging the severity of HAVS. Currently, there is no universally accepted, simple, reliable and cost-effective screening tool in use but SIMRAC project HEALTH 703 is investigating screening and diagnostic methods. Monitoring schemes can identify high-risk jobs and tools. They also monitor the effectiveness of control measures and the prevalence and severity of disease. The earliest symptoms of HAVS may be completely reversible if there is no further exposure to vibration. Workers who progress to grade 3 on the Stockholm scale should change their occupation and avoid any further vibration exposure.

7.3.4.10 Control

Control measures should primarily focus on reducing exposure. It has been reported that the early vascular symptoms of HAVS resolve if there is no further exposure to vibration. It is, therefore, important to identify early signs and symptoms of HAVS. If vibration exposure continues, control measures should be directed at reducing vibration intensity and exposure duration.

The exposure pattern may play a role and it is considered beneficial to have frequent rest periods, so breaking up periods of exposure. There are also factors that adversely affect the circulatory system such as exposure to low temperatures and tobacco smoking, which are thought to influence the progression of HAVS.
7.3.4.11 Best practice

- Vibration must be included as a factor in the design and selection of new tools and machinery.
- Remotely controlled tools that completely isolate the operator from vibration would be ideal. SIMRAC project GAP 642 has developed a rock drill that is self-thrusting and totally isolates the worker from the drill and the vibration. (N.B. It also reduces noise exposure)
- Tools should be well maintained as tools in poor repair may generate higher levels of vibration.
- Good ergonomic design and proper instruction in the use of tools can reduce the grip strength that needs to be employed, so cutting down on the transmission of vibration. A tight grip on the tool will transfer more vibration energy to the hand than will a light grip.
- The posture of the worker is important. For example, drilling on an up slope will exert more pressure and transfer vibrations more effectively to the thumbs, while drilling on a down slope will have a greater effect on the fingers.
- The vibration from tools should not exceed 2.5 ms$^{-2}$. Anti-vibration devices can be fitted to the handles of tools. SIMRAC project GAP 634, has developed a vibration absorbing handle for a rock drill that significantly reduces the vibration transmitted to the hand of the operator.
- Gloves designed to provide vibration isolation are available but their effectiveness, especially for low frequency vibration is questionable.
- Uninterrupted exposure to vibration over long periods should be avoided. Strategies involving job rotation have been employed. It is better for work to be arranged so that periods of exposure are broken by periods of work, which do not involve vibration.
- Massaging and exercising the fingers during work breaks has been suggested to increase blood flow to the fingers.
- As cold working conditions appear to contribute to HAVS, keeping the hands and body warm helps maintain a good blood flow to the hands. In colder countries, the wearing of gloves for warmth and the provision of warm and weatherproof clothing is recommended. In South African gold mines where temperatures can be uncomfortably high, this is not practical advice.
- Workers should be strongly encouraged and assisted to stop smoking tobacco.

7.3.4.12 Treatment

The pathophysiology of HAVS is not fully understood and there is no universally established medical treatment. Palliative physical therapies have been used with some subjective benefit; these include hot packs, wax baths, hot and cold baths, infrared and microwave therapy. Drugs, which may alleviate the vascular symptoms by causing vasodilatation, have been tried but have not been adopted routinely for treatment in other countries. The cessation of tobacco smoking is recommended as smoking has a general vasoconstrictory effect on the circulatory system. The best treatment, however, is avoidance of further vibration exposure.

7.3.4.13 Compensation

HAVS is specifically mentioned as a compensable disease in Schedule 3 of the Compensation for Occupational Injuries and Diseases Act, Act 130 of 1993. (See Chapter 14). To date, no compensation has been paid for HAVS.
7.4 Guide to information resources


Republic of South Africa Department of Labour 2000. WCC Instruction 171: Determination of disability in cases of noise induced hearing loss. Pretoria: Workmen’s Compensation Commissioner


218
Recommended reading: noise


Recommended reading: vibration


J. L. Van Niekerk, P. S. Heyns, M. Heyns and J. R. Hassall The measurement of vibration characteristics of mining equipment and impact percussive machines and tools. Safety In Mines Research Advisory Committee (SIMRAC) GEN 503, 1998

Health and Safety Executive (UK), 1994 Hand-Arm Vibration
HS(G)88. HMSO, ISBN 0 7176 0743 7

The occurrence of hand arm vibration syndrome (HAVS) in South African gold mines and identification of the potential effects of whole body vibration (WBV). Safety In Mines Research Advisory Committee (SIMRAC) Health 703, (in progress)

The incidence and work related risk factors in the development of musculoskeletal disorders in the South African mining industry. Safety In Mines Research Advisory Committee (SIMRAC) Health 702, (in progress)

Noel, B. 2000 Review: Pathophysiology and classification of the vibration white finger. International Archives of occupational and Environmental Health 73: 150-155


Appendices: 7.N Noise and 7.V Vibration

Appendix 7.N.1 Education, motivation and training

Learning outcomes analysis: Risk management for occupational noise

Table 7.N.1a: Target groups and relevant learning topics

<table>
<thead>
<tr>
<th>Target group and relevant learning topics</th>
<th>Employers and Senior managers</th>
<th>Line managers and Supervisors</th>
<th>HCP Management and H&amp;S Committees</th>
<th>Workers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formulation of risk management systems, procedures and implementation strategies; Consultation and communication techniques; Negotiation and motivational techniques; Training and instruction requirements; Coordinating the implementation of risk management measures; Evaluating results</td>
<td>Contributing to the development and implementation of risk control measures in own area of responsibility; Informing and motivating workers with regard to risk control measures and revised work procedures</td>
<td>Evaluation criteria for risk management systems, procedures and implementation strategies; Requirements for training content, informational, motivational and instructional materials; Promotion of communication between management and workers</td>
<td>Evaluating potential risk control measures for own workplace; Implementation requirements for measures adopted; Consulting with co-workers, supervisors and Health &amp; Safety representatives regarding control measures and remaining concerns</td>
<td></td>
</tr>
</tbody>
</table>

Table 7.N.1b: Relevant skills and knowledge for given target groups

<table>
<thead>
<tr>
<th>Employers, Senior managers, Line managers and Supervisors</th>
<th>Workers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required provisions for risk management and control measures in employer’s code of practice; Comprehensive knowledge of equipment and processes requiring noise control treatment and their prioritisation in terms of risk assessment results; Sources of appropriate expertise; Awareness of technological developments and recent research findings; Selection criteria for risk management systems, procedures and implementation strategies; Development of appropriate risk management systems, procedures and administrative mechanisms, e.g. flowcharts, proformas and record-keeping systems; Consultation during development of systems and procedures that are based on engineering, administrative and personal protection strategies; Formulation of evaluation criteria; Knowledge of training, instruction and supervision requirements and of special needs; Informational and motivational techniques for communicating risk management procedures and implementation strategies</td>
<td>Required provisions for risk management and control measures in employer’s code of practice; Prevailing risks and requirements for control measures in own workplace; Advantages &amp; disadvantages of potential risk control measures; Selection criteria for emission and exposure reduction measures; Evaluation criteria for control measures that are adopted; Awareness of mechanisms and procedures for participating in the selection and development of risk control measures for own workplace</td>
</tr>
</tbody>
</table>
Table 7.N.1c: Key Performance Indicators

<table>
<thead>
<tr>
<th>Basis of key performance indicators relevant to given target group</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Employers, Senior managers, Line managers and Supervisors</strong></td>
<td><strong>Workers</strong></td>
</tr>
<tr>
<td>Implementation of control measures to reduce noise emission and exposure levels;</td>
<td>Level of participation in the consultation process;</td>
</tr>
<tr>
<td>Inclusion of provisions for noise control in equipment operating and maintenance procedures;</td>
<td>Extent of contribution to development and implementation of risk control measures in own workplace;</td>
</tr>
<tr>
<td>Incorporation of noise emission limits into equipment maintenance procedures and procurement criteria;</td>
<td>Usefulness of feedback to line managers/supervisors and H&amp;S reps regarding effectiveness of risk control measures and any remaining concerns;</td>
</tr>
<tr>
<td>Effectiveness of consultation with workers, H&amp;S representatives and line managers/supervisors;</td>
<td>Level of compliance with procedures for reducing noise emission and risk during machinery operation;</td>
</tr>
<tr>
<td>Provision of enabling information, motivation and support, including training, instruction and supervision;</td>
<td>Extent of application of noise reduction criteria and emission limits during maintenance procedures;</td>
</tr>
<tr>
<td>Implementation of procedures for ongoing monitoring, evaluation and revision of risk control measures;</td>
<td>Level of compliance with risk control procedures, including proper use of HPDs in designated areas and during noisy operations;</td>
</tr>
<tr>
<td>Appropriateness of actions taken on basis of findings from HPD compliance and occupational hygiene monitoring and from medical surveillance;</td>
<td>Level of participation in educational, training and motivational programmes;</td>
</tr>
<tr>
<td>Appropriateness of hearing protection devices made available for all required applications, and provision for special needs;</td>
<td></td>
</tr>
<tr>
<td>Adequacy of resources allocated;</td>
<td></td>
</tr>
<tr>
<td>Achievement of targets for reducing noise emission, exposure levels and incidence of NIHL</td>
<td></td>
</tr>
</tbody>
</table>
Appendix 7.N.2 Noise control engineering

Table 7.N.2 summarises a variety of noise problems, the treatments applied and their effect on noise level. In some cases other effects are also considered, e.g. impact on performance or maintenance requirements. Noise reductions are not quantified in all examples, i.e. where specific details of the machinery, circumstances of its installation/operation and the NCE treatment constitute the principal determinants of achievable reductions.

Table 7.N.2 Examples of engineering measures to control noise

<table>
<thead>
<tr>
<th>Source</th>
<th>Nature of problem</th>
<th>Treatment</th>
<th>Effect/reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler exhaust</td>
<td>High pressure-steam vented through large-diameter pipe, producing high level, low-frequency noise</td>
<td>Fit a perforated-cone exhaust diffuser to existing vent pipe, splitting single exhaust jet into several smaller ones to reduce velocity and increase frequency; Install perforated, absorbent attenuator to reduce higher frequency noise from diffuser</td>
<td>Overall reduction up to 40 dB with no loss in performance</td>
</tr>
<tr>
<td>Coal processing screens</td>
<td>Screening process and machinery drive components produce broadband noise at high intensities</td>
<td>Install resilient screen components; Provide acoustic enclosures around screens; Install acoustic barrier curtains; Provide acoustic enclosure for drive components</td>
<td>Resilient screen components: 3 dB; Acoustic enclosures: 7 dB; Barrier curtains: 5 dB; Drive enclosure: 2 dB</td>
</tr>
<tr>
<td>Crushing and milling machinery</td>
<td>Crushing/milling of material and machinery drive components generate high levels of low-frequency noise</td>
<td>Install rubber lining in mills; Install large, high-density acoustic barrier panels around/above crushing and milling machinery, or provide acoustic enclosures; Provide isolation-mounted acoustic enclosure for operators</td>
<td>Lining reduces level by 5 dB, but periodic replacement needed; Barrier panels reduce noise by 6 dB, and enclosures provide reductions of up to 8 dB; Isolated operator enclosure reduces exposure by 17 dB</td>
</tr>
<tr>
<td>Diesel-powered machinery</td>
<td>Engine, transmission and cooling fan cause excessive noise in cabin and area of operation</td>
<td>Exhaust silencer; vibration-damping of engine, transmission and cabin mountings/interfaces; Acoustic treatment of engine compartment, cooling fan and operator cabin</td>
<td>Reductions of 3-20 dB in cabin and 2-5 dB in area of operation, depending on type of machinery and combination/extent of NCE treatments</td>
</tr>
<tr>
<td>Pneumatic rockdrill</td>
<td>High-velocity exhaust creates turbulence and noise in surrounding air; Drill steel vibration and impact between mechanical parts produces additional noise</td>
<td>Fit manufacturer’s silenced cylinder or exhaust muffler; Incorporate anti-vibration decoupler fitting into drill steel near chuck; Enclose drill steel in a collapsible bellows-type sheath, and/or damp steel with anti-vibration coating; Damp machine casing with an anti-vibration coating</td>
<td>Exhaust silencing: 7-10 dB reduction, but penetration rate reduced by 10-30 %; Decoupling steel from machine: 3-5 dB reduction; Enclosing/damping drill steel: 2-5 dB reduction; Damping drill casing: 2-3 dB further reduction</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Fan noise caused by turbulence at intake</td>
<td>Obstacle near fan, either a reduction in duct cross-section, a bend or a regulating valve, causing turbulence, vibration and noise at fan intake</td>
<td>Re-position fan or obstacle; Decrease sharpness of bend to allow turbulence to dissipate before fan intake; Install flow guides ahead of fan intake</td>
<td>Reduced turbulence lowers vibration in fan and ducting, reducing noise and mechanical stress on both</td>
</tr>
<tr>
<td>Fan noise transmitted by ducting</td>
<td>Ducting transmits noise from ventilation or extraction fan to areas far removed from source</td>
<td>Introduce changes in ducting’s cross-sectional size and add side branches to reflect some transmitted noise back towards source for reactive attenuation; Changes should be to an increased duct size, to allow expansion of air into what will act as a reactive silencer, and to prevent turbulence; Install absorbent panels in ducts</td>
<td>Reduced noise transmission, depending on details of original ducting and nature of mods; Reactive attenuation can supplement or replace attenuator; Further reductions in transmitted noise</td>
</tr>
<tr>
<td>Large fan transmitting noise to distant locations</td>
<td>Low-frequency noise produced at high intensity levels, creating a noise problem at distant locations</td>
<td>Increase number of fan blades and reduce rotational speed using an electronic speed controller, so as to maintain required fan performance</td>
<td>Frequency of noise increased in proportion with number of blades added, allowing greater attenuation with distance; Lower fan speed reduces motor noise</td>
</tr>
<tr>
<td>Turbulence in conveyance pipes generates noise</td>
<td>Sharp bends, closely spaced control valves and internal accumulations of scale create turbulence in the flow of material being conveyed</td>
<td>Install gentler bends in piping to reduce turbulence increase distance between control valves to allow settling of turbulence before next valve Control or periodically remove accumulations of scale</td>
<td>Reduced turbulence and noise; Reduced loading of pump and improved performance; Improved flow and reduced maintenance for control valves</td>
</tr>
<tr>
<td>Turbulence around in-line fluid-regulating valve generates noise</td>
<td>Small valve seat causes high flow velocity and turbulence around seat; Indirect fluid path and sharp edges inside valve add further turbulence; Vibration is transferred to pipe, causing structure-borne noise</td>
<td>Install valve with a larger seat; Install valve with more direct flow path and smoother internal edges; Install a pressure reduction insert ahead of valve to prevent cavitation downstream, and damp pipe supports to decouple them from building's structure</td>
<td>Reductions in turbulence, vibration &amp; noise, better valve performance and service life; Reduced load on pump, with less maintenance and longer service life; Reductions in fluid turbulence and structure-borne noise transmission through building</td>
</tr>
<tr>
<td>Radiated noise</td>
<td>Large, unbroken vibrating surfaces efficiently radiate energy into the surrounding air as noise</td>
<td>Replace flat, unbroken panels with perforated/expanded metal panels to reduce surface area; Increase the number of edges around radiating surfaces to equalise pressure differences</td>
<td>Reduced radiation of energy into surrounding air; Some self-cancellation of noise around edges of perforations</td>
</tr>
<tr>
<td>Structure-borne plant noise</td>
<td>Noise from a refrigeration plant or compressor is directly transmitted into structure of the building, and also throughout building by material conveyance pipes</td>
<td>Fit spring-damped machine mountings or, preferably, install an isolated machinery foundation; Damp pipe supports and brackets to decouple pipes from building's structure; Install flexible pipe sections between plant and its reticulation system; Supply power to plant by flexible cabling without steel conduit</td>
<td>Noise previously transmitted throughout the facility is confined to immediate area of the source; Additional measures may be required to protect personnel near source</td>
</tr>
<tr>
<td>Vibrating source</td>
<td>Large panel in contact with machinery is vibrating, radiating high levels of noise into the surrounding area</td>
<td>Isolate/separate machinery from panel; Damp panel or replace with perforated or expanded metal panel to allow self-cancellation of noise; Reduce size/surface area of panel</td>
<td>Considerable noise reduction, depending on the size/emission level of machinery, and the size/density of panel</td>
</tr>
<tr>
<td>Wide drive belt</td>
<td>A single, wide drive belt produces low-frequency noise at high levels</td>
<td>Replace the single, wide belt with a suitable number of narrower belts, to allow self-cancellation of noise at gaps and edges between belts and a reduction in belt surface area</td>
<td>Noise reductions of up to 10 dB attributable to self-cancellation of noise and reduced transmission from belt surfaces</td>
</tr>
<tr>
<td>Workshop with high levels of low- and high-frequency noise</td>
<td>Several machines, large and small, collectively cause high levels of broadband noise throughout the workshop, even at locations distant from any source</td>
<td>Suspend vertically oriented, high-density panels from ceiling, using taller, higher and denser panels for low frequency noise; Where vertically oriented panels will cause obstructions, suspend horizontal panels as far below the ceiling as possible</td>
<td>Vertical panels absorb sound on both sides; Horizontal panels more effective if positioned away from ceiling; Noise near individual sources unchanged, but overall levels reduced by up to 10 dB</td>
</tr>
<tr>
<td>----------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Pneumatic grinder</td>
<td>High-velocity exhaust air vented through grinder handle, causing turbulence in surrounding air &amp; noise</td>
<td>Fill handle with steel wool packing to diffuse exhaust air and reduce exit velocity</td>
<td>Noise reduction of 15-20 dB</td>
</tr>
<tr>
<td>Pneumatic scaling and cleaning gun</td>
<td>A simple, single-jet delivery nozzle generates excessive turbulence and noise at outlet</td>
<td>Replace single-orifice nozzle with compound nozzle for a lower-speed annular air stream around high-speed main stream; Install exhaust diffuser for a smoother transition of the main stream into surrounding air</td>
<td>Total noise reduction of up to 20 dB</td>
</tr>
<tr>
<td>Sandblasting bay</td>
<td>Noise from unenclosed source is transmitted throughout workshop</td>
<td>Build insulated enclosure around sandblasting bay, with heavy lead- and rubber-laminated curtains for access</td>
<td>Noise in immediate vicinity reduced by up to 20 dB, but operator will still require protection</td>
</tr>
<tr>
<td>Several small machines in workshop contribute to excessive levels of high-frequency noise</td>
<td>High frequency noise from a number of small bench-mounted machines is reflected by walls and ceiling into adjacent areas</td>
<td>Install a lightweight absorbent screen near each machine at a relatively high position; Cover ceiling with absorbent panels to prevent reflection into adjacent areas; Enclose each source with absorbent cabinet to contain noise and reduce levels at operator’s position, but avoid restricting access</td>
<td>Screen reduces high-frequency noise at operator’s position; Ceiling treatment controls propagation into adjacent areas; Enclosing individual sources reduces levels at operator positions and throughout area</td>
</tr>
</tbody>
</table>
Appendix 7.N.3 Personal protection

Table 7.N.3 Use of octave-band method in calculating noise reduction for HPD users

<table>
<thead>
<tr>
<th>Octave-band centre frequency (Hz)</th>
<th>*Sound level dB(A)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>125</td>
</tr>
<tr>
<td>1) Linear/unweighted SPL measured in workplace (dB)</td>
<td>85,0</td>
</tr>
<tr>
<td>2) A-weighting factor (dB)</td>
<td>−16,1</td>
</tr>
<tr>
<td>3) A-weighted SPL in dBA [1)-2])</td>
<td>68,9</td>
</tr>
<tr>
<td>4) HPD mean attenuation (dBA)</td>
<td>27,4</td>
</tr>
<tr>
<td>5) Standard deviation x2 (dBA)</td>
<td>7,8</td>
</tr>
<tr>
<td>6) HPD effective attenuation in dBA [4]-5])</td>
<td>19,6</td>
</tr>
<tr>
<td>7) Estimated effective SPL in dBA [3)-6])</td>
<td>49,3</td>
</tr>
</tbody>
</table>

*Sound level, in A-weighted decibels, is the logarithmic sum of the seven octave-band SPLs in same row

(Table adapted from Berger 2000, 428)
Appendix 7.N.4 Medical surveillance/audiometry

Audiometric test procedures are detailed in the two sub-sections that follow. The use of test results to evaluate hearing status and eligibility for compensation is outlined in Section 7.N.4.3.

7.N.4.1 Sequence of test frequencies

The preferred sequence of audiometric test frequencies, for each ear in succession starting with the better ear, is indicated in Table 7.N.4.1.

Table 7.N.4.1 Preferred sequence of audiometric test frequencies

<table>
<thead>
<tr>
<th>Order of audiometric test frequencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) 1 kHz</td>
</tr>
<tr>
<td>2) 2 kHz</td>
</tr>
<tr>
<td>3) 3 kHz</td>
</tr>
<tr>
<td>4) 4 kHz</td>
</tr>
<tr>
<td>5) 6 kHz</td>
</tr>
<tr>
<td>6) 8 kHz</td>
</tr>
<tr>
<td>7) 500 Hz</td>
</tr>
<tr>
<td>8) 250 Hz (optional)</td>
</tr>
<tr>
<td>9) 125 Hz (optional)</td>
</tr>
<tr>
<td>10) Repeat 1 kHz (mandatory for first ear only)</td>
</tr>
</tbody>
</table>

7.N.4.2 Determining hearing threshold levels

Procedures for determining the hearing threshold level for each test frequency are detailed in Steps a) through e), below:

a) Starting with the better ear (determined by questioning the subject or referring to previous results), present a 1-kHz test signal at a level that is 10 dB lower than that at which a response was observed during the familiarisation phase.

b) After each failure to respond to the test signal, increase the HL or loudness by 5 dB until a response is obtained.

c) After each response, decrease the level by 10 dB and present a signal. If no response is obtained, increase the level in 5-dB increments until the subject responds. Repeat this process until three responses are obtained from five presentations at the same level, and record that value as the hearing threshold level for 1 kHz.

d) Repeat Steps a)-c) for the same ear at each test frequency, until a hearing threshold level has been recorded for each.

e) Repeat Steps a) to c) at 1 kHz for the first ear. If the second result for 1 kHz agrees with the initial result to within 5 dB, proceed to the second ear, repeating Steps a) to d), and following the same sequence of test frequencies [1) to 7/8/9], as applicable], but without repeating the threshold determination for 1 kHz [10].

If a variation of 10 dB or greater is observed between the two thresholds determined at 1 kHz for the first ear, retest that ear at all frequencies and in the same order [1) to 7/8/9], as applicable], to obtain two results for 1 kHz that are within 5 dB. If inconsistencies of 10 dB or more are still apparent after the second confirmation attempt (third determination), the subject should be referred to an occupational medical practitioner for medical opinion and consideration of the possible need for an audiologist/specialist evaluation.

7.N.4.3 Evaluation of hearing status and eligibility for compensation

Workmen’s Compensation Commissioner Instruction 171 stipulates an increase in percentage loss of hearing (PLH) of 10 per cent or more, relative to the employee’s baseline audiogram, as indicative of a possible compensation claim. In terms of the COID Act [68(2)], the employer is obliged to inform the Compensation Commissioner or relevant mutual association of such cases within 14 days, irrespective of any agreement or dispute regarding their merit or validity. Tables for determining PLH attributable to hearing losses at 0.5; 1; 2; 3 and 4 kHz to may be obtained from the Compensation Commissioner.
Appendix 7.V.1 Regulations and standards for vibration

ISO 2631 Evaluation of human exposure to whole body vibration. Part 1
- Gives comfort levels for WBV
- Defines methods for the measurement of periodic, random and transient WBV
- Indicates the principle features that combine to determine the degree to which a vibration exposure will be acceptable

BS 6841 Guide to measurement of WBV and reported shock.

ISO 8041 Human response to vibration. Measuring and instrumentation.

Gives the standards for measuring equipment.


Specifically mentions HAVS

ISO 5349 Mechanical vibration. Guidelines for the measurement and assessment of human exposure to hand-transmitted vibration.

ISO 10819 Mechanical vibration and shock. Hand arm vibration.

Method for the measurement and evaluation of the vibration transmissibility of gloves at the palm of the hand.


Specifies a laboratory method of measuring vibration at the handle of hand-held power driven rock drills and rotary hammers.

Appendix 7.V.2 (source SIMRAC report GEN 503)

Vibration levels of commonly used hand-held equipment in the South African mining industry.

<table>
<thead>
<tr>
<th>Type of equipment</th>
<th>Average maximum weighted acceleration measured in ms⁻²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pneumatic rock drills</td>
<td>24</td>
</tr>
<tr>
<td>Hydraulic rock drills</td>
<td>24</td>
</tr>
<tr>
<td>Pavement breakers and jack hammers</td>
<td>19</td>
</tr>
<tr>
<td>Pneumatic grinders</td>
<td>1.3</td>
</tr>
<tr>
<td>Electrical hammer drills</td>
<td>8.8</td>
</tr>
<tr>
<td>Pneumatic wrench</td>
<td>10</td>
</tr>
<tr>
<td>Drill sharpening machine</td>
<td>2.5</td>
</tr>
<tr>
<td>Drill re-collaring machine</td>
<td>5.1</td>
</tr>
<tr>
<td>Hand-held compactor</td>
<td>13</td>
</tr>
</tbody>
</table>
### Appendix 7.V.3 Staging of HAVS

#### TAYLOR-PELMEAR CLASSIFICATION

<table>
<thead>
<tr>
<th>STAGE</th>
<th>Condition of digits</th>
<th>Work or social interference</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No blanching</td>
<td>None</td>
</tr>
<tr>
<td>0T</td>
<td>Intermittent tingling</td>
<td>None</td>
</tr>
<tr>
<td>0N</td>
<td>Intermittent numbness</td>
<td>None</td>
</tr>
<tr>
<td>0TN</td>
<td>Tingling and numbness</td>
<td>None</td>
</tr>
<tr>
<td>1</td>
<td>Blanching of one or more fingertips, with or without tingling and numbness</td>
<td>None</td>
</tr>
<tr>
<td>2</td>
<td>Blanching of one or more fingers with numbness. Usually confined to winter</td>
<td>Slight interference with home and social activities, no interference with work</td>
</tr>
<tr>
<td>3</td>
<td>Extensive blanching, frequent episodes in summer and winter</td>
<td>Definite interference at work, at home and with social or recreational activities</td>
</tr>
<tr>
<td>4</td>
<td>Extensive blanching of most fingers, frequent episodes in summer and winter, finger ulcerations</td>
<td>Occupational change to avoid further vibration exposure because of severity of signs and symptoms</td>
</tr>
</tbody>
</table>

#### THE STOCKHOLM WORKSHOP SCALES.

**Vascular component**

<table>
<thead>
<tr>
<th>Stage</th>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0V</td>
<td>No attacks</td>
<td>No attacks</td>
</tr>
<tr>
<td>1V</td>
<td>Mild</td>
<td>Occasional attacks affecting only the tips of one or more fingers</td>
</tr>
<tr>
<td>2V</td>
<td>Moderate</td>
<td>Occasional attacks affecting distal and middle phalanges of one or more fingers</td>
</tr>
<tr>
<td>3V</td>
<td>Severe</td>
<td>Frequent attacks affecting all phalanges of most fingers</td>
</tr>
<tr>
<td>4V</td>
<td>Very severe</td>
<td>As in stage 3V with trophic changes in the fingers</td>
</tr>
</tbody>
</table>

**Sensorineural component**

Staging is carried out separately for each hand. The number of affected digits on each hand must be noted.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0SN</td>
<td>Vibration exposed but no symptoms</td>
</tr>
<tr>
<td>1SN</td>
<td>Intermittent numbness with or without tingling</td>
</tr>
<tr>
<td>2SN</td>
<td>Intermittent or persistent numbness, reduced sensory perception</td>
</tr>
<tr>
<td>3SN</td>
<td>Intermittent or persistent numbness, reduced tactile discrimination and/or manipulation dexterity</td>
</tr>
</tbody>
</table>
Appendix 7.V.4 Medical examination and tests for HAVS

Clinical tests
The medical examination is performed by a doctor and includes the following:

i) Examination of the hands, fingers and upper body for callosities, scars, trophic changes and any skeletal abnormalities.

ii) Taking blood pressure on both arms.

iii) Allen’s Test- demonstrates the integrity of the radial and ulnar arteries of the hands.

iv) Tinel Test- this test is used to elicit symptoms of carpal tunnel compression.

v) Phalen’s Test- this test is used to elicit symptoms of carpal tunnel compression.

vi) Adson’s Test- detects obstruction to the arterial flow in the arm at the level of the neck.

vii) Purdue pegboard- assesses the dexterity of the hands and fingers.

viii) Grip strength- assesses the muscle strength of the hands using a dynamometer.

Objective tests for HAVS

i) Thermal Aesthesiometry assesses nerve damage.

This test measures temperature perception. The index and little fingers of both hands are tested. The fingertip is placed on a metal plate where the temperature is varied. The response button is pressed every time a change in temperature is detected. From these responses the cold and hot thermal perception thresholds are calculated. The difference between the cold and hot thermal perception thresholds is called the Thermal Neutral Zone (TNZ) which is the range of temperature, which the subject cannot detect. The more damage to the nerves of hands and fingers the larger the TNZ. The software for the Thermal Aesthesiometry has a built in safety feature which returns the temperature to the reference temperature (32.5°C) if the response button has not been pressed and the temperature reaches 55°C or 5°C. The hardware has an in built thermostat, which automatically cuts out the heat if the temperature reaches 57°C.

ii) Vibrotactile Threshold Test to assess nerve damage.

This test measures vibration perception. The index and little fingers of both hands are tested. Two vibration frequencies (31.5 Hz and 125 Hz) are applied to a probe. The fingertip is placed on the probe and a response button is pressed every time vibration is felt. From these responses the vibration perception threshold is calculated. The more damage to the nerves of hands and fingers, the higher the vibration perception threshold. The two vibration frequencies used in this test are not harmful.

iii) Cold Provocation Test to assess damage to blood vessels in the hands.

Both hands are tested. Thermocouples are attached to the fingertips. The hands are gloved and immersed in a 15°C waterbath for 5 minutes. On removal from the waterbath they are allowed to rewarm at room temperature for 10 minutes. During this time the finger skin temperature is measured. The time taken by the fingertip to rewarm by 4°C is recorded. The more damage to the blood vessels, the longer it takes for the fingertips to rewarm. The temperature in the waterbath is thermostatically controlled.
CHAPTER 8

Heat

The assessment and subsequent management of heat stress, particularly in a South African mining context, is complex. Heat stress is the net effect on the human body of the combined contributions of metabolic heat production during physical work and environmental heat loads. Factors such as inherent traits, general health and physiological status have a profound influence on the ultimate level of heat stress. In this respect, heat stress is unique and the integrity of the risk assessment-risk management process is heavily dependent on the extent to which occupational hygiene and occupational medicine are integrated.

The purpose of the chapter is to emphasise this elementary requirement and highlight the rationale and the principles underlying the risk assessment and risk management process, as well as drawing attention to some of the more common pitfalls. Figure 8.1 provides a framework against which risk assessment and risk management should be conducted, implemented and controlled. It should be noted that the process described takes into account the essential requirements specified in the Mine Health and Safety Act and the relevant Department of Minerals and Energy’s guideline for the compilation of a mandatory code of practice or, more specifically, an occupational health programme.

Dr A.J. Kielblock
Occupational Hygiene Consultant

Johan Kielblock consults to AngloGold Health Service. He is an applied physiologist whose main research interest has focussed on experimental heat stroke and human heat stress. He also has extensive experience in the broader field of occupational hygiene including hearing conservation, respiratory protection and shift systems and he has remained actively involved in health and safety legislation, serving on several tripartite committees.
Glossary

c: kilocalorie (energy unit)
DIC: disseminated intravascular coagulation (of blood)
endurance fitness: the ability of an individual to exploit his/her maximal aerobic capacity
kJ: kilojoule (energy unit)
HTS: Heat tolerance screening (a purpose developed test)
HSM: Heat stress management
SD: Standard deviation (a statistical expression)
VO₂ max or maximal oxygen capacity: inherent ability to do physical work
W/m²: the body’s energy release rate in terms of its surface area
8.1 Introduction
Circumstantial evidence suggests that human beings evolved as tropical animals: we possess a well developed sweat mechanism and our skin is practically devoid of insulative hair. In addition, our thermoregulatory system has a greater reserve of heat elimination than of heat conservation capacity indicating that heat presented a greater threat to our ancestors than cold. Despite these physical and physiological adaptations, heat disorders are of the oldest recorded disorders known.

Most people have experienced the physiological effect imposed by physical effort in the face of high environmental heat loads. It is also a stress commonly encountered in many industrial settings, fire fighting operations, and, in South Africa, in the gold and platinum mining industry as well as open cast mines in regions such as Messina and Phalaborwa. The consequences vary from slight discomfort to the extreme, heat stroke, and the impact can be deterioration in productivity, safety and health, physical and mental wellbeing and even social relationships. This chapter addresses one particular aspect, namely physical work in heat in the mining industry: it considers the thermal environment, man’s capabilities and limitations during work in heat, strategies to resolve the problems associated with heat exposure and, finally, legislation. The chapter highlights the risk assessment and risk management process. Although the emphasis falls on the South African mining industry, relevant experience from elsewhere is included.

8.2 Extent and consequences of heat stress
Heat has been recognised as a health hazard in South African mines, particularly in the gold mines, for more than eight decades since Orenstein and Ireland’s initial attempts in 1919 to quantify occupational heat stress.

Rudimentary heat acclimatisation programmes were introduced in the 1920s and a scientifically based heat acclimatisation programme in 1932. Heat tolerance testing commenced in 1977 and formal Heat Stress Management in 1991.

Responses to heat stress are extremely varied and the underlying mechanisms are often not fully understood. At lower levels of heat stress, the main signs are behavioural changes, including aggression, depression and numerous psychological problems. In an industrial setting, these present as irritability, loss of concentration, increased errors and a loss of efficiency in both mental and skilled tasks. For example, with respect to mild to moderate heat stress, the Index of Heat Stress includes ‘subtle to substantial decrements’ in tasks involving intellectual input, dexterity or alertness. At higher levels of heat stress, the impact appears to become more ‘physiological’ in nature, with progressive decrease in physical work capacity and, ultimately, the development of heat disorders. It is important to note that heat stress adversely affects mental performance much sooner than any deterioration occurs in physical work capacity. The consequences of heat stress can be expressed in terms of safety, health and production outcomes.

8.2.1 Safety and accidents
Well designed investigations demonstrated the impact of a systematic reduction in the environmental heat load on safety over the period 1977-1982 at President Steyn gold mine. The objectives were to improve working conditions in order to enhance productivity and to reduce perceived heat stress related accidents and disorders by a substantial increase in refrigeration capacity. The stope face wet-bulb temperatures were decreased from 30.2 to 28.5°C and the accident frequency rate improved from 41.8 to 16.3 incidents per thousand employees per annum, although this benefit may not be due only to the reduction in heat stress.

8.2.2 Health
Heat stress can have a positive or negative health effect. Within certain limits, there is a benign and beneficial process of adaptation. Under different circumstances, the adverse consequences present as a range of heat disorders, including heat stroke and death. The impact of heat stress on health is
determined by numerous factors. Although these are not all completely understood, heat management programmes to promote both health and well being are based on good scientific evidence that these factors or ‘determinants’ are inextricably part of the risk assessment process.

8.2.3 Production and productivity

A good correlation (0.84) has been shown between the cooling power of air (in W/m²) and productivity (in tons/man/month), suggesting a 75% increase in production for an increase in cooling power of about 150 to 300W/m². In addition, an increase in labour productivity of nearly 40% was associated with a progressive reduction in wet-bulb temperature from 30.2 to 28.5°C. These studies in the South African mining industry clearly demonstrate the benefits of an improved thermal environment. However, numerous other factors also affect productivity and to rely solely on cooling power is an oversimplification.

Efforts to link labour productivity and the thermal environment have been based on a reported maximum metabolic rate of 380W/m², not taking into account duration of work, and an assumption that cooling power should match metabolic rate. For conventional underground work in gold and platinum mines, mean metabolic rate ranges from about 130 to nearly 180W/m², with peaks close to 300W/m². Corresponding levels for mechanised mines are very similar with slightly higher peaks, i.e. 337W/m². Very hard work (i.e. 240W/m²) may, in instances, exceed one hour. These metabolic rates suggest that where objectives are defined in terms of an optimisation of production, the environmental cooling power should be set within the range of 300 to 350W/m². However, at these high metabolic rates self pacing is non existent. As a result, work tends to become more anaerobic in nature and the risk of a disproportionate rise in body temperature increases. A corollary is premature fatigue that may impact on both safety and health.

8.3 Origins of heat stress and definitions

8.3.1 Heat stress and strain

Heat stress is the net load on the human body from the combined contributions of metabolic heat production and external environmental factors. These include air (or dry-bulb) temperature, water vapour content of air (most commonly expressed in terms of wet-bulb temperature), relative humidity (as a percentage), the partial pressure of water vapour or the dew point temperature, radiant heat (also referred to as globe temperature), air movement and clothing. Heat strain, by contrast, is the physiological response to heat stress.

8.3.2 Heat balance

The exchange of heat between the body and its environment involves both human physiology and physics. The basis of this complex field is the so called heat balance equation. The heat balance equation is important because it enables hazard identification and a differential assessment of risk, establishes the risk management process, defines its limitations, and facilitates medium to longer term strategy development.

All living organisms generate heat, and it is therefore necessary to incorporate this metabolic heat (H) into the equation. (The consumption of oxygen at a rate of 1 l/min corresponds to 4.825°C/min, 20,197 kJ/min or 337W.) The equation representing steady state thermal balance is

\[ H \pm K \pm C \pm R - E = 0 \]

where K represents conduction, C convection, R radiation and E evaporation. H denotes the difference between the total energy liberation in the body (M) and the mechanical work rate (W). The term M-W may therefore replace H. In practice, the heat balance equation can be ‘manipulated’, within physiologic limitations, to describe various combinations of metabolic and environmental
conditions under which thermal equilibrium exists or could be achieved. This approach presumes a comprehensive knowledge of all the relevant variables and assumptions.

8.3.2.1 Conduction

Skin contact with solid objects is usually very small so conduction is negligible and is ignored, except in the case of body-cooling garments.

8.3.2.2 Convection

Convection is the exchange of heat between the body surface (skin and clothing) and the surrounding air. The basic equation is

\[ C = h_c (t_s - t_a) \]

where \( C \) represents the rate of heat exchange (W/m\(^2\) body surface), \( t_s \) and \( t_a \) the body surface and air temperatures respectively, and \( h_c \) the convection coefficient. The main determinant is the difference in temperatures \( (t_s - t_a) \), but this is modified through \( h_c \), by air movement and body surface area (and hence posture). It is important to appreciate that when \( t_a \) exceeds \( t_s \), convective heat gain occurs. From a health and safety point of view, air temperatures of 33°C to 35°C and above should be considered hazardous. Calculated upper limit equilibrium skin temperatures (for a probability of less than 10\(^{-6}\) that rectal temperature will exceed 40°C) range from about 33.7°C at work rate of 280 W/m\(^2\) to 35.6°C at 120 W/m\(^2\).

8.3.2.3 Radiation

Radiation is the process by which electromagnetic energy is transmitted through space. The equation is

\[ R = h_r (t_s - t_r) \]

where \( R \) represents the rate of radiant heat flow (W/m\(^2\)), \( t_s \) the mean body surface (skin) temperature, \( t_r \) the mean surface temperature of surrounding objects, and \( h_r \) the coefficient of radiant heat exchange. The coefficient makes allowance for body surface area but, it does not contain a term for air movement since air movement does not influence radiant heat exchange.

8.3.2.4 Evaporation

The process of evaporation of water from the skin results from differences in water vapour pressure between the skin and the surrounding air. The evaporation of one gram of water uses about 2.4 kJ of heat. The equation is

\[ E = h_e (p_{sk} - p_a) \]

where \( E \) represents the rate of evaporative heat loss (W/m\(^2\)), \( h_e \) the evaporation coefficient, and \( p_{sk} \) and \( p_a \) water vapour pressure at skin and ambient temperatures, respectively. The coefficient makes allowance for body surface area, air movement, and atmospheric pressure. It is complicated by the nature of sweating and subsequent evaporation. The equation should not be manipulated beyond physiological limits.

Although evaporative heat loss is suppressed by high ambient humidities, evaporative heat loss can take place in a saturated atmosphere and is determined by the term \( p_{sk} - p_a \). Thus, at a skin temperature of 35°C, the prevailing (saturated) vapour pressure of 5.6 kPa far exceeds the saturated vapour pressure of 3.2 kPa at an air temperature of say 25°C.

8.3.3 Metabolic heat production and dissipation

By far the largest source of heat results from metabolic heat production (M). Even at peak mechanical efficiency, 75% to 80% of the released energy associated with muscle contraction and relaxation is directly liberated as heat. This is not a problem if the period of exertion is relatively short and may even be of benefit. However, when the period of exertion is longer (15-30 minutes), heat storage could
be dangerous unless counteracted by effective heat dissipation. See Appendix 8.1 for scenarios to illustrate the consequences of impaired heat dissipation. Heat dissipation depends on the secretion of sweat and its subsequent evaporation for about 70% of total heat dissipation, on convection for 20 – 25%, and on radiation which, although generally not exceeding 5%, could amount to about 630 kJ/h (150 C/h) on a cloudless day.

The heat balance relationships have several important practical implications with respect to risk management.

- Risk assessments must be sufficiently comprehensive to ensure that all possible contingencies are covered. Thermal environments are often defined as ‘acceptable’ on the basis of limited information, for example using only dry-bulb temperature. However, the operator of a heavy machine working in such an ‘acceptable’ environment could be subjected to a stressful microenvironment resulting from high radiant heat loads
- Prevention of dehydration is extremely important since maximum sweat rates are of the order of about one to two litres per hour
- Clothing should be appropriate and reliance must not be placed on the cooling from sweat evaporation. Sweat loss is seldom equal to sweat evaporation since sweat often drips from the body, e.g. in very humid conditions or when air movement is low. Inappropriate clothing also reduces evaporation from the skin. Physiological adaptations to heat (heat acclimatisation, a natural process, or heat acclimation, as achieved artificially in a climatic chamber) improve both sweat secretion and distribution over the skin. Thus, unrealistic values should not be assumed for evaporation in order to predict thermal balance or homeostasis
- The air temperature at which convective heat loss becomes convective heat gain is in the region of about 35°C, i.e. an approximation of skin temperature. In other words, while air movement enhances convective heat loss below this temperature, above this temperature, increased air movement accelerates heat gain. Air velocities in excess of about 5m/s do not appear to substantially increase convective heat loss. These considerations impact on ventilation requirements, i.e. source control through engineering practices
- Solar heat gain can be substantial in many open-air surface and open-pit operations. The hazard is greater when there is also a high air (dry-bulb) temperature. Both air cooling and insulation or shielding are then necessary. As with dry-bulb temperature, the crossover point is a mean radiant temperature of 35°C, i.e. the body will start to gain heat. A temperature of 37°C should be regarded as an upper limit for sustained physical work and engineering controls must be introduced at this stage. For most people, the pain threshold for an elevated skin temperature is 45°C

8.3.4 Physical work loads in South African mines

Physical work, especially within an industrial context, is often categorized in terms of work rate and three classification systems are presented in Appendix 8.2. Any assessment based purely on rate is, however, of limited practical value. It is far more important to consider the manner in which the work is being done. Aspects include safety and health, the opportunity to influence the working situation and to govern one’s own work rate (self pacing), the general atmosphere and environment, and the arrangement of shifts. Even lifestyle cannot be ignored.

A comprehensive reference to the physical demands of both mechanised and conventional underground gold and platinum mining operations in South Africa reported that average work rates are of a moderate to heavy intensity. Production was mostly associated with heavy work, while very heavy work appeared to be the exception and, for all tasks observed, a high degree of self-pacing was evident. Applying the categorisation system of Astrand and Rodahl (1977) or that of the ACGIH (1998), as given in Appendix 8.2, work rates in the South African gold and platinum mines are only of ‘moderate’ intensity, even for 95% prediction limits. However, as heat stroke is prevalent in virtually all work categories where the mean metabolic rate exceeds 160W/m², it is equally clear that categorisation systems could be quite arbitrary unless linked to specific objectives. In an industrial context, only two major distinctions are relevant, i.e. work that is self-paced (i.e. generally not exceeding 40% of maximal aerobic capacity or heart rates of about 110 beats per minute) and work which, for a variety of reasons, is ‘driven’ and, therefore, inherently strenuous. Assessments of work
rates in mines or operations other than underground gold and platinum mines are not nearly as comprehensive as those documented by Van Rensburg et al. (1991). However, although these mines or operations are apparently less prone to the occurrence of heat disorders, unpublished surveys suggest that work rates and work rate excursions are significant. Also, while seasonal temperature fluctuations do not have a profound effect on deep-level mines, open-pit and other surface operations may face disproportionate environmental heat load escalations during the summer months. Tube mill relining, a surface operation typical of many gold mines, provides an example of work rates which can be described as ‘driven’. Local research showed that the average metabolic rate for a relining crew amounted to 248W/m² with peaks of 328W/m² and continuous work of more than 240W/m² being maintained for up to 80 minutes. Although the prevailing environmental conditions typical of springtime were translated into two heat stress indices, neither indicated any action or special precautions. However, should environmental conditions deteriorate, a very real risk is likely to develop.

8.3.5 Environmental heat loads

Sources of heat in mines can be divided into two broad classes, namely ‘natural’ and ‘artificial’. The first depends on the nature of the excavations and the rock strata, whereas the other depends on the activities and operations of the mine. In many instances, climate and weather cannot be disregarded. In underground mines, one of the main considerations is the transfer of heat from the broken rock. Virgin rock temperatures, which apply to unbroken rock, increase with depth from about 9°C/km for the Central Witwatersrand region to about double that for the Bushveld Igneous Complex. Dry-bulb temperatures are generally a close approximation of rock surface temperature (should the area be unventilated). The use of water for drilling and dust suppression, in combination with high dry-bulb (air) temperatures, creates high humidity levels. A second major source of heat results from the autocompression of downcast ventilation air and, to a lesser extent, water. The respective contributions are 9.79 and 2.18°C/km of depth. Machinery and many other sources of heat also add to the environmental heat load. In addition, slight but critical seasonal drifts are often discernible and should therefore be taken into account during the assessment of risk. Several methods have been developed to estimate overall heat loads and in this respect Hemp’s review (1982) provides an excellent reference.

In general, environmental conditions in underground platinum mines are similar to those in gold mines. Although the geo-thermal gradients are much higher on platinum mines, these mines are much shallower. Also, mining methods do not differ significantly. Therefore, the level and nature of heat stress experienced by underground employees appear to be comparable. Personal protection, as discussed elsewhere in this chapter, would obviously share a common basis.

Environmental heat loads in most underground coal mines are low and due to the extensive mechanisation of these operations, heat stress is a non issue. An exception is Tshikondeni Coal Mine. Although shallow (anticipated not to exceed 400m), the geo-thermal gradient is exceptionally high (25.8°C/km) and with surface summer temperatures exceeding 35°C and relative humidity peaks of over 90%, underground conditions are quite severe and indicative of special precautions. With a high degree of mechanisation, radiant heat loads pose a further complication, the only apparent redeeming feature being low physical work demands.

The environmental heat load of many surface and open-pit operations, is a function of climate and seasonal drifts. Although small in deep-level mines, these seasonal variations cannot be ignored. A well-established meteorological database is often indispensable. However, the operation itself must also be assessed. For example, tube mill relining is associated with very high work rates and the potential for the development of severe levels of heat stress, with even the slightest shift in the environmental heat load, cannot be underestimated.

8.4 Determinants of work in heat

Although most individuals exhibit similar response patterns to working in heat, the actual response pattern for any given individual is a function of a variety of factors. These determinants can be divided
into inherent and external categories. Inherent determinants, over which the individual has no control, include factors such as maximal work capacity, age, gender, and body dimensions. The most important external determinants, over which the individual has some control or which he voluntarily accepts, are nutrition and hydration. Inherent determinants may not be generalised; the assessment of risk should be directed at the individual through risk based medical and physical examinations, as well as through medical surveillance.

8.4.1 Work capacity

The relationship between maximal oxygen uptake (VO₂ max) and tolerance to work in heat has been well researched. Individuals with high a VO₂ max are at an advantage in terms of exercise heat tolerance. VO₂ max is regarded as a significant function of cardiac output, and hence heat tolerance because blood flow can be adequately maintained to both working skeletal muscles and the skin to meet the body’s thermoregulatory commitments. However, VO₂ max has insufficient predictive power to be used as a single criterion of heat tolerance and should not be used as a selection tool in an industrial context.

8.4.2 Endurance fitness

Whereas VO₂ max is largely a genetically determined quality, physical or endurance fitness is achieved through training. Sweat sensitivity is elevated and, for a given rise in body temperature, more sweat is produced. However, the correlation cannot be applied as a labour selection device for work in hot environments. Although significantly better than VO₂ max, endurance fitness, in isolation of other parameters of heat tolerance, remains equally inadequate.

8.4.3 Nutrition and hydration

With regard to nutrition and hydration, physical work in an industrial context, especially if complicated by high environmental heat loads, has much in common with endurance athletics. However, the constraints placed on the industry worker are greater. For the endurance athlete, peak performances are sporadic events interspersed with meticulously planned training programmes; for the industry worker, optimum performance and sustained productivity is a daily challenge in which both physical and mental recovery must be compressed into the time available between consecutive shifts. Some of the more critical aspects of nutrition and hydration are reviewed in Appendix 8.3.

8.4.4 Age

Several studies support the notion that age per se does not compromise heat tolerance. The decline in heat tolerance generally associated with advancing age is primarily a function of an age-related decline in VO₂ max, which, in turn, reflects a diminished functional capacity of the cardiovascular system. However, training in older individuals can enhance heat tolerance.

There is an apparent age-related increase in susceptibility to heat illnesses. In any population, it is likely that heat ailments, including fatalities, will be more common in older people during the challenge of thermal stress, not as a result of age per se, but rather as a result of a general decline in health. An example is the extreme heat susceptibility of patients with congestive heart disease. Industrial populations generally show a gradual decline in heat tolerance after the age of 50. There is some evidence of an age-associated reduction in cutaneous vasodilation (ability to widen the cross sectional diameter of blood vessels of the skin) and maximal sweat rate. However, most of the changes can be attributed to alterations in lifestyle, which reduce physical activity and increase the accumulation of body fat. Age does not appear to impair heat tolerance or ability to acclimatise if the individual maintains a high level of aerobic conditioning. Ageing populations are nevertheless subject to an increasing incidence of cardiovascular disease or other pathologies that may impair individual heat tolerance.

8.4.5 Gender

Early laboratory studies on women indicated that they were relatively intolerant to work in heat. However, it is now recognised that nearly all of the gender differences can be explained in terms of
body size and acquired levels of physical fitness and heat acclimatisation. There are only minor differences in heat dissipation mechanisms: higher maximum sweat rates in males may enhance tolerance for extremely hot, dry environments, while females are better able to suppress excess sweating and, therefore, conserve body water in hot, humid environments. Although the menstrual cycle is associated with a shift in basal body temperature and slightly alters thermoregulatory responses in women, these physiological adjustments are too subtle to influence heat tolerance and thermoregulatory efficiency in real work situations. In pregnancy, experimental findings show no thermoregulatory detriment; in fact, there are even some advantages, if only in the short term.

When allowance is made for individual physique and fitness, men and women are essentially alike in their responses to heat stress and their ability to acclimatise to work under hot conditions. For this reason, selection of workers for hot jobs should be based on physical capacity, not gender. Very small groups of sedentary individuals of either gender will show poor tolerance for work in heat.

8.4.6 Body composition and dimensions

In general, shorter individuals have a higher body surface area to mass ratio for the same body mass. This is regarded as the fundamental reason why women tolerate humid heat better than their male counterparts. Of course, in high environmental heat loads, a high surface area to mass ratio is a disadvantage, an event of particular relevance to children. For the same reason, prospective employees with a low body mass (45-50 kg) should not be assigned to strenuous work in heat.

With regard to obesity, an apparent conflict arises. While it is well known that obese individuals exhibit heat intolerance, the presence of an insulative layer of fat is irrelevant during heat exposure because heat conduction is determined by blood flow from the core to the periphery and not by tissue conductance. High body fat content, has little direct effect on thermoregulation, as heat dissipation at the skin involves capillaries and sweat glands which lie closer to the skin surface than the subcutaneous fat layer. However, obese persons are handicapped by their excess body weight because every movement requires greater muscular effort and therefore generates more heat than a lean person. In addition, obesity often reflects an inactive lifestyle with resulting lower aerobic capacity and absence of heat acclimatisation. In the South African mining industry, the relationship between heat stroke susceptibility and body mass is inconclusive.

8.4.7 Heat acclimatisation, heat tolerance and heat intolerance

The primary adaptive response to heat exposures may be regarded as an increased capacity to sweat. It is therefore not surprising that workers with an inherently high degree of heat tolerance also exhibit profuse thermal sweating. Although an oversimplification, it is nevertheless convenient to define heat acclimatisation as the process whereby thermoregulatory strain is transferred from the circulation to the sweat mechanism.

The underlying physiology of heat tolerance or conversely, heat intolerance, is not fully understood and, in the absence of purpose designed tests, it is difficult to predict an individual’s relative level of heat tolerance. However, a distinction can be made between what may be termed ‘inherent’ heat intolerance (or tolerance) and ‘acquired’ heat intolerance. Inherent heat intolerance applies where there is no overt physical or clinical evidence suggestive of an inability to undertake physical work in heat. This form of heat intolerance only affects a small fraction of the population. In the South African mining industry, for example, inherent heat intolerance varies between 0.7% on the basis of heat tolerance screening and 3.6% using the four hour heat tolerance test (now discontinued).

Acquired heat intolerance often follows heat stroke in the South African mining industry. Although apparently fully recovered, many individuals remain heat intolerant and cannot acclimatise, a condition that is known to last for years. Clearly, the occurrence of heat stroke in an industrial setting creates an immense dilemma with respect to continued employment in the same environment.

8.5 Heat disorders

The World Health Organisation (WHO, 1977) classification of heat disorders is presented in Table 8.1. Two distinct populations are at risk of developing heat disorders, excluding infants. The larger
population consists of the elderly, especially the poor and those with chronic conditions, such as diabetes mellitus, obesity, malnutrition, congestive heart failure, chronic alcoholism, dementia and the need to use medication that interferes with thermoregulation. The second population comprises healthy individuals who attempt prolonged physical exertion or are exposed to excessive heat stress. The South African mining industry’s labour force is mostly representative of the latter healthy population. Factors predisposing active people to heat disorders include poor physical fitness, lack of acclimatisation, and low work efficiency (i.e. having to work harder than peers to complete a given task).

Table 8.1 Classification of heat disorders

<table>
<thead>
<tr>
<th>ICD² Code</th>
<th>Clinical designation</th>
<th>Aetiological category</th>
</tr>
</thead>
<tbody>
<tr>
<td>992.0</td>
<td>Heat stroke³</td>
<td>Thermoregulatory failure</td>
</tr>
<tr>
<td>992.0</td>
<td>Heat hyperpyrexia</td>
<td></td>
</tr>
<tr>
<td>992.1</td>
<td>Heat syncope</td>
<td>Orthostatic hypotension</td>
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<tr>
<td>992.2</td>
<td>Heat cramps</td>
<td>Salt and water imbalance</td>
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<tr>
<td>992.3</td>
<td>Heat exhaustion</td>
<td></td>
</tr>
<tr>
<td>992.4</td>
<td>Heat exhaustion</td>
<td></td>
</tr>
<tr>
<td>992.5</td>
<td>Heat exhaustion</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heat fatigue</td>
<td>Behavioural disorder</td>
</tr>
<tr>
<td>992.6</td>
<td>Heat fatigue</td>
<td></td>
</tr>
<tr>
<td>992.7</td>
<td>Heat oedema</td>
<td>Lack of acclimatisation</td>
</tr>
<tr>
<td>992.8</td>
<td>Other heat effects</td>
<td></td>
</tr>
<tr>
<td>992.9</td>
<td>Unspecified</td>
<td></td>
</tr>
<tr>
<td>705.1</td>
<td>Heat rash⁴</td>
<td>Skin disorders and sweat gland injury</td>
</tr>
<tr>
<td></td>
<td>Anhidrotic heat exhaustion</td>
<td></td>
</tr>
</tbody>
</table>

1 Based on WHO (1997) and Hubbard and Armstrong (1989)
2 International Classification of Disease
3 Synonyms: sunstroke, apoplexy, pyrexia, ictus solis, sirsiasis and thermoplegia
4 Synonyms: prickly heat, miliaria (various forms)

The classification system presented in Table 8.1 is useful as a general reference. It also highlights the complexity of the pathophysiology of the respective manifestations of heat stress. In practice, however, it is convenient to make four major distinctions, namely skin disorders, heat cramps, heat exhaustion and heat stroke.

8.5.1 Skin disorders (see Chapter 13)

Miliaria is the most common skin disorder associated with heat exposure. Its incidence in the South African mining industry is uncertain but is important because it can lead to anhidrosis, i.e. an inability to release sweat through the skin.

8.5.2 Heat cramps

The term, heat cramps, is a misnomer. Exposure to heat does not elicit muscle cramps. The tetanic-like convulsions often observed during exposure to heat are secondary to the respiratory alkalosis caused by hyperventilation. This represents atypical heat exhaustion, not ‘heat’ cramps. Although oral salt therapy is believed to relieve muscle cramp rapidly, it is unlikely that such large, acute salt losses occur, even during profuse sweating. During prolonged muscle exertion, tissue electrolyte and acid-base changes become significant. In addition, reduced plasma volume is
conducive to cramps which, in turn, are alleviated by restoring plasma volume. The cause of muscle cramp is thus far more complex than simple salt depletion. The occurrence of cramps even in well trained athletes supports this view and suggests that, in general, muscle cramp originates from an impaired microcirculation.

Therefore, not all cramps that occur in heat can be recorded as ‘heat cramps’. It is obvious that the origins of ‘miner’s cramps’ are whole body salt and fluid losses. The implication is that electrolyte replacement is inadequate, so resulting in whole body salt depletion. Heat cramps differ from exertion-induced cramps in that they do not involve entire muscles but rather individual muscle bundles, especially of the abdominal wall and limbs, giving the appearance that the cramp is ‘wandering’.

Heat cramps occur mostly in unacclimatised individuals and are characterised by low plasma sodium levels, low urine sodium chloride content and high urinary specific gravity levels. Accordingly, rest and saline therapy (0.1% by mouth or 0.5-1.0 normal saline intravenously) are recommended. Although chronic salt losses tend to cause dehydration, thereby lowering the plasma volume, heat cramps may occur independently from dehydration.

The main distinguishing features of heat cramps, as opposed to exertion induced cramps, are related to the environment, the state of heat acclimatisation, the onset period, the nature of the cramp and plasma and urine sodium content.

8.5.3 Heat exhaustion

The WHO classification of heat disorders presented in Table 1 lists a range of disorders which represents a continuum of pathophysiology rather than distinct entities. With respect to heat syncope (fainting) and the respective forms of heat exhaustion and heat fatigue, the common factor is mostly of circulatory origin and is induced by a poor state of acclimatisation. For convenience, therefore, the term ‘heat exhaustion’ includes all these disorders. Heat exhaustion is attributed to an inability of the circulation to meet simultaneously the demands of thermoregulation, i.e. a vast flow of blood to the skin and to vital organs such as the brain and active skeletal muscle. Chronic heat exhaustion, in contrast to the common acute version, may have its origin in salt depletion, i.e., dietary imbalance.

Heat exhaustion is more likely to occur during the unacclimatised state and in individuals with some form of circulatory insufficiency. Obviously, the condition is aggravated by dehydration. It may also occur completely independently of dehydration as a result of an improper redistribution of the circulation. Irrespective of the precise origin, it follows that the trigger mechanism is a reduction in circulating blood volume.

Presenting symptoms of heat exhaustion reflect the underlying mechanism. Thus, weakness, a feeling of an inability to continue work, frontal headache, anorexia, nausea, faintness or actual fainting and breathlessness are typical symptoms. Body temperature is normal or slightly elevated, sweating proceeds normally, and the skin is pale. Further investigation may reveal high heart rates and low arterial blood pressure, signs of incipient to overt circulatory shock.

Heat exhaustion is normally self limiting: either the person is incapable of continued effort in heat or he faints. Subsequent treatment is aimed at restoring normal circulatory function. In uncomplicated cases of heat syncope, stopping muscular activity is sufficient to restore the circulation. Rest and removal to a cooler environment is the only treatment needed. However, dehydration induced heat exhaustion, the more usual consequence of exposure to sudden increases in the environmental heat load and/or work rate, should be treated by intravenous infusions, with care being taken to prevent circulatory overload. Dehydration induced heat exhaustion, especially during sporting endeavours, probably constitutes the critical stage between primary dehydration and imminent heat stroke.

The link between heat exhaustion and heat stroke is controversial. Heat exhaustion, by definition, represents a state of fatigue that is likely to be self limiting. The signs and symptoms of the two disorders differ and may occur independently from one another. This suggests that heat exhaustion does not necessarily progress to heat stroke. On the other hand, where such a progression does indeed exist, it depends on the level of hyperthermia at the point of collapse. Experimental studies suggest
a threshold temperature of just over 40°C (40.4°C) and most likely in a young, healthy and highly motivated individual who has a high fitness level and does not recognise a critical onset of fatigue and overt exhaustion. These factors are highly relevant in the working context and underline the importance of self pacing or the introduction of work-rest cycles.

In summary, a distinction can be made between what may be termed ‘acute’ and ‘progressive’ forms of heat exhaustion. The former is more related to fluid loss and, typically, the onset is within hours. Progressive heat exhaustion takes place over days, mainly because of an inadequate dietary electrolyte replenishment. Treatment is a combination of rest, body cooling, and fluid and electrolyte replacement.

8.5.4 Heat stroke

Heat stroke is regarded as one of the few true medical emergencies and, if effective treatment is not instituted promptly, it carries a mortality rate of up to 80%. Since predisposing factors are often ignored through apathy, or not recognised as such because of inadequate training, the onset of heat stroke often seems rapid and is notoriously unpredictable.

By current definition, heat stroke represents a condition in which elevated body temperatures are causally related to tissue damage, often of an irreversible nature. Although many tissues are damaged in heat stroke, the patient’s outcome depends mainly on the degree of injury to the nervous system, kidneys and liver; the latter two organs being damaged almost invariably. The accurate diagnosis of heat stroke, by implication, must therefore include parameters of tissue damage, the most practical being the assay of tissue enzymes in serum.

Much of the current uncertainty about heat stroke probably originates in its earlier definitions. In earlier literature, heat stroke was regarded as a ‘disorder of thermoregulation characterised by the total absence of sweating, body temperature in excess of 41.1°C (106°F), and severe disturbances in brain function.’ A major objection to such a definition is that sweat cessation is not always a fundamental sign since heat stroke may occur not only from failure of the thermoregulatory system as a result of impaired central nervous system function, but also from overloading its capacity. Moreover, the setting of an apparently arbitrary temperature level is equally unacceptable. At best, the older concepts describe a highly advanced degree of heat stroke.

While body temperature per se constitutes an invaluable guide to the severity of physiologic strain, the exposure time, which is often unknown, is of equal importance. This eliminates the need to define exactly when body temperature is too high. The decision to initiate (or withhold) treatment should, therefore, not be based on body temperature alone but rather on an assessment of events leading up to the incident, including environmental conditions, and other important signs and symptoms.

The observation that heat stroke can and often does occur in the absence of the ‘classical’ yardsticks has led to a distinction between the so called ‘exertion induced’ and ‘classical’ forms. Reference to Table 8.2 underlines the fact that, while the recognition of ‘classical’ heat stroke is relatively simple, ‘exertional’ heat stroke, which is rather typical of mining conditions, is not likely to be recognised as such. Emergency treatment, therefore, is often inappropriate or not instituted at all. A more detailed distinction between ‘classical’ and ‘exertional’ heat stroke is given in Table 8.3.

**Table 8.2 Heat stroke classification**

<table>
<thead>
<tr>
<th>‘Classical’ (thermoregulatory failure)</th>
</tr>
</thead>
<tbody>
<tr>
<td>— Body temperature &gt; 41°C</td>
</tr>
<tr>
<td>— Sweat cessation</td>
</tr>
<tr>
<td>— Nervous system disturbances</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>‘Exertional’ (thermoregulatory overload)</th>
</tr>
</thead>
<tbody>
<tr>
<td>— Atypical signs</td>
</tr>
<tr>
<td>— No fixed pattern</td>
</tr>
<tr>
<td>— Unpredictable onset</td>
</tr>
</tbody>
</table>

*Internationally recognised but in conflict with ICD Code 992.0 (Table 8.1)*

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During the prodromal period, which precedes the onset of heat stroke, the patient often has few symptoms up to the point where signs of typical heat stroke appear. However, symptoms may precede the actual onset of heat stroke for a period as long as days: typical signs and symptoms including headache, dizziness, dimming of vision, nausea, vomiting, breathing irregularities, fatigue, muscle cramps, thirst, high pulse rate and general discomfort. Individuals exhibiting any of these signs should be regarded as being at risk.

Research shows that elevation of serum enzyme levels is a consistent finding in heat stroke. Of particular prognostic significance is the elevation of AST (aspartate transaminase, also called SGOT), in that it is regarded as an indicator of the severity of tissue damage, while an elevation in CK (creatine kinase) in cerebrospinal fluid may provide a good index of neurologic damage. Furthermore, AST and LD (lactate dehydrogenase) levels are invariably increased in heat stroke. Diagnostic tests conducted for heat stroke are serum enzyme assays of LD, CK, AST, and ALT (alanine transaminase, also called SGPT) on admission and at 24 and 48 hours following admission. This diagnostic protocol should be followed in cases of overt heat stroke, and also in atypical cases, suspected cases, or even when hearsay evidence suggests a possibility of heat stroke and the patient is asymptomatic. The inclusion of suspected cases in the diagnostic protocol may have an important medicolegal implication since a positive or an unequivocally negative diagnosis of heat stroke can only be made retrospectively. Enzyme assays provide a clear distinction between classic and exertion-induced heat exhaustion and its progression to overt heat stroke.

There is also a clear distinction between serum enzyme elevations resulting from physical work in heat and heat stroke. Even prolonged endurance events, such as the 100 mile marathon, do not produce elevations that approximate those encountered in heat stroke (Table 8.4).

Table 8.3 ‘Classical’ and ‘exertion-induced’ heat stroke

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Classical</th>
<th>Exertional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Older</td>
<td>Young</td>
</tr>
<tr>
<td>Occurrence</td>
<td>Epidemic</td>
<td>Isolated cases</td>
</tr>
<tr>
<td>Pyrexia</td>
<td>Very high</td>
<td>High</td>
</tr>
<tr>
<td>Predisposing illness</td>
<td>Frequent</td>
<td>Rare</td>
</tr>
<tr>
<td>Sweating</td>
<td>Often absent</td>
<td>May be present</td>
</tr>
<tr>
<td>Acid-base disturbance</td>
<td>Respiratory alkalosis</td>
<td>Lactic acidosis</td>
</tr>
<tr>
<td>Rhabdomyolysis</td>
<td>Rare</td>
<td>Common</td>
</tr>
<tr>
<td>DIC †</td>
<td>Rare</td>
<td>Common</td>
</tr>
<tr>
<td>Acute renal failure</td>
<td>Rare</td>
<td>Common</td>
</tr>
<tr>
<td>Hyperuricaemia</td>
<td>Mild</td>
<td>Marked</td>
</tr>
<tr>
<td>Enzyme elevation</td>
<td>Mild</td>
<td>Marked</td>
</tr>
</tbody>
</table>

† Disseminated intravascular coagulation

Table 8.4 Serum creatine kinase (CK) and lactate dehydrogenase (LD) levels following ultra-distance endurance running † following heat stroke ‡

<table>
<thead>
<tr>
<th>Enzymes</th>
<th>Normal limit</th>
<th>Post ‘100 miles’</th>
<th>Post heat stroke</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0h</td>
<td>0 + 24h</td>
<td>0 + 48h</td>
</tr>
<tr>
<td>CK (U/l)</td>
<td>140</td>
<td>2 243</td>
<td>3 360</td>
</tr>
<tr>
<td>LD (U/l)</td>
<td>335</td>
<td>1 227</td>
<td>1 303</td>
</tr>
</tbody>
</table>

† Kielblock et al (1979)
‡ Kielblock (1992)
The nature of underground operations in deep level mines dictates a distinct two phased approach to treatment, i.e. an initial phase, wherein treatment is directed primarily at a satisfactory reduction in body temperature, and the subsequent phase which involves hospitalisation and clinical treatment. These procedures are detailed in a comprehensive reference (Kielblock and Schutte 1998). In different settings, where hospitalisation is possible with minimal delay, these two phases are initiated in parallel.

The signs and symptoms of heat stroke are often atypical (as already mentioned) and include hypotension, vomiting, diarrhoea, coma, convulsions, impaired mental function, sweat cessation (not a consistent finding) and irrational behaviour. The prognosis of the patient depends on the prompt institution of treatment. Treatment should under no circumstances be withheld because of indecision as to whether an individual has heat stroke or is suffering from some other condition. Initial rectal temperature levels recorded underground do not appear to hold much prognostic significance. However, patients with high rectal temperatures on admission have a poorer prognosis than patients with lower rectal temperatures (Table 8.5).

<table>
<thead>
<tr>
<th>Site of measurement</th>
<th>Outcome</th>
<th>Rectal temperature Mean ± SD°C</th>
<th>Significance P</th>
</tr>
</thead>
<tbody>
<tr>
<td>First underground recording</td>
<td>Non-fatal</td>
<td>41,20 ± 0,9</td>
<td>&gt; 0,4</td>
</tr>
<tr>
<td></td>
<td>Fatal</td>
<td>41,52 ± 0,9</td>
<td></td>
</tr>
<tr>
<td>Upon admission to</td>
<td>Non-fatal</td>
<td>38,96 ± 1,74</td>
<td>&lt; 0,001</td>
</tr>
<tr>
<td>hospital</td>
<td>Fatal</td>
<td>41,27 ± 1,37</td>
<td></td>
</tr>
</tbody>
</table>

1 Source: Kielblock (1992)

Temperature elevations only become critical over time and it is therefore not surprising that initially recorded temperatures provide very little information on outcome. The higher admission rectal temperatures often reflect poor emergency body cooling or that hospitalisation is mistakenly viewed as the overriding priority. The time taken to move a patient from underground workings to surface, and subsequently to hospital, can take many hours. Of necessity, treatment (body cooling) has to be interrupted at a time critical to the patient’s survival. However, this does not mean that body temperature monitoring should be discontinued. ‘Rebound heat hyperpyrexia’ is a well-known and reported phenomenon (see employee B in Table 8.6). This event is most probably related to prolonged intestinal ischaemia and membrane permeability changes incidental to compensatory splanchnic vasoconstriction during work in heat, as well as the subsequent absorption of endotoxin from the gut into the circulation.

Although a reduction in body temperature can be achieved by many different methods, the ultimate choice is likely to be determined by factors other than efficacy per se. There are two well-established methods, namely whole-body immersion in ice water baths and artificially enhanced evaporative cooling. The respective advantages and disadvantages are summarised in Table 8.7. The application of instant cold packs, often used to alleviate muscle injury in sporting events, only holds merit if full body coverage can be achieved. As such it is most useful when a patient has to be transported.
Table 8.6 Individual heat stroke case reports¹

<table>
<thead>
<tr>
<th>Causal factor</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>HTS conducted</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Standard of climatic chamber</td>
<td>Acceptable</td>
<td>Substandard on all previous inspections</td>
<td>Substandard; HTS outcome questionable</td>
</tr>
<tr>
<td>Medical history</td>
<td>STD and underlying malaria</td>
<td>Chronic heat exhaustion and gross weight loss</td>
<td>Frequent STD presentations</td>
</tr>
<tr>
<td>Events prior to incident</td>
<td>15 km underground reconnaissance walk on previous day</td>
<td>Normal / routine (dehydration?)</td>
<td>AWOL for six days; no records of claimed hospitalisation</td>
</tr>
<tr>
<td>Activity before / at time of incidence</td>
<td>Reconnaissance (in contravention of mine standards)</td>
<td>Drilling (strenuous)</td>
<td>Transporting materials (strenuous)</td>
</tr>
<tr>
<td>Environment</td>
<td>36°C wet-bulb (saturated)</td>
<td>Within limits</td>
<td>No pertinent records; complaints of heat ignored; not recorded</td>
</tr>
<tr>
<td>Emergency treatment</td>
<td>Initiated but inadequate</td>
<td>Exemplary initially</td>
<td>Initiated but discontinued early</td>
</tr>
<tr>
<td>Clinical treatment</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Commenced five hours after collapse</td>
</tr>
<tr>
<td>Outcome</td>
<td>Died underground</td>
<td>Died underground following secondary hyperthermia</td>
<td>Died in ICU one month later</td>
</tr>
<tr>
<td>Post-mortem cause of death</td>
<td>Dehydration</td>
<td>Bronchopneumonia</td>
<td>Multi-organ failure</td>
</tr>
</tbody>
</table>

¹ Extracted from confidential investigations conducted by Kielblock at the request of mine management.

Table 8.7 Summary of major advantages and disadvantages of body cooling methods¹

<table>
<thead>
<tr>
<th>Method</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole body ice water immersion</td>
<td>1. Most effective / rapid method</td>
<td>1. Induces shivering</td>
</tr>
<tr>
<td></td>
<td>2. Peripheral vaso-constriction beneficial to restore blood pressure</td>
<td>2. Danger of hypothermic overshoot</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Contraindicated for comatose incontinent patients</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4. Contraindicated during intubation or intravenous treatment</td>
</tr>
<tr>
<td>Evaporative methods</td>
<td>1. Most practical to deploy in difficult circumstances (e.g. underground mines)</td>
<td>1. Lower body cooling rates</td>
</tr>
<tr>
<td></td>
<td>2. Treatment and monitoring procedures facilitated</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Patient comfort</td>
<td></td>
</tr>
</tbody>
</table>


8.6 Heat stress management

Engineering strategies to counter heat over-exposure should be based on improved mechanization to minimise high metabolic rates, and/or reducing the environmental heat load (shielding, refrigeration and increased air flow) to facilitate heat dissipation. In the South African mining industry, technologic and economic constraints often preclude a purely engineering-based approach. Personal protection,
as a third strategy, then becomes the only viable alternative. Figure 8.1 shows the framework for a comprehensive occupational health programme for heat stress and should be used with the Department of Minerals and Energy guideline for thermal stress.

Figure 8.1 Framework for an occupational health programme
8.6.1 Heat stress indices

Where engineering strategies to avert heat stress fail or are inadequate, heat stress indices represent a convenient approach to providing personal protection. Such indices integrate all the factors contributing to heat stress into a single numerical value. This is complex and the derivation of an adequate index is not easy. Thus indices provide assessments of heat stress that differ quite widely. In practice, it is essential to ensure that the objectives of a given heat stress management programme are attainable through the use of a particular index. Heat stress indices can be conveniently categorised as rational, empirical or direct. Rational indices are based upon calculations involved in the heat balance equation. Empirical indices are based on establishing equations from the physiological responses of human subjects (e.g. sweat loss). Direct indices are based on the measurement (usually of temperature) obtained from instruments used to simulate the response of the human body. A comprehensive review of heat stress indices as provided by Parsons (1993), falls outside the scope of this chapter, but reference will be made to certain essentials. Table 8.8 summarises the variables relevant to a number of commonly used indices.

Table 8.8 Essential features and variables incorporated into heat stress indices

<table>
<thead>
<tr>
<th>Index</th>
<th>Environmental Variable</th>
<th>Physiological Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>db</td>
<td>wb</td>
</tr>
<tr>
<td>ET</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>CET</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>WBGT(ACGIH)</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>WBGT (ISO)</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>P4SR</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>HIS</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>SCP</td>
<td>•</td>
<td>•</td>
</tr>
</tbody>
</table>

1 Based on Brotherhood (1987) and Kielblock and Schutte (1988)
2 See text for abbreviations
3 Variables are db: dry-bulb, wb: wet-bulb, nwb: natural wet-bulb, Tg: globe / radiant temperature and v: air velocity
4 American Conference of Governmental Industrial Hygienists (ACGIH, 1988)

- The Effective Temperature (ET) is an index of equal subjective thermal effect. The ‘corrected’ version, the CET, makes provision for radiant heat by substituting the globe temperature for dry-bulb temperature. There are two scales, namely, the ‘Normal’ for lightly clothed persons and ‘Basic’ for men stripped to the waist. The main use of the ET is to provide an indication of thermal discomfort and these indices are therefore useful in productivity assessments. In German mines, shift duration is progressively reduced when the ET exceeds 28°C. In a South African context, this would be a dangerous practice in view of the early onset of heat stroke.

- The Wet-bulb Globe Temperature (WBGT) index is perhaps the most universally applied heat stress index. It assumes that deep body (core) temperature should not exceed 38°C. The index places emphasis on humidity, as can be seen from the basic equation: \[ \text{WBGT (in °C or °F)} = 0.7 \text{ wb} + 0.2 \text{ g} + 0.1 \text{ db} \] where wb represents wet-bulb temperature, g globe (radiant) temperature and db dry-bulb temperature. An obvious pitfall is to use this index where the environmental heat load is significantly influenced by high dry-bulb or radiant temperatures and where humidity is low. A number of subtle variations of this index can be recognised, e.g. NIOSH, ISO and OSHA.

- The Predicted Four-hour Sweat Rate (P4SR) has the advantage of estimating water requirements in terms of predicted sweat rate. An assumption is that workers are not dehydrated at the commencement of heat exposure.

- The Heat Stress Index (HSI), as well as Specific Cooling Power (SCP), provides useful engineering planning and diagnostic tools because the overall heat stress can be broken down into its
components. SCP is a lesser known index but it is highly relevant to underground conditions in South African gold mines. The essence of this index is that metabolic rate should not exceed the cooling power of the environment. SCP makes provision for the level of heat acclimatisation but in terms of current working conditions it would be more realistic to assume a relatively ‘unacclimatised’ state for underground workers.

8.6.2 Purpose-developed programmes

At present, the basis of heat stress management in South African gold and platinum mines can be recognised in the aetiology of heat stroke, as presented in Table 8.9. In turn, these causal factors are translated into safe work practices, with details appearing in a comprehensive guideline on the subject (Kielblock and Schutte 1998).

Table 8.9 Framework for heat stress management practices on the basis of the most important causal factors in the development of heat stroke

<table>
<thead>
<tr>
<th>Causal Factor</th>
<th>Work Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strenuous work</td>
<td>• Adequate physical work capacity (physical evaluation)</td>
</tr>
<tr>
<td></td>
<td>• Self-pacing (educational)</td>
</tr>
<tr>
<td></td>
<td>• Work-rest cycles</td>
</tr>
<tr>
<td>Suspect heat tolerance</td>
<td>• Overall fitness for work in hot environment</td>
</tr>
<tr>
<td></td>
<td>• Medical evaluation</td>
</tr>
<tr>
<td></td>
<td>• Physical evaluation</td>
</tr>
<tr>
<td></td>
<td>• Screening for heat intolerance</td>
</tr>
<tr>
<td>Dehydration</td>
<td>• Education</td>
</tr>
<tr>
<td>• alcohol-induced</td>
<td>• Provide potable and palatable water at place of work</td>
</tr>
<tr>
<td>• insufficient fluid replacement</td>
<td>• Introduce water breaks</td>
</tr>
<tr>
<td>Excessively hot environments</td>
<td>• Ongoing monitoring and control</td>
</tr>
<tr>
<td></td>
<td>• Actions plans</td>
</tr>
<tr>
<td></td>
<td>• Emergency planning</td>
</tr>
</tbody>
</table>

One of the cornerstones of local practice, is the introduction of a novel concept, namely an individual employee risk profile against which overall fitness for work in hot environments is measured. This profile consists of the following elements, namely:

- medical contraindications, i.e. a particular condition, treatment or even a medical history likely to lead to a critical job related reduction in heat tolerance
- age (50 years and above) in concert with full shift exposures to ‘strenuous’ work in heat
- obesity as measured by body mass index (BMI ≥ 30)
- inherent heat intolerance
- strenuous work per se, and
- a history of heat disorders

Recurring incidents of heat cramps and heat exhaustion should be construed as an inability to develop a satisfactory degree of heat acclimatisation for a particular job, exposure time and environmental heat load. Medical surveillance should be sufficiently sensitive to identify such employees and the Occupational Medical Practitioner should have no hesitation in reclassifying the employee as ‘heat intolerant’. However, it follows that a distinction exists between incidents of heat disorders which only affect a small number of employees in a chronic manner, thus reflecting possible inherent heat intolerance, and those linked to poor environmental control. To classify an employee as ‘heat intolerant’ within the latter context is clearly inappropriate.

The above scenario is not applicable to heat stroke. The reason is that heat stroke is generally associated with extensive multi-organ damage, often of an irreversible kind. As a result, heat tolerance is usually severely impaired, irrespective of whether the basic cause is ‘inherent heat intolerance’ or due to poor environmental control, and persists long after full clinical recovery from the incident. There is, therefore, strong evidence to suggest that heat stroke may well render an
employee permanently unfit for physical work in heat. In developing an employee risk profile on the basis of the above elements, it is obvious that no hard and fast rules can be set. The estimation of risk will, therefore, remain somewhat imprecise. A threefold approach is recommended, namely:

- a risk profile which features not more than one of the above elements, should generally be regarded as ‘acceptable’
- the presence of any two factors (elements) should be viewed with concern and should not be condoned unless the situation can be ameliorated, for example through specially developed safe work practices, and
- a profile containing more than two undesirable elements will constitute an unacceptable risk

Combinations of risk factors (elements) which should not be condoned under any circumstances are given in Table 8.10.

**Table 8.10 Employee risk profile matrix**

<table>
<thead>
<tr>
<th>Primary risk factor</th>
<th>Medical contra-indication</th>
<th>Age ≥ 50 plus strenuous work</th>
<th>BMI ≥ 30</th>
<th>Heat intolerance</th>
<th>Strenuous work</th>
<th>History of heat disorders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical contra-indication</td>
<td>X</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Age ≥ 50 plus strenuous work</td>
<td>X</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>BMI ≥ 30</td>
<td>O</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Heat intolerance</td>
<td>O</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Strenuous work</td>
<td>O</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>History of heat disorders</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

1 Source: Kielblock and Schutte (1998)

Note: X denotes a combination of risk factors that generally should be viewed as a disqualification; O denotes a combination which could be condoned if considered on merit.

In the South African mining industry, the aetiology of heat stroke is primarily related to, in descending order of importance, strenuous work, degree of heat tolerance, dehydration and excessive environmental heat loads (Kielblock, 1992). An analysis of the four main factors shown in Table 8.9 highlights the multifactorial nature of heat stroke since only 13% of cases could be linked to a single factor. In 87% of cases, two or more factors were present, in 33% three factors, and all four factors affected 6% of cases. This analysis of 121 cases also suggests a general attitude of complacency towards the prevention of heat stroke and draws attention to several other findings that may have a bearing in the design of heat stress management programmes. These are summarised in Table 8.11.

**Table 8.11 Trends in heat stroke incidence: implications for heat stress management**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Finding</th>
<th>Possible implication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of contract</td>
<td>50% of heat strokes occur in first two months</td>
<td>Acclimatisation to heat suspect, poor adjustment to mine routines</td>
</tr>
<tr>
<td>Month of the year</td>
<td>67% of cases occur in the October—March period</td>
<td>Seasonal drifts and related factors poorly understood</td>
</tr>
<tr>
<td>Day of the week</td>
<td>70% of heat strokes occur in the middle of the week</td>
<td>Progressive fatigue underestimated</td>
</tr>
<tr>
<td>Duration of shift</td>
<td>Heat stroke peaks towards middle of shift but is evident from within an hour’s work</td>
<td>Safe work practices require revision</td>
</tr>
</tbody>
</table>

1 Source: Kielblock (1992)
Surveys of heat disorders are useful in establishing strategic directions. However, they may hide the complexity of the aetiology of heat stroke because individual incidents are not revealed. The case reports in Table 8.6 highlight both the multiplicity of causal factors at an individual level and the lack of communication between key departments.

Exposure limits take into account work rate and the environmental heat load, as well as making allowances for body cooling garments. Heat stress management in the South African mining industry must address both the uniqueness of local requirements and a number of fundamentals common to programmes elsewhere. Table 8.12 summarises the main features of heat stress management at ARMCO Steel and Chrysler Motors in the USA. These elements should be ‘non-negotiable’ and common to any heat stress management programme. The operative word is ‘awareness’ and Bruening (1990) cites the Chrysler Motors’ policy in this respect ‘awareness of potential heat stress hazards . . . is just as effective . . . as any engineering control or protective gear’.

Table 8.12 Major features of some industrial heat stress management programmes

<table>
<thead>
<tr>
<th>Chrysler Motors</th>
<th>ARMCO Steel</th>
<th>SA Gold Mines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identify ‘key jobs’</td>
<td>Identify ‘high heat’ jobs</td>
<td>Identify heat stroke prone jobs</td>
</tr>
<tr>
<td>Institute preplacement medical tests</td>
<td>Conduct engagement and periodic medical examinations</td>
<td>Do physical tests</td>
</tr>
<tr>
<td>Do physical tests</td>
<td>Screen for heat intolerance</td>
<td></td>
</tr>
<tr>
<td>One week</td>
<td>Institute on the job heat acclimatisation</td>
<td></td>
</tr>
<tr>
<td>Six days</td>
<td>Six days</td>
<td>12 shifts / ongoing</td>
</tr>
<tr>
<td>Supervise employees</td>
<td>Supervise heat stroke prone work categories</td>
<td></td>
</tr>
<tr>
<td>Monitor environmental factors</td>
<td>Create awareness of heat overexposure</td>
<td>Monitor environmental temperatures</td>
</tr>
<tr>
<td>Maintain fluid and electrolyte balance</td>
<td>Encourage regular fluid intake</td>
<td>Introduce mandatory water breaks</td>
</tr>
<tr>
<td>Increase awareness or heat hazards</td>
<td>Instruct on dangers of drugs and alcohol</td>
<td>Introduce education and induction programmes</td>
</tr>
<tr>
<td></td>
<td>Cover first aid for heat related illness</td>
<td>Ensure prompt recognition, treatment and availability of emergency facilities</td>
</tr>
</tbody>
</table>

1 Extracted from Bruening (1990)

Table 8.13 Categorisation of the thermal environment

<table>
<thead>
<tr>
<th>Category</th>
<th>Temperature range</th>
<th>Interpretation</th>
<th>General action</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: Abnormally hot</td>
<td>$wb&gt;32.5^\circ C$ or $db&gt;37.0^\circ C$ or $Tg&gt;37.0^\circ C$</td>
<td>Unacceptable risk of heat disorders for routine work</td>
<td>Emergency or work of a special nature to be undertaken only on a basis of expert risk assessment, supervision and protocols.</td>
</tr>
<tr>
<td>B</td>
<td>$27.5^\circ C &gt;wb&lt;32.5^\circ C$ and $db&lt;37.0^\circ C$</td>
<td>Potentially conducive to heat disorders</td>
<td>HSM mandatory</td>
</tr>
<tr>
<td>C</td>
<td>$25^\circ C &gt;wb&lt;27.5^\circ C$ and $db&lt;32.5^\circ C$</td>
<td>Risk of heat disorders negligible</td>
<td>No special precautions. Environmental monitoring must be sufficiently sensitive to detect critical upward drifts in the environmental heat load. The monitoring programme to satisfy this requirement should be specified.</td>
</tr>
</tbody>
</table>

Note: See Table 8.8 for explanation of abbreviations
Table 8.13 summarises actions required for different ranges of temperature. The general conclusion with regard to the management of heat stress, however, is that there is no precedent that dictates a uniform approach to the problem. Heat stress indices should only be used with great circumspection; de novo approaches are certainly justifiable.

8.7 Legislation and standards

8.7.1 International practice

International legislation and practice do not reflect a consistent approach or use of uniform standards. The general tendency is conservative. From a South African perspective, particularly in deep level mining operations, it is essential to remain abreast of international developments and trends in mining legislation. Comparisons must take into consideration any fundamental differences, namely physical demands and environmental heat loads which may differ substantially from one operation to the next. The issue most basic to all standards is that of a permissible elevation in body core temperature. For general industry there has been consensus that deep body temperature should not be permitted to rise above 38°C and this standard has been built into perhaps the most universally accepted heat stress index, the Wet Bulb Globe Temperature (WBGT) index. While the choice of 38°C may seem to be too conservative, it must serve a considerable cross section of the work force: workers who differ in age, gender, inherent work capacity, and fitness. These considerations are extremely relevant to the South African mining industry. With the current emphasis on self pacing and the maintenance of safe work practices on a continuous basis, the challenge of a new norm may not be as formidable as in the past.

International legislative frameworks place emphasis on training and health monitoring (Australia), linking environmental surveys with heat strain manifestations (United States) and the use of threshold limit values based on indices such as the WBGT and ET (United States, Australia, Germany and the United Kingdom). In the United States of America, different classifications of the environment are used according to gender, i.e. a ‘hot’ environment is one that exceeds 26,1°C (WBGT) for males and 24,4°C (WBGT) for females. From a health and safety perspective, the use of the WBGT and ET indices within the context of legislation should be viewed with a degree of caution.

- Both the WBGT and ET are biased towards humid environments and, at least potentially, are likely to underestimate environments with high dry bulb and/or radiant heat loads
- The German practice of reducing, depending on circumstances, either the shift length, or the consecutive number of shifts, or even the labour force when certain ET limits are exceeded is questionable. The only consequence of note is a production or productivity penalty. In this respect, the WBGT principle, i.e. the application of work-rest cycles within each hour of the shift, is infinitely more realistic with respect to health and safety.
- Similarly, the United Kingdom practice of paying a ‘heat tolerance allowance’ when the basic ET (BET) exceeds 28°C, is indefensible because an incentive is created to maintain production at the expense of health and safety.

8.7.2 Local practice

In terms of current legislation and regulations, the Mine Health and Safety Act (Act 29 of 1996) makes provision for mandatory codes of practice to be drawn up by mines. This recognises mine-specific differences that cannot be covered adequately by a generic set of regulations. Under such circumstances, the Department of Minerals and Energy must issue a formal guideline to mines outlining the requirements of such codes of practice. Such guidelines are usually backed up by supporting documents such as provided by the Safety in Mines Research Advisory Committee project reports. It falls outside the scope of this review to consider the details of the DME guideline on thermal stress. In terms of the procedural framework, mines are required to establish an occupational health programme for thermal stress on the basis of four major components, namely risk assessment, risk management, programme monitoring and systematic review.

The guideline on thermal stress management is non prescriptive, even with regard to the use of heat stress indices. The only stipulation is that such indices must be relevant to a particular set of
conditions. Also, because of the acute way in which heat disorders develop, considerable emphasis is placed on incident analysis and review. The major advantage of a non prescriptive approach is that it promotes, or even forces, mines to apply ‘best practice’ principles.

8.7.3 Legislation versus standards

‘Best practice’ approaches to promoting health and safety can only be served by non prescriptive legislation. There is a tendency to specify exactly what ‘best practice’ should be according to international standards but under certain circumstances, these may be totally inappropriate.

The WBGT index has considerable international standing as a standard recognised by both the ACGIH and the ISO. However, this does not establish an automatic precedent for the use of the WBGT index or, for that matter, any other index. For example, conditions in South African gold mines are such that for all practical purposes the environmental heat load is expressed quite adequately simply in terms of wet-bulb temperature. This is tantamount to changing the WBGT wet-bulb temperature weighting factor from 0.7 to 1.0 in order to address a specific requirement.

Fundamentally, limits on environmental heat loads, work rate and exposure time cannot be escaped. However, indices to assess health risk, performance efficiency and eventually tolerance limits for various exposures are mostly not in agreement. Exposure times may differ and according to Henschell and Dukes-Dobos (1988) ‘... none of the standards, guidelines and recommended exposure limits has as yet achieved the status of being enforceable by law ...’ This observation has remained relevant over the past decade. Despite the ACGIH’s undoubted standing within the international occupational hygiene community, it nevertheless cautions in the policy statement that their recommendations and guidelines ‘are not developed for the use of legal standards and the ACGIH does not advocate their use as such’ (ACGIH 1998).

At present there is a surge in standardisation of indices, notably ISO 7243, both internationally and in South Africa. Obviously, this enhances the status and popularity of such indices, even to the detriment of other more meaningful indices. Here again the ACGIH disclaimer on the improper use of its guidelines and recommendations is relevant: ‘± the user must recognise the constraints and limitations to their proper use and bear the responsibility for such use’.

Heat stress, unlike hazards such as dust or noise, is not determined only by environmental conditions, but is affected substantially by work rate and physical work capacity. To impose standards that are predominantly based on the former determinant, is clearly unacceptable. Regulations and standards, particularly with regard to occupational heat stress are, and must remain, separate entities.

8.8 Guide to information resources

ACGIH. 1998 Threshold limit values for chemical substances and physical agents. Cincinnati: American Conference of Governmental Industrial Hygienists.


Bruening, J.C. 1990 Beat the heat! Occupational Hazards (June): 63-66


Appendix 8.1: Scenarios illustrating suppressed heat dissipation

The following scenarios illustrate the danger of metabolic heat production to thermal balance. In each case, heat dissipation has been discounted and a body mass of 70kg has been assumed throughout for the subjects. The specific heat of body tissue (collectively) is 0.83 C/kg°C or 3.47 kJ/kg°C.

**Scenario A:** The ACGIH (ACGIH 1998) upper limit for light work (‘sitting/standing to control machines, performing light hand or arm work’) is 200 C/h. This equates to an oxygen consumption of 0.69 l/min or work rate of 232 W.

**Scenario B:** In practice, the time weighted average metabolic rate should not exceed 350 W to avoid fatigue and a need for commensurate work rest cycles. This work rate corresponds to an oxygen consumption of 1.04 l/min or 301 C/h.

**Scenario C:** Although exceptional, endurance athletes are capable of maintaining high work rates for many hours, typically in the region of 3.5 litre of oxygen per minute (1013 C/h or 1176 W).

<table>
<thead>
<tr>
<th>Scenario</th>
<th>A (C/h)</th>
<th>B (C/h)</th>
<th>C (C/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rise in mean body temperature (°C)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>— after 30 minutes</td>
<td>1.7</td>
<td>2.6</td>
<td>8.7</td>
</tr>
<tr>
<td>— after 60 minutes</td>
<td>3.4</td>
<td>5.2</td>
<td>17.4</td>
</tr>
</tbody>
</table>

Assuming a base-line body temperature of 37.0°C it should be evident that the only scenario without ‘overt risk’ is the performance of light work for a period not exceeding 30 minutes. Although the examples may seem unlikely, body temperature elevations of up to 43°C have been reported after about 14 km during the Sydney ‘City to Surf Fun Run’ in 1979. The above calculations underline the importance of not overestimating both man’s physiological capability and the capacity of the environment to facilitate heat dissipation. A case in point is underground work in a gold mine.

Appendix 8.2: Categorisation of physical work rates

To facilitate comparison with one another, the original units of the respective categorisation systems have been converted to W/m² body surface area. (For this purpose, a value of 1.7m² has been assumed to represent the mean of the majority of the local labour force)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
<td>90 100</td>
<td>115</td>
<td>235</td>
</tr>
<tr>
<td>Moderate</td>
<td>110 200</td>
<td>180</td>
<td>240</td>
</tr>
<tr>
<td>Heavy</td>
<td>130 300</td>
<td>240</td>
<td>340</td>
</tr>
<tr>
<td>Very heavy</td>
<td>150 400</td>
<td>&gt;240</td>
<td>—</td>
</tr>
</tbody>
</table>

Note: Values denote ‘up to’

Modern technology (e.g. the ‘Polar’ or Oxford ‘Medilog’ heart rate monitoring systems) provides an easy and relatively inexpensive way to categorise work and work rates. Such measurements could be refined though the use of the International Standard ISO/DIS 8996 (1987) procedure. Data analysis should place special emphasis on peak rates and duration; in this respect means, ranges and other statistical abstractions, although relevant, may be misleading in terms of meeting the overall objectives of the programme. The approach used by Van Rensburg et al. (1991) provides a useful basis for such analyses.
Appendix 8.3: Nutrition and hydration during physical work in heat

The turnover of certain nutrients is accelerated by strenuous physical labour, especially when performed in hot environments. For example, heavy exposures could lead to a significant loss of zinc, thus impairing normal growth, development, health and ossification. The same applies with regard to magnesium, the relevance of which should be viewed against the relationship between deaths ascribed to ischaemic heart disease and low magnesium intake. Post exertional levels of plasma magnesium are frequently low as a result of intravascular shifts and should not be construed as hypomagnesaemia. Prolonged strenuous work may produce iron deficiency that requires supplementation. Iron deficiency leads to a measurable decline in work capacity; conversely, significant increase in work productivity can follow iron supplementation in iron depleted individuals. Undernourished groups work at lower intensities and for shorter periods than supplemented groups, resulting in less work accomplished per time unit.

Perhaps the most dramatic turnover occurring during work in heat is that of vitamin C. It has been demonstrated that heat acclimatisation in the South African gold mining industry could be accelerated by vitamin C supplementation and that the required level is at least 250 mg per day. Nutritional deficiencies are more related to chronic work in heat, emphasising the basic importance of providing diets which are sufficiently ‘balanced’ to cater for longer-term requirements. Equally important, particularly for acute requirements, is the sustained generation of energy, from carbohydrates and fat. Considering total body economics, fat has the advantage of being a more compact form of energy; it can also be stored in vast quantities, e.g. as in obese individuals. By contrast, carbohydrates are poorly stored (about 0.5 to 1.0 per cent of body mass), but have the advantage of being able to sustain intense short-term activity. A progressive increase in physical activity is characterised by a shift from fat to carbohydrate as the predominant source of energy. This is of particular relevance to physically demanding work, as in mining.

Carbohydrate depletion during sustained intense physical effort is a serious limitation to continued activity. This may already become evident within two to four hours following the commencement of the shift. Impaired work performance can be attributed to carbohydrate depletion as a result of sporadic eating habits and limited storage capability. Optimal rates of carbohydrate (glycogen) storage are achieved at a total intake of about 7-10 g/kg body mass over a 24 hour period, i.e. 500 to 700 g of carbohydrate for a worker of average build (70 kg) or a mean rate hourly of about 20 to 30 g. In this respect, the type of carbohydrate is also important. Simple carbohydrates (e.g. glucose and sucrose) are of greater benefit during the first six hours of recovery while ‘complex’ carbohydrates (polysaccharides) serve glycogen storage better in the longer term. The form in which it is ingested, i.e. fluid or solid, is immaterial.

Continued work in hot environments depends on both energy supply and the integrity of thermoregulation. Sweating, the main route of heat dissipation, leads to dehydration. Fluid replacement regimens should be based on a thorough understanding of sweat losses which may amount to rates of 1-2 l/h. The maintenance of optimum levels of hydration is not, however, a simple matter of ‘demand and supply’. The underlying physiology is of fundamental importance in establishing effective replacement regimens. The following facts are important.

- Drinking water according to the dictates of thirst is insufficient to prevent involuntary dehydration of up to (or even exceeding) 1% of body mass
- Upon drinking water, a person’s thirst is alleviated well before the fluid deficit is recovered, the attenuation of drinking subjectively being attributed to stomach fullness
- Once dehydration has set in, the subsequent rate of water absorption from the gut will be reduced as a result of compensatory splanchnic vasoconstriction. This reflex, by which a redistribution of cardiac output is achieved, occurs at dehydration levels approximating only 1.5% of body mass
- Sweat is a hypotonic fluid with electrolyte content varying between 0.2 to 0.3%. The most important constituent is sodium chloride (salt) which accounts for about 80% of the tonicity of sweat. On a balanced diet, or in the short-term (hours), the threat to continued well being does not reside in salt depletion but in dehydration
Optimum hydration is best achieved by drinking relatively small amounts of water at relatively short intervals, e.g., about 250-300 ml every 20-30 minutes. Basic physiologic requirements are effectively met by ordinary tap water. Cool, hypotonic beverages could be preferred. Of importance is the availability of water: a man is less likely to drink regularly if it involves effort and time. Finally, it is evident that worker education is essential.

A potential conflict between energy supply and fluid replacement arises because gastric emptying and water absorption from the gut is suppressed in direct relation to the tonicity of the fluid replacement beverage. Obviously, this impairs heat dissipation profoundly. Critical carbohydrate levels appear to be of the order of 5.7 g/ml, i.e. a tonicity range of about 150-200 mOsm/l which, relative to blood serum (285-295 mOsm/l), is hypotonic. However, these levels can only be tolerated in relatively small volumes at intervals not exceeding about 15 minutes. This regimen, therefore, is likely to satisfy the requirements of both carbohydrate intake for optimal glycogen storage and, to a lesser extent, thermoregulation. During work in heat, thermoregulation is best served by providing pure water and not hypo-or isotonic beverages. By contrast, restoring exercise-induced dehydration and plasma volume during the recovery phase may require high sodium intake and fluid levels of about 50-100% more than lost. Sodium chloride content of sweat varies with the degree of acclimatisation but generally falls within the range of 5 to 20 mmole/l.

Recommended intake levels for restoration of plasma volume should approximate sweat composition at lower end of the range (i.e. 10-25 mmole/l) in order to take into account palatability and satisfy market appeal. For rapid restoration, sodium supplements of between 50-90 mmole/l should be ingested. Although Western diets are often notorious in respect of high salt content, profuse daily exertion may lead to long term deficits and weight losses of as much as 4 kg due to loss of isotonic body fluids. Potassium loss is an associated finding.

The role of the much-acclaimed isotonic energy/fluid replacement beverages should be viewed more within the context of enhancing recovery. For example, the range of salt intake referred to above (50-90 mmole/l) equates to tonicities ranging from about 90 to 170 mOsm/l. With a further 150 mOsm represented by carbohydrate supplementation, total osmolarity approaches that of body fluids, i.e. isotonic. Such tonicities suppress fluid absorption from the gut and lead to suboptimal plasma volume and heat dissipation.

Research places considerable emphasis on ‘palatability’ and, within the context of the supply of drinking water in underground South African mines, ‘potable’ may not be adequate. An optimum temperature, in terms of palatability, is 15°C. Finally, both alcohol and caffeine-containing beverages significantly increase diuresis and, therefore, counteract full rehydration.
CHAPTER 9

Chemical Hazards

This chapter discusses chemical hazards in the mining industry and the adverse health effects associated with the common chemicals encountered. A detailed guide to medical surveillance and biological monitoring is provided. The chapter includes a generic classification of chemical hazards, assessment and monitoring of exposures and control strategies.

The chapter has been prepared from resources on the Internet and extensive Internet links are provided for further information. The links have also been incorporated into the ASOSH (Association of Societies for Occupational Safety and Health) website (asosh.org) where they will be updated from time to time.

Dr. D.W. Stanton
Occupational Hygienist

David Stanton holds a Ph.D. and occupational hygiene qualification from the United Kingdom and is a Fellow of the Royal Society of Chemistry, Institute of Occupational Safety and Health and the British Institute of Occupational Hygiene. He is webmaster of the website asosh.org and is employed by the Chamber of Mines of South Africa.

Dr. M.F. Jeebhay
Occupational Health Practitioner

Mohamed Jeebhay is a medical practitioner with postgraduate qualifications in occupational health and epidemiology. He is employed in the Occupational and Environmental Health, Research Unit, Department of Public Health, University of Cape Town.
Glossary

**Accreditation**: approval process whereby a laboratory is sanctioned to conduct specific analyses

**ACGIH**: American Conference of Governmental Industrial Hygienists

**Acute**: quick response/effect

**Allergenic**: immune system response/effect

**Chronic**: longer-term response/effect

**CIL**: Carbon in leach

**CIP**: Carbon in pulp

**CONCAWE**: Oil Companies’ European organisation for environment, health and safety (Conservation of clean air and water in Europe)

**EXIS**: External Information System, Department of Minerals and Energy — Western Australia

**Hazard**: potential to cause harm

**Medical surveillance**: programme to monitor/observe the health status of individuals/groups

**Metabolite**: a breakdown product of a given substance in the body

**Monitoring**: measuring environmental or biological parameters

**MSDS**: Materials safety data sheet — a source of safety etc. information relating to a substance/product

**Neuro-**: relating to the nervous system

**OEL**: Occupational exposure limit — a guideline on acceptable concentrations in air

**PEL**: Permissible exposure limit — a guideline on acceptable concentrations in air

**Respirable**: (airborne particles) of such a size as to be able to penetrate into the lung depths

**Systemic**: pertaining to the body as a whole

**Target organ**: site in the body where an absorbed chemical can exert its effect
9.1 Introduction

This chapter provides a general approach to dealing with chemical hazards and the health effects associated with common chemicals encountered in mining.

The word chemical can be defined as any element, chemical compound, or mixture of elements and/or compounds. A one component chemical is called a substance e.g. acetone, mercury or trichloroethylene. A mixture composed of two or more substances is called a preparation e.g. glues, inks, lubricating oils, paints, and products for treating metal surfaces.

A chemical may be hazardous because it can cause fires and explosions, is a danger to health, is corrosive or irritant, or dangerous for the environment. Certain chemicals can possess several of these properties at the same time. Toluene for example, is both harmful to health and highly flammable.

A large number of chemicals are utilised, generated or naturally present in the mining industry, each with their own hazard potential. These range from the cements and explosives used in mining, the commodities mined, the associated naturally occurring gases, fuels and lubricants for machinery and transport, engine exhaust and stack emissions, refrigerants for mine cooling and substances and preparations used in laboratory testing. A variety of chemicals is utilised for mineral processing to assist in the extraction of both precious metals and non-precious metals from rock. Chemicals are used in concentrating industrial minerals and in producing further chemicals e.g. phosphoric acid from phosphate rock.

Chemicals have been essential to the development of the South African mining industry. Amalgamation with mercury was the principal gold recovery method used in South African gold mines in the 19th century. Crude amalgamation is still practised by some artisanal gold miners in South Africa with the potential for mercury poisoning from the inhalation of mercury vapour.

The cyanide process was introduced to the Witwatersrand gold mines in 1890. Sodium cyanide is used in mining to extract gold (and silver) from ores, particularly low-grade ores and ores that cannot be readily treated through simple physical processes such as gravity. This chemical is known to exert its toxic effects as a result of inhalation, ingestion or absorption through the skin and mucous membranes. It also reacts with acids to liberate toxic and flammable hydrogen cyanide gas.

9.2 Common chemical hazards in the mining industry

9.2.1 South African commodity production data

The most important mineral commodities produced in South Africa, in respect of value, are coal, gold and platinum-group metals (PGMs). Additionally, world-class output of metallic minerals includes ores and/or smelted products of antimony, chromium, iron, manganese, titanium, uranium, vanadium and zirconium. Important output of industrial minerals includes andalusite, dimension stone, diamond, fluorspar, phosphate rock and vermiculite. Commodity production data for 1999 from the Department of Minerals and Energy (DME) website (http://www.dme.gov.za) are given in Table 9.1.

In 1999 the combined workforce (including contractors) of mines, quarries and processing plants was approximately 440 000. In 2000 there were some 830 such establishments ranging in size from part-time operations to a mine with some 30 000 employees.

Each of the commodities produced will have its own occupational health hazards. Exposure to airborne lead may be associated with adverse health effects on the blood forming organs (e.g. anaemia). Adverse effects on the nervous system can also occur with lead exposure as well as in manganese mining and smelting. Exposure to asbestos or silica is associated with pneumoconiosis and lung cancer, while the risk of lung cancer and skin allergies is increased in nickel miners. For further information on lung and skin diseases see the chapters on Occupational Lung Diseases and Skin Diseases in Mining.
Table 9.1 Commodity production data for South Africa 1999

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Unit</th>
<th>Production Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate and sand</td>
<td>t</td>
<td>11 561</td>
</tr>
<tr>
<td>Andalusite</td>
<td>t</td>
<td>136 949</td>
</tr>
<tr>
<td>Asbestos — chrysotile</td>
<td>t</td>
<td>18 707</td>
</tr>
<tr>
<td>Antimony</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>Attapulgite</td>
<td>t</td>
<td>7 067</td>
</tr>
<tr>
<td>Barytes</td>
<td>t</td>
<td>2 844</td>
</tr>
<tr>
<td>Bentonite</td>
<td>t</td>
<td>50 363</td>
</tr>
<tr>
<td>Coal</td>
<td>t</td>
<td>223 514 169</td>
</tr>
<tr>
<td>Cobalt</td>
<td>kg</td>
<td>305 837</td>
</tr>
<tr>
<td>Copper</td>
<td>t</td>
<td>144 263</td>
</tr>
<tr>
<td>Chromite</td>
<td>t</td>
<td>6 817 050</td>
</tr>
<tr>
<td>Diamonds</td>
<td>ct</td>
<td>10 019 282</td>
</tr>
<tr>
<td>Feldspar</td>
<td>t</td>
<td>57 736</td>
</tr>
<tr>
<td>Fire clay</td>
<td>t</td>
<td>120 971</td>
</tr>
<tr>
<td>Flint clay</td>
<td>t</td>
<td>88 647</td>
</tr>
<tr>
<td>Fluorspar</td>
<td>t</td>
<td>217 540</td>
</tr>
<tr>
<td>Granite</td>
<td>t</td>
<td>—</td>
</tr>
<tr>
<td>Gold</td>
<td>kg</td>
<td>451 294</td>
</tr>
<tr>
<td>Gypsum</td>
<td>t</td>
<td>513 760</td>
</tr>
<tr>
<td>Iron ore</td>
<td>t</td>
<td>29 507 849</td>
</tr>
<tr>
<td>Iron-pyrites from Gold Mill</td>
<td>t</td>
<td>141 427</td>
</tr>
<tr>
<td>Kaplin</td>
<td>t</td>
<td>122 413</td>
</tr>
<tr>
<td>Lead concentrate</td>
<td>t</td>
<td>80 191</td>
</tr>
<tr>
<td>Limestone and lime</td>
<td>t</td>
<td>19 030 096</td>
</tr>
<tr>
<td>Manganese ore</td>
<td>t</td>
<td>3 121 994</td>
</tr>
<tr>
<td>Mica</td>
<td>t</td>
<td>1 010</td>
</tr>
<tr>
<td>Nickel</td>
<td>t</td>
<td>35 798</td>
</tr>
<tr>
<td>Natural gas</td>
<td>t</td>
<td>1 616 462</td>
</tr>
<tr>
<td>Natural gas condensate</td>
<td>t</td>
<td>300 288</td>
</tr>
<tr>
<td>PGMs</td>
<td>kg</td>
<td>216 469</td>
</tr>
<tr>
<td>Petroleum crude</td>
<td>b</td>
<td>5 493 357</td>
</tr>
<tr>
<td>Phosphate Rock</td>
<td>t</td>
<td>—</td>
</tr>
<tr>
<td>Pigment minerals</td>
<td>t</td>
<td>216</td>
</tr>
<tr>
<td>Pyrophyllite</td>
<td>t</td>
<td>2 606</td>
</tr>
<tr>
<td>Salt</td>
<td>t</td>
<td>358 584</td>
</tr>
<tr>
<td>Sandstone</td>
<td>t</td>
<td>—</td>
</tr>
<tr>
<td>Shale</td>
<td>t</td>
<td>11 561</td>
</tr>
<tr>
<td>Shales for cement manufacture</td>
<td>t</td>
<td>309 961</td>
</tr>
<tr>
<td>Silica</td>
<td>t</td>
<td>2 176 197</td>
</tr>
<tr>
<td>Silver</td>
<td>kg</td>
<td>151 960</td>
</tr>
<tr>
<td>Slate</td>
<td>t</td>
<td>—</td>
</tr>
<tr>
<td>Sodium sulphate</td>
<td>t</td>
<td>53 400</td>
</tr>
<tr>
<td>Special clays</td>
<td>t</td>
<td>389 461</td>
</tr>
<tr>
<td>Sulphur (grand total)</td>
<td>t</td>
<td>405 636</td>
</tr>
<tr>
<td>Talc</td>
<td>t</td>
<td>18 544</td>
</tr>
<tr>
<td>Titanium</td>
<td>t</td>
<td>—</td>
</tr>
<tr>
<td>Uranium oxide</td>
<td>kg</td>
<td>1 092 638</td>
</tr>
<tr>
<td>Vanadium</td>
<td>t</td>
<td>—</td>
</tr>
<tr>
<td>Vermiculite</td>
<td>t</td>
<td>—</td>
</tr>
<tr>
<td>Zirconium</td>
<td>t</td>
<td>—</td>
</tr>
<tr>
<td>Zinc</td>
<td>t</td>
<td>69 733</td>
</tr>
</tbody>
</table>

The following USA and Australian data and information are presented to demonstrate the important chemical hazards in the mining industry. There is an absence of reliable local published data, a deficiency which should be addressed.

9.2.2 Chemical inventories

The National Occupational Health Survey of Mining (NOHSM) conducted in the USA 1984-89 by the National Institute for Occupational Safety and Health (NIOSH Publication No. 96-136) included a chemical inventory of a sample of mines representing 66 different mineral commodities. A total of 491 mines was surveyed including 431 metal-nonmetal mines and 60 coal mines. The NIOSH inventory recorded some 2,570 chemical substances and 84,939 trade name products at the mines surveyed. The trade name products were those that could not be identified by a specific chemical name or formula e.g. Windex Glass Cleaner, WD-40 and Certanium 705 Welding rod.

In “product use” terms and listed A to Z the list ranged from Acid, Battery to Wood Preservative. Taking the top 100 product use terms NIOSH calculated the highest projected number of workers potentially exposed. The top five potential exposures were to fuel, grease, oil, welding rod and lubricant. Locations with the highest projected number of chemical substance and trade name product potential exposures were Surface Shop (30%), Surface Mine (19%), Underground Mine (11%), Surface Miscellaneous (10%) and Other (28%). The latter included underground shop, coal preparation plant, underground warehouse, surface laboratory, surface warehouse, underground mill, surface crushing, surface grinding, surface flotation and reagents and surface mill.

Table 9.2 lists the 100 chemicals with the highest projected number of workers potentially exposed. The table does not take into account the number of workers that were potentially exposed to chemicals contained in the ore being mined. The table only contains those chemicals which were purchased and then used at the mining facility. Hence coal miners are not listed as being potentially exposed.
exposed to coal, asbestos miners are not reported as being potentially exposed to asbestos, and so forth. Diesel fuel, acetylene, gasoline and propane were the chemicals with the highest number of projected workers potentially exposed. The full document is available at the NIOSH website (http://www.cdc.gov/niosh/96-136.html).

Table 9.2 100 chemicals with the highest projected number of workers potentially exposed in the US mining industry

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Chemical</th>
<th>Chemical</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Diesel Fuel No. 2</td>
<td>35 Calcium Sulphate</td>
<td>69 Phosphoric Acid</td>
</tr>
<tr>
<td>2 Acetylene</td>
<td>36 Coke (Petroleum)</td>
<td>70 Creosote Ties</td>
</tr>
<tr>
<td>3 Gasoline, Unleaded</td>
<td>37 Ligninsulphonate</td>
<td>71 Potassium Iodide</td>
</tr>
<tr>
<td>4 Gasoline, Leaded</td>
<td>38 Argon</td>
<td>72 Methane, Dibromo-</td>
</tr>
<tr>
<td>5 Diesel Fuel No. 1</td>
<td>39 Mineral Oil</td>
<td>73 Silver Nitrate</td>
</tr>
<tr>
<td>6 Propane</td>
<td>40 Coke</td>
<td>74 Ethanol</td>
</tr>
<tr>
<td>7 Coal</td>
<td>41 Chloroprene</td>
<td>75 Ammonia</td>
</tr>
<tr>
<td>8 Kerosene</td>
<td>42 Methyl Alcohol</td>
<td>76 Tin</td>
</tr>
<tr>
<td>9 Calcium Chloride</td>
<td>43 Iron Scale</td>
<td>77 Potassium Nitrate</td>
</tr>
<tr>
<td>10 Limestone</td>
<td>44 Carbonic Acid Monosodium Salt</td>
<td>78 Alumund</td>
</tr>
<tr>
<td>11 75% Argon 25% Carbon Dioxide</td>
<td>45 Ammonium Hydroxide</td>
<td>79 Iron Salts, Soluble</td>
</tr>
<tr>
<td>12 Natural Gas</td>
<td>46 Graphite</td>
<td>80 Magnesium Chloride</td>
</tr>
<tr>
<td>13 Gypsum</td>
<td>47 Iron Ore</td>
<td>81 Sulphuric Acid, Cobalt (2+) Salt (1:1)</td>
</tr>
<tr>
<td>14 95% Argon 5 % Oxygen</td>
<td>48 Nitric Acid</td>
<td>82 Glycerine</td>
</tr>
<tr>
<td>15 Sulphuric Acid</td>
<td>49 Methyl Acetylene-Propadiene Mixture</td>
<td>83 Calcium Fluoride</td>
</tr>
<tr>
<td>16 Hydrogen Chloride</td>
<td>50 Dichlorodifluoromethane</td>
<td>84 Potassium Permanganate</td>
</tr>
<tr>
<td>17 Sodium Hydroxide</td>
<td>51 Denatured Alcohol</td>
<td>85 Isopropyl Alcohol</td>
</tr>
<tr>
<td>18 Methyl Chloroform</td>
<td>52 Carbolic Acid, Dithio, O-Pentyl Ester, Potassium Salt</td>
<td>86 Sodium Oxide</td>
</tr>
<tr>
<td>19 Ammonium Nitrate</td>
<td>53 Iron (Fe)</td>
<td>87 Coal Tar Pitch Volatiles</td>
</tr>
<tr>
<td>20 Stoddard Solvent</td>
<td>54 Silicic Acid, Disodium Salt</td>
<td>88 Mg, Magnesium-MF Unknown</td>
</tr>
<tr>
<td>21 Calcium Oxide</td>
<td>55 Acetic Acid</td>
<td>89 Al, Aluminium-MF Unknown</td>
</tr>
<tr>
<td>22 Nitrogen</td>
<td>56 Sodium Cyanide</td>
<td>90 Bentonite</td>
</tr>
<tr>
<td>23 Gasoline</td>
<td>57 Methyl Isobutyl Carbinol</td>
<td>91 Hydrogen Fluoride</td>
</tr>
<tr>
<td>24 Naphtha, Coal Tar</td>
<td>58 Acetone</td>
<td>92 Copper Slag</td>
</tr>
<tr>
<td>25 Petroleum White</td>
<td>59 Portland Cement</td>
<td>93 Sodium Chloride</td>
</tr>
<tr>
<td>26 Xylenes</td>
<td>60 Phenolphthalein</td>
<td>94 Sulphamic Acid</td>
</tr>
<tr>
<td>27 Carbonic Acid Disodium Salt</td>
<td>61 Liquid Petroleum Gas</td>
<td>95 Diesel Fuel No. 6</td>
</tr>
<tr>
<td>28 Magnesite</td>
<td>62 Stearic Acid, Calcium Salt</td>
<td>96 Boric Acid</td>
</tr>
<tr>
<td>29 Diesel Fuel</td>
<td>63 Diatomite</td>
<td>97 Ammonium Chloride</td>
</tr>
<tr>
<td>30 Silica, Crystalline</td>
<td>64 Bauxite</td>
<td>98 Zn, Zinc-MF Unknown</td>
</tr>
<tr>
<td>31 Aluminium Sulphate</td>
<td>65 Tetrachloroethylene</td>
<td>99 Asbestos</td>
</tr>
<tr>
<td>32 Iron Oxide (Fe3O4)</td>
<td>66 Chlorine</td>
<td>100 Magnesite</td>
</tr>
<tr>
<td>33 Calcium Hydroxide</td>
<td>67 Chromic Acid and Chromates</td>
<td></td>
</tr>
<tr>
<td>34 Carbon Dioxide</td>
<td>68 Barium (Soluble Compounds)</td>
<td></td>
</tr>
</tbody>
</table>

In May 2000 the Environmental Protection Agency (EPA) published its Toxic Release Inventory (TRI) in the USA for 1998. This was the first year that seven new industries including metal mining and coal mining had to report their releases and other waste management quantities to the EPA. For 1998, metal mining recorded close to half of all the releases under TRI (48%). The chemicals that
contributed the most to the metal mining sector’s releases were copper compounds (1.2 billion pounds), zinc compounds (616 million pounds), and arsenic compounds (513 million pounds). The majority of the releases of these three chemicals is to land on-site. Together, these three chemicals make up 66.7% of the total releases for the metal mining sector. Many of the releases reported in TRI by metal mines are from release of waste rock and processed rock to land. Some mines reported high releases of cyanide. Releases of mercury were also reported. Mercury is no longer used in the US, as it had been historically to remove gold from ore. The mercury emitted originates as a natural occurring element often found in gold-bearing ore. Some mines use heat to pretreat ore to improve leaching characteristics, a step which may generate air release of mercury. Another emission point is at the retort/refinery process. Mercury is generally leached out of the ore along with the gold, and must be removed from the final product. Some facilities use heat to vaporize mercury from the gold, most of which is captured and sold as a product. Detailed information on mercury sources in the cyanidation process can be obtained at the web site of the US Mine Safety and Health Administration (MSHA) in their publication Controlling Mercury Hazards in Gold Mining: A Best Practices Toolbox (http://www.msha.gov/s&hinfo/mercury/hgletter.htm).

The chemicals that contributed the most to the coal mining sector’s releases were barium compounds (7 million pounds), manganese compounds (1.8 million pounds), and zinc compounds (1.8 million pounds). The coal mining sector total releases were less than 0.4% of the metal mining sector. The full TRI data for the two mining sectors can be obtained at the TRI site (http://www.epa.gov/tri/) via the TRI Explorer tool.

9.2.3 Generic classifications

The Australian Mining and Quarrying Occupational Health and Safety Committee (MAQOHSC) published a practical guide (http://www.maqohsc.sa.gov.au/Documents/MQHazSub.pdf) for the control of hazardous substances in quarries in 1998. It covers the common chemicals found in the industry and simplifies identification, assessment and control methods that may be used to minimise risks to health. Hazardous chemicals were grouped into fourteen generic classifications:

- **Acids** such as sulphuric acid (battery acid) and hydrochloric acid (used as a cleaner, particularly for concrete transit mixers) are the two common inorganic acids encountered in quarries. Both are highly corrosive and can cause burns to the skin, mouth, throat, eyes and respiratory system. Contact with the eye may result in blindness. Both acids can react with certain metals to generate potentially explosive hydrogen gas. These acids can also react with other compounds to produce poisonous gases.

- **Adhesives** may contain substances that are classified as hazardous such as organic volatiles, epoxy resins and epichlorohydrin.

- **Bitumens** are a combination of oxidised and non-oxidised petroleum asphalts and are used in blending plants (pugmills) in some quarries for the production of bitumen-treated crushed rocks and rubbles for use as a roadbase. Some quarries use asphaltic precoats to supply surface coated screenings for the spray sealing market. This range of precoats is a blend of small proportions of asphalt, kerosene and possibly other light solvents in a diesel fuel (distillate) base.

- **Bottled gases** are a diverse group of substances used predominantly for welding/cutting operations or in refrigeration systems. The gases normally encountered range from inert ‘non-toxic’ gases such as nitrogen and argon, highly flammable gases such as acetylene and propane/propane to highly reactive gases such as oxygen.

- **Cements — general purpose** are used in quarries to produce stabilised road base products or in a few instances in batch plants to produce traditional concretes. Cements may contain crystalline silica and their caustic, alkaline nature can result in burns to the skin and eyes.

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Dusts are one of the major health hazards in quarries. Dust is generated at all stages of the production process and the smallest, invisible particles are the most hazardous due to their ability to reach the deeper part of the lung (the alveolae). The most widely recognised toxic component of the dust is crystalline silica.

Explosives commonly used in the quarrying industry are predominantly ammonium nitrate based. Accessories such as detonators, primers, boosters, lead lines, delays and detonating cords may use one or more of a variety of substances such as black powder, pentaerythritoltetranitrate, trinitrotoluene, sodium nitrate and lead azide. Hazards associated with these products are mainly due to their dangerous nature as explosives and strict safety standards are required in handling, storage, transport and use.

 Fluxes may be encountered as discrete solids or as liquids for use in soldering and brazing operations or as an integral part of another product such as the flux coating on normal welding rods and in multi-core solders. The main hazard is from the metal oxides, gases and fumes generated during use.

Fuels are petroleum-based hydrocarbons with the main fuel in quarries being distillate (diesel) with petrol and liquid petroleum gas (LP gas) being used to a lesser degree. They may contain additives or substances such as; Toluene, Xylene, Benzene and benzene compounds, N-Hexane, Tetraethyl lead etc. Fuels in general are hazardous substances due to their flammable nature and the fact they can contain cyclic and polycyclic aromatic hydrocarbons which by themselves have been associated with skin disorders including cancer. The most likely effect, if any, could be dermatitis due to drying and defatting actions.

"Fumes" such as exhaust gases (mainly from diesel engines but also some petrol or gas driven engines) and fumes from welding operations are the most significant groups in this category. To a lesser degree (and this is a significant danger for underground operations) there are fumes and gases emanating from the use of explosives.

Lubricating oils and greases are generally petroleum based although there are a few which are vegetable based, as well as a number of silicone or graphite based products. Many contain various chemical additives such as lithium or molybdenum compounds and antifoam agents, etc. Some greases contain small quantities of organic lead. Oils and greases as used in the quarry industry are not considered a significant hazard in normal use provided good standards of personal hygiene are followed.

Office consumables include a diverse range from medicines, insect repellents/killers, air fresheners, vehicle and office cleaning items. Many products are in pressurised aerosol form. There are some health risks associated with the use of strong household cleaners, bleaches and disinfectants, particularly those which are caustic and contain hypochlorites.

Paints/Thinners/Solvents/Cleaning fluids are a group of substances that may be derived from hydrocarbons, often aromatic and volatile, or from plastic polymers and co-polymers. Some additives are classified as hazardous such as zinc phosphate, lead chromate and isocyanates. A multitude of other fillers and pigments may be used.

9.2.4 Exposure data

Injuries, illnesses, and hazardous exposures in the US mining industry, 1986 —1995 were published by NIOSH (Publication No. 2000-117). Two tables (based on MSHA data) from the NIOSH report are reproduced which show the percent of samples under the permissible exposure limit (PEL) and in excess of the PEL (http://www.cdc.gov/niosh/ciss/pdfs/iiahe.pdf). In the coal industry, 7.8% of all respirable dust samples were above the PEL. Of silica dust samples obtained during the 10-year period, 23.7% were above the PEL in coal, 16% in metal, 10.8% in non-metal, 9.1% in stone, and 7.6% in sand and gravel.
Of metal fume exposures, silver samples showed the largest percentage above the PEL — approximately 48% of samples in both metal and non-metal. Exposures recorded in the metal industry in excess of 2 x PEL were for chromic acid/chromate (2,3%), copper (3,5%), lead (2,3%), mercury (5,7%) and silver (37,9%). The PEL values utilised were not given in the report.

Table 9.3 Dust samples, 1986-1995. Number of samples related to PEL (US data)

<table>
<thead>
<tr>
<th>Sample type</th>
<th>Total samples</th>
<th>Samples under PEL</th>
<th>Samples &gt; PEL and &lt; 2xPEL</th>
<th>Samples &gt; 2xPEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal respirable dust</td>
<td>194,682</td>
<td>179,584 92,2%</td>
<td>11,751 6,0%</td>
<td>3,347 1,7%</td>
</tr>
<tr>
<td>Coal silica dust</td>
<td>49,044</td>
<td>37,434 76,3%</td>
<td>7,213 14,7%</td>
<td>4,397 9,0%</td>
</tr>
<tr>
<td>Metal silica dust</td>
<td>9,044</td>
<td>7,593 84,0%</td>
<td>873 9,7%</td>
<td>578 6,4%</td>
</tr>
<tr>
<td>Non-metal silica dust</td>
<td>10,347</td>
<td>9,230 89,2%</td>
<td>668 6,4%</td>
<td>449 4,3%</td>
</tr>
<tr>
<td>Stone silica dust</td>
<td>45,608</td>
<td>41,453 90,9%</td>
<td>2,435 5,3%</td>
<td>1,720 3,7%</td>
</tr>
<tr>
<td>Sand and gravel silica dust</td>
<td>34,924</td>
<td>32,275 92,4%</td>
<td>1,487 4,3%</td>
<td>1,162 3,3%</td>
</tr>
</tbody>
</table>

Table 9.4 Metal Industry: metal fume samples, 1986-1995. Number of samples related to PEL (US data)

<table>
<thead>
<tr>
<th>Sample type</th>
<th>Total samples</th>
<th>Samples under PEL</th>
<th>Samples &gt; PEL and &lt; 2xPEL</th>
<th>Samples &gt; 2xPEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum oxide</td>
<td>778</td>
<td>776 99,7%</td>
<td>0 0,0%</td>
<td>2 0,3%</td>
</tr>
<tr>
<td>Arsenic</td>
<td>379</td>
<td>379 100,0%</td>
<td>0 0,0%</td>
<td>0 0,0%</td>
</tr>
<tr>
<td>Beryllium</td>
<td>465</td>
<td>464 99,8%</td>
<td>1 0,2%</td>
<td>0 0,0%</td>
</tr>
<tr>
<td>Cadmium oxide</td>
<td>495</td>
<td>494 99,8%</td>
<td>0 0,0%</td>
<td>1 0,2%</td>
</tr>
<tr>
<td>Chromic acid/chromate</td>
<td>444</td>
<td>419 94,4%</td>
<td>15 3,4%</td>
<td>10 2,3%</td>
</tr>
<tr>
<td>Cobalt</td>
<td>483</td>
<td>481 99,6%</td>
<td>0 0,0%</td>
<td>2 0,4%</td>
</tr>
<tr>
<td>Copper</td>
<td>858</td>
<td>812 94,6%</td>
<td>16 1,9%</td>
<td>30 3,5%</td>
</tr>
<tr>
<td>Fluoride</td>
<td>4</td>
<td>4 100,0%</td>
<td>0 0,0%</td>
<td>0 0,0%</td>
</tr>
<tr>
<td>Iron oxide</td>
<td>1,038</td>
<td>1,008 97,1%</td>
<td>13 1,3%</td>
<td>17 1,6%</td>
</tr>
<tr>
<td>Lead</td>
<td>797</td>
<td>757 95,0%</td>
<td>22 2,8%</td>
<td>18 2,3%</td>
</tr>
<tr>
<td>Magnesium oxide</td>
<td>743</td>
<td>743 100,0%</td>
<td>0 0,0%</td>
<td>0 0,0%</td>
</tr>
<tr>
<td>Manganese</td>
<td>793</td>
<td>793 100,0%</td>
<td>0 0,0%</td>
<td>0 0,0%</td>
</tr>
<tr>
<td>Mercury</td>
<td>156</td>
<td>137 87,8%</td>
<td>10 6,4%</td>
<td>9 5,7%</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>453</td>
<td>452 99,8%</td>
<td>1 0,2%</td>
<td>0 0,0%</td>
</tr>
<tr>
<td>Nickel</td>
<td>559</td>
<td>559 100,0%</td>
<td>0 0,0%</td>
<td>0 0,0%</td>
</tr>
<tr>
<td>Silver</td>
<td>248</td>
<td>129 52,0%</td>
<td>25 10,1%</td>
<td>94 37,9%</td>
</tr>
<tr>
<td>Titanium dioxide</td>
<td>602</td>
<td>601 99,8%</td>
<td>1 0,2%</td>
<td>0 0,0%</td>
</tr>
<tr>
<td>Vanadium</td>
<td>512</td>
<td>511 99,8%</td>
<td>1 0,2%</td>
<td>0 0,0%</td>
</tr>
<tr>
<td>Zinc oxide</td>
<td>698</td>
<td>697 99,9%</td>
<td>1 0,1%</td>
<td>0 0,0%</td>
</tr>
</tbody>
</table>

Exposure data for airborne respirable dust and quartz in South African mines is presented in SIMRAC Report SIMRISK 401 published in 1997. This report includes data from the DME dust exposure database. It was stated that despite the availability of a comprehensive airborne dust database, there is considerable uncertainty on the exposure of mineworkers to dust. The reliability of the sampling equipment used and the strategies used by mines for dust monitoring have been called into serious question with a strong suspicion that dust levels may be substantially under-reported. A limited amount of exposure data from the DME dust database has been published in the recent annual reports of the DME.
9.2.5 Underground operations

Chemicals in the mining industry pose a range of hazards from mild effects to death. Serious injuries and deaths have occurred from the inhalation of airborne contaminants, particularly in mine areas not well ventilated. Fatalities have been caused by direct inhalation of blasting fumes, heavy metal fumes (e.g. cadmium fume from flame cutting cadmium coated roof bolts), mine gases such as carbon monoxide, hydrogen sulphide or methane, and vapours (e.g. cleaning solvent vapours). In some cases loss of consciousness caused a serious injury or fatality e.g. a fall from height or a collapse into shallow water and drowning.

A computer search of the South African Mines Reportable Accidents Statistics System (SAMRASS) for Inhalation (Gassing), 1995 to mid 2000, indicated twenty-eight underground fatalities (excludes fuming after an explosion of gas/coal dust or fire). The fatalities were reported as caused by deficiency of oxygen, gassing or exposure to blasting fumes. In the same period there were eighty-two underground incidents, of which at least 50% were due to blasting fumes.

The gases produced by underground blasting, called afterdamp, are typical of what might be expected from any combustion process and may include carbon monoxide, carbon dioxide, nitric oxide, nitrogen dioxide, ammonia and methane. Exposure to blasting fumes can result in systemic effects and lung or respiratory damage. Exposure to high concentrations can be immediately fatal. Lower exposures may result in nausea, vomiting, headaches and eye and respiratory irritation. Nitrogen dioxide and oxides of nitrogen can produce delayed respiratory damage that may not be apparent until several days after exposure (http://www.masha.on.ca/ftpfiles/blastingpackage.pdf).

In stagnant air, much of the oxygen may be removed by oxidation of minerals and organic matter or by absorption into mine water. In addition, gases such as carbon monoxide, methane and hydrogen sulphide may accumulate, sometimes to the point of making the stagnant atmosphere toxic and/or explosive. A Hazard Alert (http://www.gov.on.ca/LAB/ohs/m03e.htm) published in 1995 by the Department of Labour, Ontario, Canada, reported that a worker died of asphyxiation after climbing up an unventilated manway. The atmosphere in the raise was deficient in oxygen.

Methane and hydrogen sulphide are considered the most important naturally occurring gases in coal mines; methane, hydrogen and radon in gold mines and radon in uranium and other mines. Radon is a naturally occurring radioactive gas and is discussed in Chapter 10. Carbon monoxide is found in engine exhaust and can be generated in lethal concentrations in mine fires. A table of common gases found in mines is provided in Chapter 4 on Airborne Pollutants.

Incidents involving overexposure to diesel fumes have been reported in SAMRASS. Diesel engine exhaust is a complex mixture of gases, vapours and particulate matter. The most hazardous gases are carbon monoxide, nitrogen oxide, nitrogen dioxide and sulphur dioxide. There are many volatile organic compounds (VOCs), such as aldehydes and unburned hydrocarbons, polycyclic aromatic hydrocarbons (PAHs) and nitro-PAH compounds (N-PAHs). PAH and N-PAH compounds are also adsorbed onto diesel particulate matter. Nitrogen oxides, sulphur dioxide and aldehydes are all acute respiratory irritants. Many of the PAH and N-PAH compounds are carcinogenic (http://www.iocis.org/). SIMRAC reports GEN 010 and GEN 208 provide detailed information on diesel exhaust emissions. Diesel Particulate Final Rules published in the US Federal Register by MSHA in 2001 are an excellent source of information on diesel particulate (http://www.msha.gov/01-995/Dieselpart.htm).

Plastics containing urea-formaldehyde and polyurethane foams are used in mines to plug up holes and improve ventilation and to provide a better anchor for roof supports. Formaldehyde and isocyanates, two starting materials for these two foams, are respiratory irritants and both can cause allergic sensitisation making it nearly impossible for sensitised miners to work near either ingredient. Formaldehyde is a human carcinogen (http://www.iocis.org/).

A wide variety of purchased chemicals will be used underground such as fuels, lubricants, battery acids, solvents, paints, electrical contact cleaners, etc. MSHA in their Hazard Communication
quote the example of a coal miner periodically assigned to seal permanent brattices using a highly alkaline mortar. The miner was not provided with the necessary hazard information and his hands were severely affected by the mortar. He was hospitalised for six days and missed two weeks of work.

9.2.6 Surface operations

Purchased chemicals used in surface operations have been outlined earlier and include sodium cyanide for gold recovery in large operations and mercury for gold recovery in small/artisanal operations. Process reagents include acids, alkalis, frothers and collectors, modifiers, flocculants and coagulants. Solvents are utilised in solvent extraction plants. Asbestos will be found on various plants and polychlorinated biphenyls (PCBs) in some transformers. Freons and halons are present in cooling equipment and fire protection devices. Gases and fumes are generated from industrial combustion engines, furnaces and converters. The crushed rock passed through the processing plant to extract the desired mineral or metal is discharged from the plant as waste tailings. Tailings may contain heavy metals, cyanide or other chemicals depending on the geological composition of the ore body and the process used. Effluent or wastewater can contain spent solvents and coolants (http://mineralresourcesforum.unep.ch/docs/pdfs/hazmatmgnt.pdf).

Detailed information on the types of mineral processing plants utilised in South Africa and the health hazards associated with heavy metals in these processes is provided in SIMRAC Report HEALTH 603. The report includes process flow diagrams with the reagents used and discharge streams. An extension of this project, HEALTH 804 will include information on the broad range of chemical hazards in mineral processing operations. HEALTH 709 provides information on health hazards in silicon smelters.

Several other research projects under SIMRAC also include information on hazardous substances in mining or are relevant for the control of hazardous substances. HEALTH 605 covers welding fumes and SIMRISK 401 (Ref G, I and Q) health risks in general in the South African mining industry. The SIMRAC reports are available on CD-ROM and via the SIMRAC website (http://www.simrac.co.za).

The Integrated Pollution Control Guidance Notes (IPCGNs) published on the web by the Environment Agency in the UK (http://www.environment-agency.gov.uk/business/techguide/IPC/) are another useful source of information on the mineral industry sector and metals production and processing. Potential release routes for hazardous substances in different processes are outlined.

Artisanal and small-scale gold mining is associated with environmental damage from mercury contaminated waste. High exposures to mercury vapour can occur when mercury-gold amalgam is heated in an open cycle. There are several alternatives to amalgamation for obtaining gold but few have been generally accepted. Careful demonstration and promotion will be required if they are to replace amalgamation in small-scale mining (Minesafe International 2000).

The types of hazards typically found in metalliferous mines, and minerals processing plants are provided in Table 9.5. The information is from a paper presented at the Queensland Mining Industry Health & Safety Conference 2000 (http://www.qmc.com.au/docs/conferences/QMC_2000/conf_donoghue.pdf).
Table 9.5 Occupational health hazards in metalliferous mining and in minerals processing ranked according to risk

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Health Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radon, crystalline silica, arsenic, ± diesel in underground mining</td>
<td>Lung cancer</td>
</tr>
<tr>
<td>Arsenic in copper smelters</td>
<td>Lung cancer</td>
</tr>
<tr>
<td>Nickel compounds in nickel refineries</td>
<td>Lung cancer</td>
</tr>
<tr>
<td>Aluminium smelter potroom work</td>
<td>Occupational asthma</td>
</tr>
<tr>
<td>Cyanide</td>
<td>Fatal toxicity</td>
</tr>
<tr>
<td>Confined space</td>
<td>Toxicity, oxygen deficiency</td>
</tr>
<tr>
<td>Asbestos</td>
<td>Mesothelioma</td>
</tr>
<tr>
<td>Welding fumes and gases</td>
<td>Pneumonia, chemical pneumonitis</td>
</tr>
<tr>
<td>Ammonia refrigerant spill</td>
<td>Fatal pulmonary oedema</td>
</tr>
<tr>
<td>Sulphur dioxide in smelters</td>
<td>Fatal exacerbation of asthma</td>
</tr>
<tr>
<td>Hydrofluoric acid vapour</td>
<td>Fatal pulmonary oedema</td>
</tr>
<tr>
<td>Hydrofluoric acid spill</td>
<td>Chemical burns</td>
</tr>
<tr>
<td>Welding fumes and gases</td>
<td>Occupational asthma, chronic bronchitis</td>
</tr>
<tr>
<td>Crystalline silica dust in underground mining</td>
<td>Silicosis</td>
</tr>
<tr>
<td>Xanthate reagent mixing</td>
<td>Acute or chronic carbon disulphide toxicity</td>
</tr>
<tr>
<td>Irritants</td>
<td>Irritant dermatitis</td>
</tr>
<tr>
<td>Sulphur dioxide in smelters</td>
<td>Exacerbation of asthma, irritant effects</td>
</tr>
<tr>
<td>Welding fume</td>
<td>Metal fume fever</td>
</tr>
<tr>
<td>Lead dust and fumes in lead smelters</td>
<td>Symptomatic lead poisoning</td>
</tr>
<tr>
<td>Xanthate reagent mixing</td>
<td>Acute mild carbon disulphide toxicity</td>
</tr>
</tbody>
</table>

Typical incidents that occur in mines with regard to the inhalation of fumes, gases and vapours can be found in the EXIS (External Information System) database (http://notesweb.dme.wa.gov.au/exis/Exisonweb.nsf), Department of Minerals and Energy — Western Australia (DME-WA). Tables 9.6 illustrates some of the unconsciousness/fuming incidents that have occurred in recent years for underground and surface operations.

Table 9.6 Selection of incidents reported by mine sites to the Department of Minerals and Energy, Western Australia: unconsciousness/fuming

**Underground**

A truck driver inhaled smoke when a fire occurred on an Atlas Copco MT5000 truck. The cause of the fire is unknown.

While driving down the decline, a safety representative was exposed to sulphurous fumes following a sulphide dust explosion in a drive.

A jumbo operator’s offsider suffered exposure to diesel fumes causing nausea and chest pains.

Two diamond drillers suffered the effects of blast fumes after re-entering a drive after a blast. The fumes were generated by a blast lower down in the mine and had travelled through the ventilation system.

An underground mine worker entering a drill drive was exposed to gas fumes. The victim felt nauseous and light headed after he noticed an odd smell. As a precaution oxygen was administered in the first aid room, and he was then evacuated to hospital for overnight observation. The fumes are understood to have been generated by grouting and glueing operations. The ventilation was not turned on at the time of entry.

A long hole driller suffered fuming while operating a diesel/hydraulic long hole rig in the ventilation drive of the decline. The secondary ventilation in the area was poor and the driller showed symptoms of fuming while being transported to the surface at the end of shift. He was released from hospital after being treated for Carbon Monoxide poisoning.
A fitter suffered from fumes while using oxy acetylene equipment near the concentrate silo.

Three scaffolders were affected by carbon monoxide gas which leaked from the gas plant.

A supervisor is believed to have been affected by the inhalation of fumes when inspecting the tunnel under the primary crusher. The fumes may have been sulphur dioxide or ammonia.

Six employees were affected by a cyanide spillage in the mill. One employee suffered caustic burns and four others minor itching and rashes. The sixth employee is believed to have suffered from inhalation of fumes through the air conditioning unit. The cause of the incidents was the overflowing of the cyanide tank and the mist associated with it.

A technician suffered from acid inhalation when walking past the acid line. A small hole in the line was allowing acid mist to escape.

A welder suffered from respiratory irritation and shortness of breath when welding around a gas manifold in the acid plant. Welding splatter ignited sulphur on the ground causing sulphur dioxide to be emitted.

A laboratory technician was exposed to acetone fumes when he opened an oven door to remove samples.

A fitter received oxygen when he reported feeling unwell after working with polyurethane prepolymer.

A fuming occurred when a boilermaker was exposed to zinc fumes while welding galvanised gridmesh over a period of two days.

An employee reported feeling unwell after observing his supervisor using a rubber glue compound.

While digging out a tailings line two trades assistants were sprayed with tailings solution, some of which entered their mouths. Each subsequently experienced nausea and vomiting.

A security officer experienced difficulties breathing after inhaling fumes from an acid leak in the bulk acid storage area.

A painter was affected by fumes whilst using thinner to remove paint from his hair. He was transferred to emergency services and oxygen was administered until he recovered.

A contract cleaner using a cocktail of proprietary cleaning agents to clean floors and toilets was found unconscious. After a visit to the first aid office, where oxygen was administered, she was taken to hospital and then to a GP. Contract cleaners are to have more training, especially in chemical handling and usage.

A truck driver became affected by fumes when hydraulic oil leaked on the motor causing excessive smoke.

A refinery operator had an asthma attack after being sensitised to fumes.

The SAMRASS database for Inhalation (Gassing) 1995 to mid 2000 indicated six surface fatalities including one suspected carbon monoxide poisoning and one fatality whilst working in an open top cyanide tank at a Carbon Leach Plant (five persons were overcome by cyanide in the rescue). There were thirty-eight surface incidents over a third of which were due to cyanide inhalation.

More detailed examples of potential chemical exposures that can occur in mineral processing are given in Table 9.7. The particular process is a smelter for producing converter matte for nickel, copper and cobalt refining and platinum group metal refining.

Typical health hazards associated with the nickel, copper and cobalt refining include sulphuric acid mist containing nickel and copper salts generated during copper electrowinning. At the refinery there is the risk of exposure to allergenic platinum salts.

Information on hazardous waste is available in the papers presented at the 3rd Asia Pacific Training Workshop on Hazardous Waste Management in Mining held in Beijing, China, September 2000 (http://mineralresourcesforum.unep.ch/docs/pdfs/hazmatmngt.pdf). In their HazCom Interim Final Rule, MSHA detailed an incident at a copper mine in which a tailing pond was so acidic it was damaging the system’s pumps. A contractor was hired to place lime in the pond to neutralize the acid and a miner was assigned to the project. The miner walked down the slope of the pond and stepped onto an area of lime that appeared solid but he then sank into the lime. He spent over a month in...
hospital with second- and third degree burns to the legs and missed more than two months work, returning to restricted duty while receiving a series of skin grafts (http://www.msha.gov/regs/fedreg/final/2000final/00-24803.pdf).

Table 9.7 Some potential chemical exposures at a mineral processing plant

<table>
<thead>
<tr>
<th>Rail Delivery From Mines</th>
<th>Potential Chemical Exposures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Transfer Bins</strong></td>
<td></td>
</tr>
<tr>
<td>(wet ore)</td>
<td>Ore dust (0.2% Ni) low quartz content (&lt;5%). Dry ore from spillage may also be added from dumper trucks. Ammonia gas from ore.</td>
</tr>
<tr>
<td><strong>Millling</strong> (wet)</td>
<td>Milled ore slurry — dust.</td>
</tr>
<tr>
<td><strong>Mill Relining</strong></td>
<td>Confined space — gases, fumes. Mill relining activities involve gas torch cutting operations on high manganese steel. Cutting operations in confined spaces, especially with an oxy-gas flame, can result in dangerous concentrations of nitrogen oxides, and fatalities have resulted from exposures as short as 15 minutes (e.g. in shipbuilding). Care required in ensuring adequate mill ventilation during relining.</td>
</tr>
<tr>
<td><strong>Flotation Reagent Mixing</strong></td>
<td>Handling of liquid reagents in drums and bagged reagent powders. Sodium Isobutyl Xanthate powder — causes caustic burns to the skin with prolonged contact, will burn eyes and is poisonous on ingestion. The main hazards from exposure to xanthates are considered to arise from carbon disulphide. Acrol (natural vegetable gum), when wet will make any floor surface extremely slippery.</td>
</tr>
<tr>
<td><strong>Flotation</strong></td>
<td>Surface bubbles which when burst can generate a mist and release particulates. Potential for eye irritation from ‘Flotation water’. Spillage is a common occurrence in flotation and as these spills dry, further particulates may be released into the air from the floor. Cresylic acid — corrosive to skin, eyes and mucous membranes. Grading rooms — potential for airborne sample dust.</td>
</tr>
<tr>
<td><strong>Catalyst Recovery</strong></td>
<td>Auto exhaust catalyst dust (normal 0.4% lead but could be up to 3-4% lead) — potential for lead inhalation and ingestion.</td>
</tr>
<tr>
<td><strong>Dryers</strong></td>
<td>Concentrate dust (1-2% Ni), carbon monoxide. Coal Bunker area — Vehicle and wind generated dust. Hot Gas Generator — Silica dust (intermittent work inside to remove slag from the fluidised sand bed or to change the bed).</td>
</tr>
<tr>
<td><strong>Submerged Electric Arc Furnaces</strong></td>
<td>Fumes and furnace dust, sulphur dioxide, burnt lime. Concentrate dust from pneumatic transfer system. Particular attention required to protect those working on the top floors of the furnaces such as paste crews. Furnace rebuild and Ladle relining — silica dust.</td>
</tr>
<tr>
<td><strong>Converters</strong></td>
<td>Sulphur dioxide, metal fumes and silica dust (Silica sand added). Converter section dust (11% Ni). Need for adequate control of furnace and converter emissions to ensure compliance with OEL values for sulphur dioxide and nickel. Crane drivers working above the converters need particular protection. Electrostatic precipitators — Deposits of lead and other fumes</td>
</tr>
<tr>
<td><strong>Converter Matte</strong></td>
<td>Wet granulated matte (49% Ni). Bagged wet, little dust produced.</td>
</tr>
<tr>
<td>(Product for Refinery)</td>
<td></td>
</tr>
<tr>
<td><strong>Acid Plant</strong> (Sulphuric acid produced from SO₂)</td>
<td>Sulphur dioxide, sulphuric acid, water treatment chemicals, vanadium pentoxide catalyst, arsenic. Operators may be required to wear SCBA in an emergency or full-body encapsulating chemical resistant suit.</td>
</tr>
</tbody>
</table>
Laboratory

| Variety of chemicals including bromine, hydrofluoric acid and lead — containing fluxes used in fire assay. Pipetting and siphoning — potential for inhalation and ingestion hazards. Fume cupboards — with poor performance potential for exposure to fumes that should have been captured by the fume cupboards. Bottle washer — often the highest exposed person in the lab without adequate exhaust hood over the “bottle washing” sinks. |

Abrasive Blasting

| Exposure to broken-down abrasive material, pulverised surface coatings and encrusted material (which may contain toxic metals or other toxic substances), and abraded material from the object being blasted. Essential to have a good quality abrasive-blast airline supplied hood with adequate supply of breathing air. |

Spray Painting

| Two component epoxy paints — known irritants and sensitisers. Durathane type paints — isocyanate in the hardener and zinc chromate in the filler. Repeated or prolonged inhalation exposure may cause asthma and nasal ulceration. Zinc chromate is carcinogenic to humans. Airline supplied helmets for paint spraying should be used giving both respiratory and face/eye protection. |

Welding, Cutting, Soldering and Brazing

| Large amount of welding and cutting operations conducted in the Boiler-makers workshop, other workshops and around the plant. Potential for exposure to mild/stainless steel welding fumes or fumes from coated steels. Potential for exposure to brazing fumes during brazing and for cadmium exposure from soldering with cadmium-containing silver soldering rods. Local extraction required to capture at source fumes and gases. |

Laboratory health and safety information and information on spray painting, and welding, cutting, soldering and brazing can be located via the Association of Societies for Occupational Safety and Health (ASOSH) web site Chemicals page (http://www.asosh.org/WorldLinks/chemicals.htm). Health and safety training materials for abrasive blasting can be obtained from Michigan State University, USA. Their package includes an Instructor’s Manual, User’s Manual plus general comments for instructors, overhead transparencies and a training exercise (http://web2.chm.msu.edu/oem/index.htm).

9.3 Adverse health outcomes from exposure to chemicals

Although most chemicals have a toxic potential, the extent to which they pose a hazard to health will depend on the interplay between a number of factors.

9.3.1 Factors determining hazard potential

- The physical state of the chemical

Chemical substances may exist as a single phase medium such as a solid, liquid, aerosols or gas, or coexist in more than one form. Solids can give off hazardous gases or vapours, be changed to fumes by burning or melting (e.g. heavy metals) or be changed to airborne dusts by grinding, cutting or abrasion. Dispersed in the air they are easily inhaled and are able to exert their toxic effects. Lipid soluble liquids (e.g. phenol, aniline) are easily absorbed through the skin. Liquids can be dispersed as mists or give off vapours by industrial processes and in this way become airborne.

- The route of exposure of the chemical

Chemical substances can enter the body through inhalation, which is by far the most common route of entry for a large number of chemicals. Absorption through the skin or via the eyes occurs either through direct skin contact or from contact with contaminated surfaces or clothing. Chemical ingestion in the workplace may occur either by chemicals settling directly on food or workers eating food with contaminated fingers.

- The exposure dose of the chemical

The most important environmental factors determining exposure dose include the concentration, duration and frequency of exposure to the chemical concerned. Certain chemicals such as sensitisers
and irritants may produce adverse local health effects from single episodes of exposure to very high concentrations of the substance. Other chemicals such as solvents and heavy metals exert their systemic health effects as a result of repeated low dose exposure to these chemicals. The presence of administrative controls such as job rotation, use of personal protective equipment and engineering controls (e.g. local exhaust ventilation) may also modify the exposure dose.

- Individual differences among exposed individuals

There are a number of host factors that determine the extent to which chemicals are absorbed, distributed, metabolised and excreted by the body. Individual physical characteristics such as physical work load (e.g. heavy manual work underground) and skin characteristics (e.g. presence of pre-existing eczema) can increase the amount of chemical absorbed by the body. Furthermore, dietary patterns can also increase the amount of chemicals absorbed due to chemical contamination of the food chain (e.g. arsenic in fish), making it difficult to differentiate between occupational exposure and general background environmental exposure. The body size and composition (fat content) are particularly important since they determine the potential surface area available for distribution and deposition of the chemical in various parts of the body. Certain solvents (e.g. benzene) have a high affinity for fat deposition and result in increased blood levels even after exposure has ceased. There are various factors such as age, gender, and social habits that modify the manner in which the chemical is metabolised and excreted by the body. Social habits such as smoking tobacco and alcohol consumption increase the absorption and the metabolism of chemicals such as lead. Pre-existing kidney disease and old age is associated with decreased excretion of the chemical, thereby increasing the concentration of heavy metals (e.g. mercury, cadmium and lead) in the body to exert their toxic effects.

9.3.2 Fate of chemicals entering the body

Once the chemical enters the body, it is transported by blood to organs, such as the liver, where it is converted through various metabolic processes into a less toxic (or occasionally a more toxic) water-soluble metabolite before being excreted from the kidneys and/or liver (Figure 9.1). The rate at which substances are absorbed into the body and the rate at which they are distributed to different tissues, metabolised and excreted, can differ markedly between substances.

The biological half-life \( t_{1/2} \) of a substance or its metabolite is the time taken for its concentration to fall to 50% of its original value after the end of exposure. Half-life can be measured in minutes, hours or days. Some chemical substances have a shorter biological half-life and a shorter residence time within which to exert their toxic effects e.g. benzene, carbon monoxide. Other substances have low excretion rates, a long biological half-life and may therefore persist in body tissues for a long period of time (months or years) causing chronic ill-health e.g. lead, mercury. It is this dose fraction of the chemical that enters and persists in the tissue of the target organ that causes impaired functioning and the manifestation of clinical disease. Biological monitoring procedures are designed to detect the presence of these absorbed substances in body fluids such as blood/plasma and urine.

9.3.3 Mechanisms of disease causation

Chemical substances exert their effects through various mechanisms:

- **Acute**: effect exerted immediately or within a few hours of exposure (implies rapid accumulation at the target organ site; the severity of the reaction is directly proportional to the exposure dose rate) e.g. asphyxiants (cyanide, methane, carbon monoxide, hydrogen sulphide, nitrogen dioxide), irritants (chlorine, sulphur dioxide, ammonia) and corrosives (acids)

- **Chronic**: effect exerted after months or years of exposure (implies gradual accumulation at the target organ site; severity is directly proportional to the exposure dose rate) e.g. heavy metallic toxins such as lead. Certain substances demonstrate a delayed effect following a prolonged latency period (can occur with prolonged exposure or transient exposure) e.g. carcinogens such as asbestos
Figure 9.1 Fate of chemicals after entry into the body from the workplace environment and the role of various monitoring techniques for hazardous chemicals
• **Allergenic**: effect exerted through the immune system (multiple initial doses result in sensitisation with the accumulation of antibodies; subsequent low-level exposure triggers a response; pronounced individual susceptibility) e.g. respiratory and skin sensitisers (chrome, nickel, platinum salts).

**9.3.4 Health effects on specific body systems**

Depending on their physical characteristics, certain chemicals have an affinity for specific target organs or body systems (Figure 9.2). Once deposited, they cause impaired functioning of the normal metabolic processes, which if permanent, ultimately results in disease. Biological effect monitoring is able to detect some of these early sub-clinical biochemical changes, while medical surveillance programmes are designed to detect early adverse health effects due to exposure to a particular chemical substance before they become clinically apparent (Table 9.8, Figure 9.1). This impaired functioning progresses to a clinically diseased state and manifests in the individual worker as symptoms and signs referable to the specific target organ affected. Some chemical substances exert their toxic effect on a specific target organ, usually locally at the site of entry. Other chemicals exert their effects systemically (more than one organ system distant to the site of entry). With mixed exposures, individual substances can act through similar toxicological mechanisms so that the effects reinforce one another and their effects can be additive. In some instances the overall effect is considerably greater than the sum of individual effects and the system is synergistic. Table 9.9 indicates the most common organs affected, the symptoms associated with abnormal function and the tests commonly used in medical surveillance.

*For detailed toxicology and adverse health effects information refer to Patty’s Industrial Hygiene and Toxicology; NIOSH Occupational Health guidelines for chemical hazards (http://www.cdc.gov/niosh/chem-inx.html) or the NIOSH Pocket Guide to Chemical Hazards (http://www.cdc.gov/niosh/npg/pgdstart.html); ILO Encyclopedia of Occupational Health and Safety; International Agency for Research on Cancer (IARC) Cancer Databases (http://www.iarc.fr/).*

**Table 9.8 Relationship between environmental monitoring, biological monitoring, biological effect monitoring, medical surveillance and clinical diagnosis**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental monitoring</td>
<td>Measures the airborne concentration of the chemical in the workplace environment</td>
<td>lead fumes, mercury vapour</td>
</tr>
<tr>
<td>Biological monitoring</td>
<td>Measures the extent of absorption of the chemical by the worker by determining the concentration of the substance and its metabolites in human tissue or fluids (e.g. blood, urine, adipose tissue)</td>
<td>blood lead, urinary arsenic</td>
</tr>
<tr>
<td>Biological effect monitoring</td>
<td>Measures early physiological/biochemical effects of exposure on the human body, which are reversible on removal from exposure</td>
<td>zinc protoporphyrin, red cell cholinesterase</td>
</tr>
<tr>
<td>Medical surveillance</td>
<td>Aims to identify workers with early adverse health effects, which are likely to be reversible or do not progress to significant functional impairment when exposure conditions are improved</td>
<td>serum creatinine, urea, serum transaminases, skin prick tests, neurobehavioural tests</td>
</tr>
<tr>
<td>Clinical diagnosis</td>
<td>Identifies workers with clinical signs and symptoms of an occupational disease with significant functional impairment, which is commonly irreversible despite improvements in exposure conditions</td>
<td>clinical assessment accompanied by confirmatory diagnostic tests e.g. tissue biopsy</td>
</tr>
</tbody>
</table>
Figure 9.2 Examples of chemicals affecting various target organs in the body (adapted with permission from Industrial Health Research Group, University of Cape Town)
Table 9.9 Adverse health effects associated with exposure to hazardous chemical substances according to target organ system and appropriate tests used in medical surveillance

<table>
<thead>
<tr>
<th>Target organ system</th>
<th>Examples of hazardous chemicals</th>
<th>Health effects</th>
<th>Symptoms of impaired function</th>
<th>Medical surveillance tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood and blood forming organs</td>
<td>- chemical asphyxiant gases (cyanide, carbon monoxide, hydrogen sulphide, nitrogen dioxide) - arsine, cyanide - benzene, lead</td>
<td>- asphyxiation due to tissue hypoxia or chemical-specific response - bone marrow dysfunction (anaemia, low platelets) - intravascular haemolysis - leukaemia</td>
<td>- asymptomatic - jaundice, dark urine - abdominal pain and swelling</td>
<td>- full blood count - zinc - protoporphyrin* (ZPP)</td>
</tr>
<tr>
<td>Nervous system</td>
<td>- chemical asphyxiant gases (cyanide, carbon monoxide, hydrogen sulphide, nitrogen dioxide) - lead, manganese, mercury - solvents (hexane trichlorethylene)</td>
<td>- encephalopathy - cognitive effects (memory, concentration, speech) - mood and personality effects - peripheral neuropathy (sensory/motor effects)</td>
<td>- headache, drowsiness - vision/hearing loss - loss of memory, concentration - abnormal limb sensation and movements - mood and personality changes</td>
<td>- visual fields - audiometry - nerve conduction tests* - neurobehavioural test battery*</td>
</tr>
<tr>
<td>Liver</td>
<td>- solvents (toluene, trichlorethylene, xylene, dinitrobenzene) - arsenic</td>
<td>- hepatitis, cirrhosis, cancer - production of toxic chemical metabolites</td>
<td>- jaundice, dark urine - abdominal pain and swelling</td>
<td>- liver function tests (Transaminases: ALT, AST; Gamma-glutamyl transpeptidase: GGT)</td>
</tr>
<tr>
<td>Kidneys and bladder</td>
<td>- lead, cadmium, mercury, platinum, chromium, arsenic - solvent mixtures, trichlorethylene - amines</td>
<td>- glomerulonephritis - tubular necrosis - cancer</td>
<td>- increased or decreased urine output - dark urine</td>
<td>- proteinuria - serum urea, creatinine, uric acid - urine cytology</td>
</tr>
<tr>
<td>Reproductive system</td>
<td>- lead, cadmium, methylmercury, toluene</td>
<td>- infertility - miscarriages - foetal birth defects</td>
<td>- inability to conceive</td>
<td>- semen analysis* - hormonal analysis*</td>
</tr>
<tr>
<td>Skin</td>
<td>- oils, acids, alkalis, solvents - cement - nickel, mercury, chrome, arsenic</td>
<td>- contact allergic and irritant dermatitis - skin burns, ulcers - cancer</td>
<td>- red, swollen, itchy, scaly, crusty skin - skin burns, ulcers</td>
<td>- skin patch tests*</td>
</tr>
<tr>
<td>Respiratory system</td>
<td>- chlorine, sulphur dioxide, ammonia - chrome, nickel, platinum salts - oxides of nitrogen - metal fumes - asbestos, silica, coal</td>
<td>- respiratory tract irritation - occupational asthma - hypersensitivity pneumonitis - chronic obstructive lung disease - pneumoconiosis - cancer, mesothelioma</td>
<td>- nasal perforations, ulcers, bleeding - wheezing, shortness of breath, tightness - cough - excessive phlegm production</td>
<td>- chest radiography - spirometry - skin prick tests - serum antibodies (RASTs) - non-specific challenge tests*</td>
</tr>
</tbody>
</table>

* Specialised expertise required
9.4 Assessment and monitoring of exposure to chemical hazards

Assessment and monitoring of exposure to hazardous chemical substances is an important aspect of initial and ongoing risk assessment and control. The primary prevention strategy should always be to prevent exposure to agents associated with toxic effects. When it is not possible to prevent such exposures, then the appropriate strategy is to limit exposure and minimise the possibility of adverse health effects. Exposure monitoring encompasses two basic techniques viz. environmental air monitoring (occupational hygiene) and biological monitoring. Environmental and biological monitoring are ways of investigating different problems and should be seen as complementary procedures. A practical approach in setting up an exposure monitoring programme for hazardous chemical substances is outlined in Table 9.10. For more information on environmental monitoring see the chapter on Airborne Pollutants.

9.4.1 Advantages and disadvantages of biological monitoring

Although environmental measurements can be very useful in determining the sources of exposure and in identifying priorities for control measures, biological monitoring may offer several advantages for the following reasons:

- More direct indicator of risk to health since it measures the total absorbed dose of the substance
- Takes into consideration absorption by routes other than lungs and is especially useful for substances absorbed through the skin or which enter the body by ingestion
- Accounts for individual variations that influence uptake as well as non-occupational background exposure e.g. smoking, dietary habits
- By integrating absorption from all exposure sources it can be used to gauge the overall effectiveness of workplace controls or where there is great dependence on personal protective equipment

One of the major drawbacks of biological monitoring is that it detects uptake of hazardous substances after exposure has occurred. It also has little preventive value in monitoring workers with exposure to substances that exhibit their toxic effects at sites of first contact (e.g. primary lung irritants). Furthermore biological monitoring cannot always be used as an indicator of health risk unless the relationship between external exposure and internal dose is known.

9.4.2 Sampling strategies for biological monitoring

Since the amount of the chemical substance or its metabolites in collected samples of blood or urine is very small, utmost care is required in sample collection to avoid contamination and, possibly, misleading results. The sampling strategy is determined by prior knowledge of the biological half-life of the substance in the biological fluid that is sampled. The shorter the biological half-life of a substance (e.g. benzene, arsenic), the more indicative it is of recent exposure. For this reason, it is recommended that samples are taken at the end of the shift or the work week (i.e. when levels are expected to be at their highest). For substances with relatively long half-life (e.g. mercury, lead), the timing of the sample is less important. However, the timing for the collection of a chemical with a long biological half-life generally requires a period of exposure (e.g. six months) before biological monitoring will give meaningful results. If samples are not representative, or are not correctly collected or stored, the analytical results can be meaningless or misleading.


For information on biological monitoring tests indicated for individual substances refer to NIOSH database on Specific Medical Tests Published in the Literature for OSHA Regulated Substances (http://www.cdc.gov/niosh/nmed/medstart.html)
Table 9.10 A stepwise approach to developing an exposure monitoring programme for hazardous chemical substances

<table>
<thead>
<tr>
<th>Step 1</th>
<th>What is the nature of the job? — outline the various activities.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 2</td>
<td>Identify the hazardous chemicals associated with exposure to chemicals in the various activities.</td>
</tr>
<tr>
<td>Step 3</td>
<td>Identify the potential routes of exposure to the particular hazardous chemical substance.</td>
</tr>
<tr>
<td>Steps 1-3</td>
<td>Steps 1-3 are part of the risk assessment process. If a potential health risk is identified, proceed to Step 4. (See also chapter on Risk Assessment)</td>
</tr>
<tr>
<td>Step 4</td>
<td>If the exposure route is mainly airborne, proceed to environmental monitoring (EM). (See also chapter on Airborne Pollutants)</td>
</tr>
<tr>
<td>Step 5</td>
<td>If the exposure route is mainly through non-inhalation routes (skin, ingestion) or if major reliance on personal protective equipment, proceed to biological monitoring (BM).</td>
</tr>
<tr>
<td>Step 6</td>
<td>Develop a sampling strategy for EM and/or BM based on exposure zone characterisation (groups of workers performing similar activities). For EM, it is preferable to do personal sampling. The timing of the sampling strategy for BM is based on the biological half-life of the substance in the sample medium (blood, urine) concerned. Conduct sampling in a standardised manner. Ensure that samples are appropriately stored after collection.</td>
</tr>
<tr>
<td>Step 7</td>
<td>Identify the appropriate analytical test that has a high degree of validity, and a quality-certified laboratory that will conduct the analysis of samples.</td>
</tr>
<tr>
<td>Step 8</td>
<td>Decide beforehand the criteria to be used to define an abnormal test result using the DME/ACGIH/NIOSH OELs for airborne substances or Department of Labour (DOL)/ACGIH BEIs for BM samples.</td>
</tr>
<tr>
<td>Step 9</td>
<td>Outline the process of referral to confirm abnormal result in the case of BM, removal of the person from exposure; determining the presence of adverse health effects through medical surveillance and/or diagnostic medical assessment; initiating treatment in instances of acute toxicity; and where appropriate submitting a workers’ compensation claim (COIDA) should there be abnormal results.</td>
</tr>
<tr>
<td>Step 10</td>
<td>Outline the procedure for notification of employer, worker (ongoing worker notification procedures; exit certificate) and enforcement agency (notify incident to DME) as to the outcome of the exposure assessment.</td>
</tr>
<tr>
<td>Step 11</td>
<td>Ensure input of the information obtained in this process into systems and procedures of the mine in assessing the efficacy and improvement of existing control measures such as engineering controls, work procedures, education and training. (See also chapter on Occupational Health Management)</td>
</tr>
<tr>
<td>Step 12</td>
<td>Ensure evaluation and audit of the programme on a regular basis.</td>
</tr>
</tbody>
</table>

9.4.3 Quality control

The analysis of blood or urine should be carried out only by laboratories accredited to do the analyses so as to ensure quality control. The South African National Accreditation System (SANAS) has a database of laboratories that have been certified to perform analysis of environmental samples and biological monitoring specimens (Table 9.11). Current guidelines being developed by the Department of Minerals and Energy (DME) indicate that it will require all laboratories to be accredited by SANAS, which will use the ISO 60025 standard for this purpose. The DOL, on the other hand, is currently using “Approved Inspection Authorities”, which are laboratories certified for performing analyses of chemicals in environmental and biological monitoring samples.

When analysing results, it should be borne in mind that interpretation of results may be confounded by diet and by background exposures and by the variability of occupational and non-occupational exposures. Pre-placement tests are therefore useful for providing a baseline level against which future exposure may be compared.
Table 9.11 Accreditation systems for laboratories performing hazardous chemical substances determinations of environmental and biological monitoring samples in South Africa

<table>
<thead>
<tr>
<th>Accreditation System</th>
<th>Contact Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>South African National Accreditation System (SANAS)</td>
<td>Programme Manager, General Testing Laboratories Tel: (012) 349 2017, Fax: (012) 349 1449 Email: <a href="mailto:monicac@sanas.co.za">monicac@sanas.co.za</a> website: <a href="http://www.sanas.co.za/Accedlabs.htm">http://www.sanas.co.za/Accedlabs.htm</a></td>
</tr>
<tr>
<td>Department of Minerals and Energy (DME)</td>
<td>Director of Occupational Hygiene Tel: (012) 317 9439, Fax: (012) 322 1345 Email: <a href="mailto:bruced@mepta.pwv.gov.za">bruced@mepta.pwv.gov.za</a></td>
</tr>
<tr>
<td>Department of Labour (DOL) Approved Inspection Authorities: Occupational Health and Safety</td>
<td>Director of Occupational Health and Hygiene Tel: (012) 309 4408, Fax: (012) 309 4763 Email: <a href="mailto:tim.curtis@labour.gov.za">tim.curtis@labour.gov.za</a></td>
</tr>
</tbody>
</table>

9.4.4 Interpreting biological monitoring results

Biological monitoring results are compared to Biological Exposure Indices (BEIs), which are reference values intended as guidelines for the evaluation of potential health hazards and are primarily an index of exposure. They do not indicate the presence of health effects that may be produced from exposure to a workplace chemical. While biological monitoring can only be used for a limited number of hazardous substances in the workplace, the existence of a BEI does not indicate a need to conduct biological monitoring unless it is warranted from the findings of the risk assessment and/or air monitoring. For substances associated with acute toxic effects e.g. acids, alkalis, asphyxiants, routine biological monitoring may not be appropriate unless used to determine the cause of an accidental poisoning incident. With mixed exposures, exposure assessment is usually based on the concentrations of each of the constituent substance, unless effects are known to be additive or synergistic. In some instances, where routine monitoring indicates that the relative concentration of chemicals is constant, selection of a key marker, which may be one of the constituents, can be used. Exposure to the marker is then controlled to a level such that exposures to all components will be controlled. Some examples of BEI for individual substances commonly encountered in mining are presented in SIMRAC Report HEALTH 603. For detailed information on BEI for a particular substance refer to the ACGIH Documentation of the Threshold Limit Values and Biological Exposure Indices and the ACGIH booklet TLVs and BEIs. See also the South African Society of Occupational Medicine (SASOM) publication Medical and Environmental Surveillance Guidelines.

The results of biological monitoring can be interpreted at an individual level or on a group level by considering their distribution. Greater significance should be given to the variations in an individual’s level from period to period than to differences between individuals within a group. At a group level, if all the observed values are significantly below the BEI, the working conditions may be assumed to be satisfactory. If the majority (needs to be defined at the outset) of the results are above the BEI, the cause of the excessive values must be investigated and proper action taken to reduce exposure. The Department of Minerals and Energy should also be notified when such incidents denote high exposure.

9.4.5 Ethical considerations

To prevent results from being used in a discriminatory manner, knowledge of associated ethical considerations (informed consent, confidentiality of results) is required in the application of biological monitoring in the workplace. Since monitoring is undertaken to provide an indication of the level of absorption of a workplace hazardous substance, group data should be made available to people who will investigate and, when necessary, improve the work environment. For this reason, it is important that worker participation is on a voluntary basis and informed written consent of the individual worker is obtained before individual quantitative results are released to the employer.

9.4.6 Worker notification programmes

A biological monitoring programme must be well planned and part of a larger programme which includes environmental monitoring. Participating workers must understand its requirements and
objectives, and be informed of how the results will be handled. Appropriate feedback to the individual, employer and enforcement agency is a necessity. Under the MHSA requirements, the results of biological monitoring must be clearly stated in the exit certificate issued to the worker on termination of employment.

9.5 Medical surveillance and case management

Another element of managing hazards associated with exposure to hazardous chemical substances is the medical surveillance programme. The need for medical surveillance is based on whether there is a significant risk to health of workers from a hazardous substance. From a legal point of view, this means when there is exposure to a hazardous substance for which:

- an identifiable disease or health effect reported may be related to the exposure; and
- there is a reasonable likelihood that the disease or health effect may occur under the particular conditions of work; and
- there are valid techniques for detecting indicators of the disease or the effect

9.5.1 Objectives

The objectives of the medical surveillance programme for mine workers are to:

- assess the health status of workers by collecting relevant health information on a regular basis so as to detect adverse health effects at the earliest opportunity
- enable appropriate and timely corrective action to be taken in order to safeguard the health and well-being of individual workers
- improve risk management by identifying adverse health effects among groups of workers similarly exposed
- enable workers to be fully informed of the risks associated with their work and procedures to minimise those risks, thereby preventing work-related disease
- identify work-related disease from current or previous occupational exposure and refer for confirmation of diagnosis, treatment where appropriate, placement, rehabilitation and assistance with application for compensation
- provide data which may be useful for future epidemiological studies

9.5.2 Developing a medical surveillance programme

Medical surveillance programmes are always run as an adjunct to risk assessment processes such as environmental and biological monitoring and are an integral part of risk management. The existence of sentinel cases of work-related diseases associated with specific chemicals may also inform the process. The common chemical-induced health effects that are the focus of medical surveillance in most mines worldwide are lead, mercury, cadmium and arsenic. The first three chemicals exert their toxic effects on multiple organ systems (e.g. kidneys, nervous system) and require multiple tests (e.g. serum urea and creatinine, neuro-behavioural tests) geared towards specific target organ systems. It is important that educational programmes are instituted when medical surveillance programmes are established and workers are involved in the development of these programmes. These tests should be performed by impartial and appropriately qualified occupational health personnel. A practical approach in developing a medical surveillance programme is outlined in Table 9.12.

For detailed methodology on what tests to use for medical surveillance refer to:

- “Specific medical tests published in the literature for OSHA regulated substances” (http://www.cdc.gov/niosh/nmed/medstart.html);
- SASOM publication on “Medical and Environmental Surveillance Guidelines;
- MSHA website on “Medical Surveillance and Biological Monitoring for Miners Exposed to Arsenic, Cadmium, Lead and Mercury” (http://www.msha.gov/s&hinfo/toolboxes.htm);
Table 9.12 A stepwise approach to developing a medical surveillance programme

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>What is the result of the risk assessment process? If risk exists, proceed to prioritisation of chemicals (e.g. lead) based on information of level of risk.</td>
</tr>
<tr>
<td>2</td>
<td>What are the target organ health effects (e.g. blood forming organs, nervous system, kidneys) associated with exposure to the particular hazardous chemical substance? (Table 9)</td>
</tr>
<tr>
<td>3</td>
<td>Identify the appropriate tests which have high degree of validity (sensitivity and specificity) to make the assessment e.g. questionnaire, specific neurological examination, full blood count, neuro-behavioural tests, serum urea and creatinine (Table 9). The availability of a valid test must be regarded as a prerequisite irrespective of the importance of the hazard.</td>
</tr>
<tr>
<td>4</td>
<td>Ensure that the requirements for conducting and analysing tests in a reliable manner are fulfilled: - machine specifications - calibration of equipment - qualifications of persons conducting the tests - accreditation of laboratory for analysis</td>
</tr>
<tr>
<td>5</td>
<td>Standardise methodology for conducting tests at appropriate time intervals e.g. - questionnaires - neurological examination protocol</td>
</tr>
<tr>
<td>6</td>
<td>Decide beforehand what action criteria will be used to define an abnormal test</td>
</tr>
<tr>
<td>7</td>
<td>Outline the process of referral to confirm diagnosis, remove the person from exposure, initiate treatment where appropriate and submit a workers’ compensation claim (COIDA/ODMWA) should there be abnormal results or disease</td>
</tr>
<tr>
<td>8</td>
<td>Outline the procedures for notification of employer, worker (ongoing worker notification procedures) and enforcement agency (notify incident to DME; annual report to Medical Inspector of Mines)</td>
</tr>
<tr>
<td>9</td>
<td>Arrange for post-employment examinations and exit certificate on termination of employment at a particular mine. Store historical medical surveillance records at facility for at least 40 years.</td>
</tr>
<tr>
<td>10</td>
<td>Ensure evaluation and audit of the programme on a regular basis. Use information obtained through medical surveillance to assess the effectiveness of existing control measures. (See chapter on Occupational Health Management)</td>
</tr>
</tbody>
</table>

9.5.3 Tests used in medical surveillance

An important requirement of medical surveillance is the use of techniques of high sensitivity and specificity that can detect adverse effects related to the nature and degree of exposure to hazardous chemical substances. This is however not possible in most cases due to various limitations in the occupational setting. A number of conventional clinical tests (e.g. serum creatinine used as a marker of kidney dysfunction) have low sensitivity in detecting early organ damage and can yield a false negative result. On the other hand, low specificity of tests (e.g. a single elevated liver enzyme) will produce a number of false positive results and cause healthy workers to be classified as not-healthy. This may result in undue anxiety, wasted additional tests and unnecessary shifting of workers.

Medical surveillance procedures should be safe, non-invasive, acceptable to workers and easy to perform. Informed consent should always be sought prior to conducting medical tests and/or examinations. The health professional must develop a system to ensure the confidentiality of medical test results, as with all medical records.

Depending upon the potential hazardous chemical substance present, some or all of the following tests may be used:

- work history (in conjunction with exposure assessment information)
- biological effect monitoring results
- other specified further health assessments and special investigations depending on the target organ affected (refer to Table 9.9 on adverse health effects associated with exposure to chemical substances)
9.5.4 Types of medical examinations

There are various types of examinations that are performed at various stages during the worker’s employment at a particular mine. These include:

- initial examination: for workers who begin working at a particular mine, an initial health assessment is conducted prior to commencing work
- placement examination: when a worker is transferred to another job in the mine
- periodical examination: these assessments are conducted at regular intervals depending on the level of risk to health and the actual health outcome(s) being monitored
- exit examination: on termination of employment in current job on the mine
- post-employment examination: after the worker has left the job

While it is generally accepted that the responsibility for the medical surveillance in these various forms is that of the employer through the mine occupational health service, the post employment examination is generally conducted by the Department of Health through services provided by the Medical Bureau for Occupational Diseases (MBOD) and the public sector occupational health services. Occupational health personnel must ensure that any medical surveillance records of workers are retained as confidential records for at least 40 years under the MHSA. These records are usually handed over to the Medical Inspector of Mines when the mine closes down. Important information on the workers’ health status during employment provides useful background for future medical surveillance programmes.

9.5.5 Worker notification programmes and reporting results

Results of medical surveillance programmes should be reported on an individual and group basis. Individual results should be provided to the worker together with any necessary explanation of the results and counselling where appropriate. An exit certificate is issued to the worker on termination of employment with the mine. Under the MHSA, workers have recourse to an appeal to the Medical Inspector of Mines should there be a dispute regarding the worker’s fitness to work or the contents of an exit certificate issued by the mine occupational medical practitioner.

Group results should be made available to all parties (employer, trade union, enforcement agencies) in an understandable manner outlining disease patterns in relation to exposure status, and identifying areas needing remedial action by the employer. This is required annually under the MHSA in the form of the Annual Medical Report submitted to the Medical Inspector of Mines. Incidents of acute toxicity or occupational disease must be reported to the mining enforcement agency (DME).

9.5.6 Procedures in dealing with abnormal results

There should be clear procedures that deal with abnormal individual results arising out of medical surveillance programmes. These include one or more of the following:

- referral to confirm diagnosis
- removal of the worker from exposure
- appropriate treatment and rehabilitation
- relocation and placement (redployment — which may be temporary)
- filing a worker’s compensation claim under COIDA or ODMWA depending on condition
- application for state disability grant or company disability insurance, in the event of disability

Refer to Chapter on “Fitness for work, disability management & compensation”. For list of compensable diseases refer to Schedule 3 under COIDA and the list of compensable diseases under ODMWA for occupational lung diseases relevant to the mining industry. For assistance with compensation application procedures, refer to the Industrial Health Research Group (IHRG) Guide to the Compensation for Occupational Injuries and Diseases Act.
9.5.7 Audit and health information systems

An important function of the medical surveillance programme is to generate reliable information to assess the effectiveness of risk reduction strategies. In this way systems and procedures can be developed to improve existing control measures such as engineering controls, work procedures, education and training activities. Ongoing audit (both internal and external) of medical surveillance programmes are essential to ensure effective functioning of such risk management strategies. (See chapter on Occupational Health Management)

9.6 Chemical control

In South Africa considerable opportunities exist for improved chemical control particularly in mineral processing operations. A plant built in the 1990s to produce potassium dichromate from chromite ore was closed down by the Department of Labour over concerns for employee health due to the lack of effective chemical controls. This was in spite of the fact that the required controls to protect health on dichromate production plants were outlined in detail by the ILO as far back as 1930. To avoid such problems it is important to have competent occupational hygiene input at the plant design stage and occupational hygiene supervision during plant startup and production.

9.6.1 Need for occupational hygiene and medical expertise

In 1996 the opportunity was provided for occupational hygienists to sit examinations in South Africa to obtain internationally recognised professional qualifications in occupational hygiene through the British Institute of Occupational Hygienists (BIOH). The BIOH qualifications and the associated modules and course material have been important factors to help raise the standard of occupational hygiene practice. The examinations and course material are adapted to South African regulations and standards. The modules include a considerable chemical content covering: risk assessment, toxicology, measurement and control. Already a few mining occupational hygienists have obtained the BIOH Certificate of Operational Competence and one the Diploma of Professional Competence. It is important for the development of improved working conditions in the South African mining industry that future senior hygienists strive to obtain internationally recognised professional qualifications in occupational hygiene such as the BIOH Diploma or the American Board of Industrial Hygiene (ABIH) Certified Industrial Hygienist (CIH).

Currently both the Southern African Institute for Occupational Hygiene (SAIOH) and the Mine Ventilation Society of South Africa (MVS) are working to raise the standards of their examinations in the broad aspects of occupational hygiene.

The mandatory requirement under the Mine Health and Safety Act for medical and nurse practitioners responsible for the health of mineworkers to have a recognised qualification in occupational health/medicine will ensure that occupational health issues are dealt with in a multidisciplinary manner utilising the expertise of occupational medical and nurse practitioners and occupational hygienists. A recent development is the training of occupational medicine specialists at major academic institutions who will support the work of occupational health practitioners at primary level, thereby raising the standard of occupational medicine expertise in the country.

9.6.2 New process designs

Examples of technologies and/or products that have a health or environmental impact on the mining industry are available from Mintek (http://www.mintek.ac.za/). To avoid the health and environmental problems of the mercury amalgam process, Mintek introduced a safer alternative based on chloride leaching, using inexpensive, easily obtainable reagents. After the leach solution has been filtered to remove the tailings, a reducing agent is added to precipitate metallic gold in powder form. Mintek is currently promoting the gold leaching process amongst small miners in South Africa and providing training on the safe use of the chemicals utilised.

Modern methods that mix cyanide compounds in water-based solutions can recover nearly 100% of the gold, making it profitable for companies to process lower grade ores. Although chemical
replacement for cyanide has been investigated for decades, it remains the leaching agent of choice in
the base and precious metals industries worldwide. The Mintek cyanide control and management
system (Cynoprobe) improves the management of cyanide on gold plants, reducing the amount of
cyanide used and the resultant impact on the environment.

9.6.3 Training

Training is essential for the safe use of chemicals at work. A wide range of quality training material
can be obtained via the Internet. Useful free training resources can be accessed via the Online
Training, Chemicals and Mining pages at the ASOSH website (http://www.asosh.org). The ILO
publication on Chemicals in the workplace and the International Programme on Chemical Safety
(IPCS) Training Modules on Chemical Safety are particularly useful. Health protection training
material from Penn State University titled Protect Yourself When Using Chemicals is available via the
web pages of the Pennsylvania Bureau of Deep Mine Safety, USA.

An Occupational Hygiene Manual for the Coal Mining Industry is available from the Joint Coal
substances, organic vapours, PCBs, spontaneous combustion (toxic gases, PAHs) and welding fumes
are provided.

9.6.4 Labelling and Material Safety Data Sheets

Safety chemical information is provided to users of chemicals through labelling of chemical
containers and the provision of Material Safety Data Sheets (MSDSs). The relevant standards
that provide information on labelling and MSDS information are SABS 0265 and SABS ISO
11014-1. The ASOSH website provides extensive links to chemical information and resources on
labelling and MSDS explanation. An example of a completed 16 section MSDS is available in
SABS 0265.

9.6.5 Audit and chemical checklists

An occupational hygiene audit guide with typical audit questions and model answers is available from
CONCAWE (http://www.concawe.be/Download/Reports/Rpt99_58.pdf), the oil companies’ Euro-
pean organization for environment, health and safety. A wide variety of audit templates and guidelines
for underground and surface operations are available via the web pages of the Mining Operations
Division Audit Management System (MODAMS), DME-WA. The ILO publication Chemicals in the
workplace includes a number of training exercises and a chemical checklist for workers to evaluate
the workplace.

Laboratory audit and chemical checklists can be located via the Laboratory and Chemical Safety page
at Oklahoma State University, USA (http://www.pp.okstate.edu/ehs/links/labchem.htm).

9.6.6 Transport

Chemicals are transported to and from mines by rail, road, sea and air. To assist the first responder and
the emergency services in identifying the goods in transit, an emergency system is utilised. This
consists of placards on the vehicle or wagon, Dangerous Goods Declarations (road transport), Vehicle
lists (trains), Tremcards and Emergency Response Guides (ERGs). The Tremcard lists the hazards
and emergency information for a material that is being conveyed for use by the driver during an
incident, or by the emergency services. The Vehicle list for trains includes the quantity, Substance
Identification Number (S.I.N.) and class numbers of the dangerous goods on or in each wagon and the
correct shipping name of the dangerous goods.

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By use of the shipping name, S.I.N., or the hazard class diamond on the placard, the correct Emergency Response Guide (ERG) can be selected. The S.I.N. is identical to the UN Substance number which consists of a four-digit number, which has been assigned to an individual substance (e.g. 1831 — sulphuric acid) or a group of similar substances (e.g. 2758 — carbamate pesticides). The numbers are primarily intended to facilitate the identification of substances without the need for a knowledge of the language in which the chemical name is printed.

The North American Emergency Response Guide is employed by local authorities in South Africa and others responsible for HazMat such as the Spoornet HazMat Fire and Emergency Services. The 2000 version (ERG2000) was developed jointly by Canada, the U.S. and Mexico. This guide is available on the web (http://www.tc.gc.ca/canutec/erg_gmu/erg2000_menu.htm) and as a free download for the PC. ERG2000 incorporates dangerous goods lists from the most recent United Nations Recommendations. The relevant standards for road and rail transport of dangerous goods include SABS 0228, 0229, and 0231. An Emergency response handbook is included with SABS 0232 as annex A.

9.6.7 Industry codes and standards

The Chamber of Mines of South Africa published a Code of Practice on handling and storage of hazardous chemicals in 1984. This covered factors common to the bulk handling and storage of hazardous chemicals, transport by road tanker, and the safe handling and storage of anhydrous ammonia (refrigerant), caustic soda, liquid and solid (flake) cyanide and acids (hydrochloric, nitric and sulphuric).

Recent tailing spills in Romania causing extensive river catchment pollution by cyanide and heavy metals has focused international attention on the mining industry. An international voluntary Industry Code of Practice on Cyanide Management (http://mineralresourcesforum.unep.ch/) is now under development under the leadership of the United Nations Environment Programme (UNEP) and the International Council on Metals and the Environment (ICME). The purpose of the Code is to: establish high standards of management practices and control relating to the use of cyanide by the gold-mining industry; drive improved performance in mines around the world; and provide the public with the confidence that the adopted standards meet its expectations and are being applied. A web site for the Code has been published (http://www.cyanidecode.org/).


A HazChem standard has recently been developed to reduce injuries and illnesses related to chemicals in the US mining industry. The MSHA interim final rule entitled “Hazard Communication (HazCom)” (30 CFR Part 47) (http://www.msha.gov/regs/fedreg/final/2000fin/00-24803.pdf) requires mine operators to assess the hazards of chemicals they produce or use and provide information to miners concerning chemical hazards by means of a written chemical hazard communication programme; labeling containers of hazardous chemicals; providing access to MSDS; and training miners.


9.6.8 Hazardous substances management procedures

The various approaches to minimise chemical risks should be addressed in Hazardous Substances Management Procedures. The core elements of such procedures are outlined in Table 9.13 and are adapted from the Mining Guidelines: Management of Hazardous Substances on Minesites published in 1997 by the DME-WA (http://www.dme.wa.gov.au/safetyenv/mining/pdfs/hazsubstances.pdf).
Table 9.13 Hazardous substances management procedures

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.0 Introduction</strong></td>
<td><strong>1.1</strong> Hazardous substances can be found throughout a mine including stores, workshops, laboratories and process plants. Some hazardous substances such as cyanide are easily recognisable by name, while others used under trade names are less obvious. Hazardous substances can also include some gases and fumes generated as byproducts on site. This guideline is intended to be used on mines to identify and to eliminate or reduce employee exposure to hazardous substances.</td>
</tr>
<tr>
<td><strong>2.0 Hazardous Substances Management Procedures</strong></td>
<td><strong>2.1 Company Policy.</strong> Each mine needs to have an integrated occupational health and safety management system as part of the operational procedures. Part of this management system is the development of hazardous substances management procedures to eliminate or reduce employee exposure to hazardous substances.</td>
</tr>
<tr>
<td></td>
<td><strong>2.2 Documentation of Procedures.</strong> These procedures must be documented, and cover all aspects of the storage, handling, use, spill control and disposal of hazardous substances. Apart from general procedures for control of hazardous substances, there may be a need for either process or substance specific procedures, (e.g. cyanide, lead, and hydrofluoric acid), where there is the possibility of exposure to a hazardous substance which has particularly toxic or corrosive properties.</td>
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<td><strong>3.0 Material Safety Data Sheets (MSDSs)</strong></td>
<td><strong>3.1 Requirement for Register.</strong> All mine sites should keep a register of MSDSs for all hazardous substances used or produced in the mine. A walk through inspection of the mine site will ensure all substances are included in the register.</td>
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<td><strong>3.2 Obtaining MSDSs.</strong> For old chemicals or products held in stock for years, MSDSs may not be readily available from suppliers. The storage or retention of such old materials is discouraged, but if still required, then MSDSs in the required format, including MSDSs for non-standard substances can be prepared from information available via the Internet or specialised services.</td>
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<td><strong>3.3 Format of MSDSs.</strong> Older style MSDSs are often deficient in safety and health information including the nature of the ingredients. Deficient MSDSs should be replaced with those prepared in accordance with SABS ISO 11014-1 and SABS 0265.</td>
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<td><strong>3.4 Availability to Employees.</strong> MSDSs are increasingly available in the form of computerised databases. These systems are of particular benefit to health and safety professionals, who can often integrate the database with stock management and safety systems. There are also advantages if the database can be networked to a number of terminals throughout the mine. However, it should be remembered that not all personnel have access to terminals, or are adequately trained in their use. Hard copies of MSDSs relevant to their workplace should be available to all employees.</td>
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<td><strong>3.5 Training in Use of MSDSs.</strong> Employees need to be aware of where MSDS registers are located and trained in the use of MSDSs. Training must include how to interpret information contained in an MSDS, such as the identity of the ingredients and properties of the substance. In particular, employees must be able to understand any hazards including health effects associated with the substances they use, plus precautions for use and safe handling, including use of personal protective equipment (PPE).</td>
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<td><strong>4.0 Assessment of Requests to Purchase</strong></td>
<td><strong>4.1 Requisition and Review Procedures.</strong> In order to reduce both the number of products on site as well as the incidence of unauthorised products, the purchase of new products containing hazardous substances must follow a set of documented procedures. A request to purchase any new chemical product must be documented with an MSDS attached where possible, stating what the new product is intended to do and a description of its use. The request must be reviewed by at least one person with a knowledge of hazardous substances, such as a person involved in occupational health and safety, a chemist or a chemical engineer.</td>
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<td><strong>4.2 Contractors.</strong> Special attention must be given to contractors who may bring chemical materials on site with them. Each contractor must provide MSDSs for all materials intended for site use.</td>
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</table>
5.0 Receipt of Chemical Products on Site

5.1 Delivery Records. A designated person or group (generally the stores personnel) must co-ordinate receipt of all chemical products delivered to a mine. The products delivered are to be checked with the invoice and original requisition to ensure the correct order has been received, ideally before the delivery vehicle leaves site.

5.2 Receipt Procedures. Dedicated delivery areas ought to be separate from normal mine site operations. This is to allow control of deliveries, with the provision of spill control facilities close to hand. For bulk deliveries manifests must be checked before unloading to ensure the correct product is being delivered to the correct storage tank. Precautions must also be taken to ensure the storage tank can receive the full volume of the delivery.

5.3 Labelling and Packaging. All deliveries must be checked to ensure that they are appropriately labelled and packaged correctly.

6.0 Storage Facilities

6.1 Approval of New Storage Facilities. All new installations for storage of dangerous goods and significant alterations to existing facilities are required to comply fully with the relevant regulations, codes of practice and standards.

6.2 Emergency Plan. Each mine site storing dangerous goods must have an emergency plan, with the complexity dependent on the type and amount of dangerous goods present. Emergency plans may need to be worked out with the fire and police services before an installation is commissioned e.g. bulk storage of anhydrous ammonia for mine refrigeration.

6.3 Placarding of Dangerous Goods. Bulk storage of dangerous goods must be correctly placarded. It is good practice for all bulk storage to be identified even if the contents are not dangerous goods or hazardous substances.

6.4 Segregation of Dangerous Goods. Incompatible dangerous goods require segregation. Apart from ensuring that storage is segregated, care must be taken that incompatible chemicals do not mix when in use, or through spillage. An example is the requirement that tanks, pipework and process vessels containing acid are separated from cyanide solutions in gold treatment plants.

6.5 Bunding Requirements. An essential element of the storage of dangerous goods is the need to provide bunding in order to provide containment in case of leaks or spillages. The amount of containment required depends on the packaging group and quantity of dangerous goods stored. However with tank storage the minimum requirement is for the bund to contain the potential loss of the largest tank in the bund. Where tanks are interconnected the bund must contain the combined volume in case of a leak or spill. A safety factor is generally applied.

6.6 Secondary Containment. Spillages, which occur during delivery of, bulk acids, alkalis, and cyanide must be controlled. This can be achieved either by bunding the delivery vehicle, or by diverting any spillage into the storage bund where it can then be treated.

6.7 Fire-Fighting Equipment. A site plan listing the type and location of all fire-fighting equipment on the mine should be provided to the person(s) undertaking the maintenance procedures. Where applicable, the site plan ought to include contractors, mobile equipment, and underground fire-fighting equipment.

7.0 Stock Management

7.1 Stock Management. Potential health and safety benefits of stock management systems include:
- the rationalisation of materials held on site, leading to a very significant reduction in the number of hazardous materials in stock
- reducing the incidence of incorrect materials being used for a particular task
- reducing the quantity of redundant chemicals and
- rationalisation in the type and quantity of PPE required for the materials used.
A stock management system may also be used to control unauthorised access to hazardous materials. When a completed requisition is forwarded for processing, the individual or work area requesting the material can be compared against a list of personnel or work areas authorised to use that particular material.

8.0 Use of Hazardous Substances

8.1 Containers. The transfer of hazardous substances from bulk to smaller containers has often been undertaken without considering whether the new container is suitable for the substances it will hold. Suppliers ought to be asked to provide containers which are compatible with the substance being dispensed, as certain types of plastic container can be degraded by acids or organic solvents. Specialised containers are available such as flash-proof safety cans for flammable liquids. Under no circumstances are food containers to be used for the storage of any hazardous substances.

Used containers should be returned to the supplier where permitted, or cleaned and disposed of carefully. Empty drums of hazardous substances such as cyanide should not be supplied to third parties.

8.2 Labels. The outer packaging of all hazardous substances received on site must be correctly labelled as per SABS 0265. Once hazardous substances are transferred to smaller containers the container must be appropriately labelled. The choice of labelling will depend on a number of factors. For example if a substance is first decanted into a container such as a bucket, then immediately used or transferred to a further container, then the bucket need not be labelled. However if the substance is kept in the bucket for a reasonable period of time before use then the bucket requires labelling.

8.3 Risk Assessment. One of the most important requirements of the MHSA (1996) is the need to undertake a risk assessment. This is the evaluation of how hazardous substances are used on a mine, and the health risks involved. If a significant risk is indicated, then a written report is required, which must also include means by which the risk can be reduced.

Many mine sites may wish to undertake the assessments themselves using expertise within the organisation. Sometimes the resources are not available, or the assessments may be complex. In these cases then the mine may decide to use consultants such as occupational hygienists or other external specialists.

Considerable planning is required prior to undertaking a proper risk assessment, which includes the following steps:

1. Deciding who will do the assessment.
2. Dividing the work into units for assessment (if necessary).
3. Identifying substances in the work unit being assessed.
4. Determining whether there are any hazardous substances.
5. Obtaining information about hazardous substances.
6. Inspecting the workplace and evaluating employee exposure.
7. Evaluating the risk.
8. Identifying actions required resulting from risk evaluation.
9. Recording the assessment.
10. Reviewing the assessment.

8.4 Register of Hazardous Substances. In addition to a register of MSDSs each mine must keep a register of hazardous substances, which is freely accessible to all employees. This register contains details of the duties or operations, which have the potential for an employee to become exposed to a hazardous substance. In addition the register of hazardous substances must contain the MSDS for that substance and details of any assessment and report conducted.
8.5 Reducing Risk of Exposure to Hazardous Substances. Once an assessment has been completed, measures may be required to reduce employee exposure to the hazardous substances concerned. There is a list of measures referred to as the hierarchy of control measures, which is used in priority order to eliminate or minimise exposure to hazardous substances. These are:

- **Elimination** — Determining whether the hazardous substance is essential e.g. replacing a cleaning solvent by use of ultra-sound.
- **Substitution** — For example, replacing a toxic chemical such as benzene with less toxic toluene.
- **Isolation** — Using barriers, or distance (e.g. remote control) to separate the process from the employee.
- **Engineering Controls** — Plant or processes which can minimise the generation or spread of hazardous substances. An example is local extraction ventilation during welding operations.
- **Safe Work Practices** — These are administrative practices designed to make people work in safer ways, for example prohibiting eating, drinking or smoking in contaminated work areas, or ensuring water suppression devices are activated when a crusher is in use.
- **Personal Protective Equipment** — The use of personal protective equipment (PPE) should only be considered where the use of other control measures is impracticable, or in conjunction with other measures to increase protection.

8.6 Workplace Monitoring, Biological Monitoring and Medical Surveillance. The results of a particular assessment may recommend that air monitoring is required. The assessment may also indicate that biological monitoring and/or medical surveillance may be required.

8.7 Generic Assessments. A particular hazardous substance may be used under the same conditions in a number of different workplaces throughout the mine site. In such cases the nature of the hazard and degree of risk may be comparable. In these cases a single assessment could be applied to each of the workplaces. An example could be cleaning of parts where the same solvent and design of degreasing bath are used. However, the employer is responsible for ensuring that a generic assessment is applicable within the mine site and that risks are adequately controlled.

8.8 Training Requirements. Employees need to be given adequate instruction and training in safety procedures, systems of work and the emergency plan. The employee must be made aware of the potential hazards associated with any substance used. Records are to be kept of any induction and training.

9.0 Sampling

9.1 Workplace Atmospheric Monitoring. Baseline and routine employee exposure monitoring is required to ensure that exposures to air contaminants are in compliance with the DME, DOL or other occupational exposure limits.

9.2 Biological Monitoring. For some specified occupational exposure work, there may be a valid biological monitoring procedure. In these cases the employer must ensure that biological monitoring of employees is carried out where there is a reasonable likelihood that accepted values may be exceeded. Examples are: arsenic in urine, lead in blood and mercury in urine.

9.3 Medical Surveillance. Medical Surveillance must be carried out on employees both on initial employment and periodically. In addition, further health assessments may be required on employees engaged in specified occupational exposure work at a mine.

10.0 Personal Protective Equipment (PPE)

10.1 Requirement for PPE. Where possible, exposure to hazardous substances ought to be minimised by proceeding through the hierarchy of control measures described previously. If exposure still has not been adequately controlled, then the employer must ensure employees are supplied and fitted with appropriate PPE.
10.2 Selection of PPE. The selection of the correct PPE is critical and all personal protective clothing and equipment must conform to relevant standards. Risk assessments must indicate the type and level of the respiratory protective equipment (RPE) required. Many operations suitable protection is offered by disposable facepieces, or half and full face respirators. The type of RPE will depend on the air contaminant and the required minimum protection factor.

10.3 Confined Spaces. Where employees may be required to enter tanks, tunnels or similar confined spaces, any assessment should consider the likelihood of oxygen deficiency as well as atmospheric contaminants. A filter respirator suitable for atmospheric contaminants would not be adequate in an oxygen-deficient atmosphere.

10.4 Safety Gloves. Leather, knitted or stitched gloves are not suitable when handling hazardous substances. PVC gloves are often worn when handling oils and corrosives (acids and alka-lis), but may offer little protection against many organic substances. The MSDS should be reviewed for the particular type of glove required, such as PVC, PVA, or Nitrile, for the hazardous substance concerned. However, other factors such as feel and dexterity may need to be considered, so the glove supplier must be asked whether the brand provided is satisfactory for handling the particular substance concerned.

10.5 Availability and Maintenance. The employer is to provide all PPE required for any operation involving hazardous substances, and most mines keep the bulk of the PPE in the stores. Small quantities of stock ought to be available in workshops, plant areas etc where they may be required. This particularly applies during night shift when stores may be closed, or in more remote working locations. This stock is to be kept in a clearly marked dedicated area, such as a wall or post mounted cabinet, to which employees have ready access.

For non-disposable PPE such as respirators and gloves, a proper maintenance programme needs to be developed. The programme must follow manufacturer instructions and include: cleaning and sanitising of equipment, storage, repair, and inspection for defects.

10.6 Training in Use. PPE must be used when required and worn correctly to be of value. An employee-training programme is required whenever there is likelihood that PPE may be required. Training should be interactive and demonstrate the use of PPE. The following elements must be covered in RPE training: identification of the hazard, reasons for respirators, respirator selection, use and proper fitting of respirators, wear time, limitations of respirators, and maintenance and storage. More advanced training may be required e.g. where self contained-breathing apparatus and/or a full body suit is required to be worn.

11.0 Audit Procedures

11.1 Audit Criteria. An audit is a survey to determine whether a particular system is in place and working effectively. The extent and complexity of any audit will depend on a number of factors including the size of the operation, the type of processes, and the range of hazardous substances used. A full occupational health and safety audit can have a number of elements. Audits may be carried out internally by the company, or by specialist consultants. Either way, the person(s) undertaking the audit must be trained and aware of auditing procedures.

11.2 Preparation of Manifests. The initial step of a hazardous substances management audit is to ascertain exactly what materials are kept on site. This requires a detailed survey of the site to determine the identity, amount and location of all chemical materials, not just hazardous substances. During this initial survey all areas must be inspected, as redundant or unlabelled materials are often moved into remote or neglected areas. The survey is best undertaken using in-house personnel, as they generally have an understanding of the site and are likely to know where materials may be stored.

Once completed, the findings must be compiled, and incorporated on a site map i.e. a manifest. By surveying all materials on site a manifest of dangerous goods on site can also be prepared.
11.3 **Hazardous Substance Audits.** A review of hazardous substances management is just one facet of a full occupational health and safety audit, and during the survey it may become evident that there are deficiencies in some areas of the occupational health and safety management system. The information collected during the survey can be used to:

- amend entries in the MSDS register
- review chemical material purchase procedures
- review labelling and storage procedures
- assist with the rationalisation and disposal of chemical products on site
- help optimise both the choice and location of emergency and protective equipment
- provide information for the register of hazardous substances when used in conjunction with the risk assessments and
- provide information for the emergency plan

Where deficiencies are found there needs to be full management commitment to correct the problems. Re-audits of problem areas are required to ensure that corrective action has been taken, i.e. the feed-back loop has been closed.

11.4 **Audits of biological monitoring and medical surveillance activities.** Audits of the biological monitoring and medical surveillance activities will determine whether adequate quality control measures are in place to ensure that the data collected are reliable. Furthermore, this will also ensure that the occupational health and safety management system is responsive in addressing any deficiencies in the control measures leading to workers being inadvertently exposed and at greater risk of developing adverse health effects.

12.0 **Emergency Plans**

12.1 **Requirements for an Emergency Plan.** Mining is an inherently hazardous industry and the employer is required under the Mine Health and Safety Act to ensure that a plan is prepared to deal with any emergency which occurs at the mine (Chapter 24 of the Mine Health and Safety Regulations (Minerals Act) outlines the requirements for first aid and rescue brigades).

12.2 **Elements of an Emergency Plan.** A wide range of elements will be included in an emergency plan, ranging from the purpose of the plan, through emergency response and control, to incident investigation after the event.

One of the requirements is the provision of a manifest with a map which shows the location of dangerous goods storage on site. Copies of the manifest must be placed in secure locations where they are readily available in cases of emergency.

13.0 **First Aid Procedures**

13.1 **Health Hazards.** Appropriate first aid equipment, facilities and services must be available. The varied nature of the hazards associated with mining operations shall be considered and virtually all mines must be provided with resuscitation equipment. The health effects from exposure to different hazardous substances vary, and the MSDSs required on site can provide essential health hazard information, including details of first aid treatment. Qualified first aid personnel must be available at all times when the mine is working, including at least one person who is trained in the use of resuscitation equipment.
13.2 **Specific Hazards.** Some very toxic and hazardous substances are used on mines particularly in treatment plants and laboratories. The following are examples where first aid procedures must be fully in place before the substances are used.

**Cyanide**
Cyanide is widely used in gold treatment plants and exposure to cyanide most commonly occurs as inhalation of hydrogen cyanide gas around Carbon in pulp/Carbon in leach (CIP/CIL) tanks or screens. On occasion employees are also exposed to cyanide solutions when fittings or pipes burst. The correct first aid and professional medical treatments for the different sorts of cyanide exposure must be available.

**Corrosive Substances**
Acids and alkalis such as sulphuric and hydrochloric acid, and caustic soda are to be found on all mine sites. Concentrated solutions are very corrosive to the skin and mucous membranes, and may cause permanent eye damage. Hydrofluoric acid, which is still used in some laboratories and workshops is extremely hazardous, and may only be used where there are documented operating procedures, with specified first aid treatment readily available.

13.3 **Safety Showers and Eye Wash Facilities.** Where there is physical contact with a hazardous substance the first action is generally to place the exposed person under a safety shower, while the MSDS is referred to for more specific directions. The speed with which a safety shower is accessed often decides the extent of any injuries, particularly with corrosive substances, burns, or where the eyes are affected.

For this reason the location and accessibility of safety showers and eyewash facilities are all-important. They are required to be well signposted, maintained in good condition and have a dedicated supply of cool clean water.

14.0 **Laboratories**

14.1 **Safety in Laboratories.** The size of mine site laboratories can vary, but many use or store a considerable range of hazardous substances which may require specific management procedures. Chemical handling, spill cleanup, fume cupboards, ventilation and emergency procedures are areas often found to require special attention within mine site laboratories.

15.0 **Disposal**

15.1 **Disposal.** Part of the company policy on hazardous substance management procedures must address the correct disposal of hazardous substances and other materials used on site.

### 9.7 Guide to information resources

9.7.1 **Internet resources**

Important links to information obtained in this chapter preparation have been added to the Chemicals, Mining, Online Training and other pages in the World Links component of the ASOSH website (http://www.asosh.org). The Chemical pages provide links to a vast amount of chemical information (including MSDS data). Links for South African legislation and brief summaries of SABS standards are found via the Legislation and Standards pages (Southern Africa component). The mirror site for asosh.org is http://asosh.tripod.com. For an explanation on how to rapidly access occupational exposure limits (OELs), analytical methods, MSDS and documentation on OELs visit the Examples page at the SAIOH website (http://saioh.org/OELs/examples.htm). An easy way to access the SIMRAC research reports is via the Topic Index — (http://www.asosh.org/Research/SIMRAC/simrac.htm#1A).
### 9.7.2 Printed materials

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CHAPTER 10

Ionising Radiation

This Chapter describes the nature and extent of exposures to natural sources of radiation in the mining industry, the health effects of radiation, international principles of radiation protection, and the legal framework within which exposures are controlled in the South African mining industry. Best practice radiation protection guidelines are provided, including monitoring of exposures, health surveillance, and engineering and administrative controls. Further technical and regulatory information is appended, together with a comprehensive list of international references providing more detailed guidance pertinent to the identification, assessment and control of radiation hazards in mines.

Dr. D. Wymer
Physicist

Denis Wymer is a physicist at the Chamber of Mines. He is involved in a number of safety, health and environmental issues arising in the course of the Chamber’s advocacy activities. Radiation protection in mines has been a particular focus of his attention over the past few years.
Glossary

**Absorbed dose**: The fundamental dosimetric quantity \( D \), defined as:

\[
D = \frac{d\bar{E}}{dm}
\]

where \( d\bar{E} \) is the mean energy imparted by ionising radiation to matter in a volume element and \( dm \) is the mass of matter in the volume element.

**Activity (of a radionuclide)**: The quantity for an amount of radionuclide in a given energy state at a given time, defined as:

\[
A(t) = \frac{dN}{dt}
\]

where \( dN \) is the expectation value of the number of spontaneous nuclear transformations from the given energy state in the time interval \( dt \). The SI unit of activity is the reciprocal second (s\(^{-1}\)), termed the becquerel (Bq).

**Activity concentration (of a material)**: The activity per unit mass of material. The SI unit of activity concentration is Bq\,g\(^{-1}\).

**ALARA**: As low as reasonably achievable, economic and social factors being taken into account.

**Atomic number**: The number of protons in the nucleus of an atom.

**Atomic mass**: The mass of an atom measured in units equal to one twelfth of the mass of an atom of carbon-12.

**Becquerel**: The name of the SI unit of activity, equal to one nuclear transformation per second.

**Bioassay**: Any procedure used to determine the nature, activity, location or retention of radionuclides in the body by direct (in vivo) measurement or by in vitro analysis of material excreted or otherwise removed from the body.

**Bq**: The abbreviated form of “Becquerel”.

**Committed effective dose**: The quantity \( E(\tau) \), defined as:

\[
E(\tau) = \sum_T w_T \cdot H_T(\tau)
\]

where \( H_T(\tau) \) is the committed equivalent dose to tissue \( T \) over the integration time \( \tau \) and \( w_T \) is the tissue weighting factor for tissue \( T \). When \( \tau \) is not specified, it will be taken to be 50 years for adults and to age 70 years for intakes by children.

**Committed equivalent dose**: The quantity \( H_T(\tau) \), defined as:

\[
H_T(\tau) = \sum_{t_0}^{t_0+\tau} \bar{H}_T(t)\,dt
\]

where \( t_0 \) is the time of intake, \( \bar{H}_T(t) \), is the equivalent dose rate at time \( t \) in organ or tissue \( T \) and \( \tau \) is the time elapsed after an intake of radioactive substances. When \( \tau \) is not specified, it will be taken to be 50 years for adults and to age 70 years for intakes by children.

**Contamination**: Radioactive substances on surfaces, or within solids, liquids or gases (including the human body), where their presence is unintended or undesirable, or the process giving rise to their presence in such places.

**Cosmogenic**: Produced by cosmic-ray particle interactions.
**Decay:** For a radionuclide in a given energy state, the process by which it undergoes a spontaneous nuclear transformation from that energy state.

**Deterministic (health effect):** A radiation health effect for which generally a threshold level of dose exists above which the severity of the effect is greater for a higher dose.

**Detriment:** The total harm that would eventually be experienced by an exposed group and its descendants as a result of the group’s exposure to radiation from a source.

**Dose:** A measure of the energy deposited by radiation in a target, where the use of a more specific term such as “effective dose” or “equivalent dose” is not necessary for defining the quantity of interest.

**Dose limit:** The value of the effective dose or the equivalent dose to individuals from controlled practices that shall not be exceeded.

**Dose rate:** The dose per second or dose per hour.

**Effective dose:** The quantity $E$ defined as the summation of the tissue equivalent doses, each multiplied by the appropriate tissue weighting factor:

$$E = \sum T w_T H_T$$

where $H_T$ is the equivalent dose in tissue $T$ and $w_T$ is the radiation weighting factor for tissue $T$. The unit of effective dose is J.kg$^{-1}$, termed the sievert (Sv).

**Equilibrium:** The state of a radioactive decay chain (or part thereof) where the activity of each radionuclide in the chain (or part of the chain) is the same.

**Equilibrium factor:** The ratio $F$ of the equilibrium equivalent concentration to the actual radon concentration.

**Equilibrium equivalent concentration:** The activity concentration of radon in radioactive equilibrium with radon progeny that would have the same potential alpha energy concentration as the actual (non-equilibrium) mixture.

**Equivalent dose:** The quantity $H_{T,R}$, defined as:

$$H_{T,R} = w_R \cdot D_{T,R}$$

where $D_{T,R}$ is the absorbed dose delivered by radiation type $R$ averaged over a tissue or organ $T$ and $w_R$ is the radiation weighting factor for radiation type $R$. When the radiation field is composed of different radiation types with different values of $w_R$ the equivalent dose is:

$$H_T = \sum R w_R \cdot D_{T,R}$$

The unit of equivalent dose is J.kg$^{-1}$, termed the sievert (Sv).

**Exposure:** The act or condition of being subject to irradiation. The term is also used in a more general sense to describe the act or condition of being in contact with certain radioactive materials, particularly radon or other airborne radionuclides (resulting in exposure to the radiation emitted by those radionuclides).

**Exposure pathway:** A route by which radiation or radionuclides can reach humans and cause exposure.

**Half life:** For a radionuclide, the time required for the activity to decrease, by a radioactive decay process, by half.

**Individual monitoring:** Monitoring using measurements by equipment worn by individual workers, or measurements of quantities of radioactive materials in or on their bodies.

**Intake:** The act or process of taking radionuclides into the body by inhalation or ingestion or through the skin.
**Intervention:** Any action intended to reduce or avert exposure or the likelihood of exposure to sources which are not part of a controlled practice or which are out of control as a consequence of an accident.

**Ionising radiation:** For the purposes of radiation protection, radiation capable of producing ion pairs in biological materials.

**Isotope:** One of two or more forms of an element differing from each other in atomic mass, and in nuclear but not chemical properties.

**Long-lived:** Having a half life greater than 30 years.

**Microsievert:** One millionth of a sievert.

**Millisievert:** One thousandth of a sievert.

**Monitoring:** The measurement of dose or contamination for reasons related to the assessment or control of exposure to radiation or radioactive substances, and the interpretation of the results.

**mSv:** Abbreviated form of millisievert.

**µSv:** Abbreviated form of microsievert.

**Natural background:** The doses, dose rates or activity concentrations associated with natural sources or any other sources in the environment which are not amenable to control.

**Natural source:** A naturally occurring source of radiation, such as the sun and stars (sources of cosmic radiation) and rocks and soil (terrestrial sources of radiation).

**Optimize:** Determine what level of protection and safety makes exposures, and the probability and magnitude of potential exposures, ALARA.

**PAEC:** Potential alpha energy concentration in air.

**Personal monitoring:** Synonymous with “individual monitoring”.

**Potential alpha energy:** The total alpha energy ultimately emitted during the decay of radon progeny or of thoron progeny through the decay chain.

**Potential exposure:** Exposure that is not expected to be delivered with certainty under the normal operating conditions of a facility or activity, including minor mishaps that can be kept under control.

**Practice:** Any human activity that introduces additional sources of exposure or exposure pathways or extends exposure to additional people or modifies the network of exposure pathways from existing sources, so as to increase the exposure or the likelihood of exposure of people or the number of people exposed.

**Radiation:** Ionising radiation.

**Radiation weighting factor:** A number by which the absorbed dose in a tissue or organ is multiplied to reflect the relative biological effectiveness of the radiation in inducing stochastic effects at low doses, the result being the equivalent dose.

**Radioactive:** Exhibiting radioactivity.

**Radioactivity:** The phenomenon whereby atoms undergo spontaneous random disintegration, usually accompanied by emission of radiation.

**Radionuclide:** A radioactive atom characterized by the number of protons and neutrons in its nucleus.

**Radon:** Any combination of isotopes of the element radon.

**Radon daughters:** The short-lived radioactive decay products of radon-222.
**Radon progeny**: Synonymous with “radon daughters”.

**Short-lived**: Having a half life not greater than 30 years.

**Sievert**: Name for the SI unit of equivalent dose and effective dose, equal to 1 J.kg\(^{-1}\).

**Source**: Anything that may cause radiation exposure — such as by emitting ionising radiation or by releasing radioactive substances or materials — and can be treated as a single entity for protection and safety purposes.

**Stochastic (health effect)**: A radiation-induced health effect, the probability of occurrence of which is greater for a higher radiation dose and the severity of which (if it occurs) is independent of dose.

**Sv**: Abbreviated form of “sievert”.

**Thoron**: Radon-220.

**Tissue weighting factor**: Multiplier of the equivalent dose to an organ or tissue used for radiation protection purposes to account for the different sensitivities of different organs and tissues to the induction of stochastic effects of radiation.

**Workplace monitoring**: Monitoring using measurements made in the working environment.
10.1 Introduction

All rocks and soils contain traces of the natural radioactive elements uranium and thorium. Uranium is present as the isotopes uranium-238 (99.3%) and uranium-235 (0.7%), while thorium is present as thorium-232. These naturally occurring radionuclides have extremely long half-lives and have survived since the formation of the earth, hence their name ‘primordial radionuclides’. Each forms the ‘parent’ of its own particular decay chain containing other radionuclides that decay ultimately to stable isotopes of lead. Details of the two most important decay chains — uranium-238 and thorium-232 — are given in Appendix 10.1. The presence of these primordial radionuclides in human habitats, together with the cosmic radiation permeating the earth and the cosmogenic radionuclides continuously generated by this radiation, have always been a source of radiation exposure to humans. This exposure can be loosely described as exposure to natural sources of radiation.

Various aspects of human behaviour such as living and working in enclosed structures have generally increased the level of exposure to natural sources of radiation, particularly because of increased exposure to radon-222, a gaseous decay product of uranium-238 which permeates into enclosed areas through floors and walls. These increased exposures have largely become accepted as part of our normal ‘natural background exposure’.

Work activities involving natural raw materials, particularly mining and minerals processing, have further increased exposures to natural sources of radiation. In some cases, these increased exposures are significant and need to be controlled in order to protect the health of workers and members of the public. Radiation exposures of members of the public arise principally from the controlled discharge of mine effluents and from the storage and ultimate disposal of mine tailings in surface impoundments. Control of public exposures forms part of a mine’s responsibility in terms of mine waste management, rehabilitation, and closure and — while important — is outside the scope of this Handbook.

10.2 Radioactivity and ionising radiation

Radioactivity is the spontaneous release of energy in the form of particles and waves from unstable atoms. The particles are referred to as alpha and beta radiation and the waves as gamma radiation. The radiation produced by radioactive elements, as well as by particle accelerators and X-ray machines, has sufficient energy to produce ion pairs in biological materials and, for this reason, is referred to as ionising radiation.

Alpha radiation consists of positively-charged particles composed of two neutrons and two protons. Alpha radiation will not usually penetrate the epidermis and can be stopped completely by a sheet of paper or a few cm of air.

Beta radiation consists of negatively charged particles in the form of high-speed electrons. It is much more penetrating than alpha radiation and can, depending on the energy, pass through 1-2 cm of water, 5 mm of human tissue, or about 3 m of air.

Gamma radiation is electromagnetic radiation of very short wavelength. Its penetrating power depends on the energy, but is capable of passing through the human body. Dense materials such as concrete or lead are used to provide shielding against gamma radiation.

A brief explanation of the units of measurement used in radiation protection is provided in Appendix 10.2. Further useful information can be found in the MVS Data Book (MVS 1999, vol. 2).

10.3 Health effects of ionising radiation

When ionising radiation passes through human tissue, damage may be caused to cells which, if not adequately repaired, may have two possible outcomes, ‘deterministic’ or ‘stochastic’.

10.3.1 Deterministic Effects

When the dose (the energy imparted to the cell) is greater than a certain threshold, the cell is prevented from surviving or reproducing. If the number of cells lost is large enough, observable harm reflecting
a loss of tissue function will occur within a short time of the exposure. Above the threshold, the severity of the harm increases steeply with dose. This type of effect is called deterministic, and is usually associated only with accidents at nuclear installations or with accidental exposures to highly radioactive medical or industrial radiation sources. Exposure to natural sources of radiation cannot give rise to deterministic effects.

10.3.2 Stochastic Effects

When the energy imparted to the cell is below the threshold for deterministic effects, the irradiated cell will survive, but may become modified. Because of exposure to natural background radiation, about 10 million cells in an individual are hit by radiation every minute. Our ability to deal with this ‘onslaught’ of radiation is due to the existence of highly effective defence mechanisms. Despite this, it is still possible for a clone of cells resulting from the reproduction of a modified but viable cell to result in the development of a cancer after a prolonged and variable latency period. This kind of effect is called stochastic, meaning ‘of random or statistical nature’. Because of the long latency period, typically decades after the exposure was incurred, radiation-induced cancer — as with most other cancers — is primarily a disease of old age, the average victim being about 65 years old.

If the radiation damage occurs in germ cells, this damage may be transmitted and become manifest as hereditary disorders in the descendants of the exposed individual. Radiation has not been identified as a cause of such effects in humans, but it is presumed from the results of animal studies that such effects may occur and due allowance is made for them in international standards.

The average radiation dose from natural background exposure is 2.4 mSv per year. For doses of up to about 40 times this value, no firm conclusions on health effects can be drawn, despite the multitude of cellular, animal and epidemiological studies that have been conducted. Some researchers have produced evidence supporting a linear dose-response relationship with no apparent threshold, others have produced evidence consistent with a threshold below which there are no effects, while others have produced seemingly convincing evidence of beneficial health effects at low doses. It is unlikely that this problem will be resolved in the foreseeable future by epidemiological studies since, to be conclusive, they would need to be conducted under controlled conditions on an impossibly large population over a very long period. Even then, it is almost impossible to observe, in large population groups, minor changes in patterns of cancer incidence and to distinguish them from similar patterns of incidence that could have a host of other causes.

The American Health Physics Society (HPS 1996) states that “In accordance with current knowledge of radiation health risks, the Health Physics Society recommends against quantitative estimation of health risk below an individual dose of 5 rem [50 mSv] in one year or a lifetime dose of 10 rem [100 mSv] in addition to background radiation. Risk estimation in this dose range should be strictly qualitative accentuating a range of hypothetical health outcomes with an emphasis on the likely possibility of zero adverse health effects.”

For doses greater than about 40 times the dose from average natural background exposure, there is conclusive epidemiological evidence that the probability of cancer resulting from radiation usually increases in a way that is roughly proportional to dose. For the low doses and dose rates likely to be received in the mining situation, the probability of attributable cancer per mSv of dose is estimated to be $4 \times 10^{-5}$ for adult workers and $5 \times 10^{-5}$ for the general population.

The system of radiation protection adopted internationally is designed to ensure that the probability of stochastic effects will not exceed a level that is regarded as unacceptable when viewed in perspective with other risks, so that society’s resources are not inappropriately expended. In dealing with the lack of conclusive knowledge in the low dose region referred to above, international standards, for the purposes of caution and regulatory convenience, are based on the “Linear No-Threshold” (LNT) hypothesis, i.e. on the hypothesis that health effects are linearly related to dose with no threshold.
The LNT hypothesis, despite its adoption as the basis for international standards, remains a controversial issue. This is particularly because of the social and economic implications of extending regulatory control to exposures to natural sources, when such exposures are similar to the variations in natural background exposures.

Many cellular, animal and epidemiological studies have been conducted to investigate the combined health effects of low doses of radiation in conjunction with other deleterious agents, and in particular to establish whether there are significant deviations from additivity. More research is required to elucidate fully these combined effects but, with the exception of radiation and tobacco smoking, there is no evidence at this stage that low-level exposures to multiple agents yield combined effects far from additivity. This includes exposures to multiple agents that may be found in the mining industry such as radiation plus dust and radiation plus diesel fumes. The situation is different for the combined effects of radiation exposure and tobacco smoking. The results of the most recent review of epidemiological evidence from earlier studies on relatively highly exposed uranium miners suggest synergism between smoking and radon progeny exposures that is statistically most consistent with a slightly sub-multiplicative interaction. A best estimate from miner data indicates that the lung cancer risk for smokers expressed in absolute terms is higher by a factor of at least three.

10.4 Radiation protection standards

World-wide, there is a high degree of consensus on radiation safety standards and the regulatory approach to radiation, as reflected in the International Basic Safety Standards (the “BSS”) (IAEA, 1996). The BSS is based on the recommendations of the International Commission on Radiological Protection (ICRP), an international advisory body which provides guidance on the fundamental principles of radiation protection and safety, and updates such guidance in the light of new knowledge and thinking.

The ICRP recommendations and the standards contained in the BSS have in turn formed the basis for European Commission (EC) legislation via the so-called “Euratom Directive” (EC, 1996), and are being adopted as regulations in many individual countries around the world, recent examples being the UK Ionising Radiation Regulations 1999 and the Australian Radiation Protection and Nuclear Safety Regulations 1999.

The basic principles of radiation protection, as recommended by the ICRP and adopted in international standards, are summarized in Table 10.1.

Because exposure to natural sources of radiation forms part of our everyday life, work activities involving such exposures may have characteristics of both practices and intervention. Further information on international recommendations, standards, and guidance, including guidance on how to deal with work activities involving exposure to natural sources of radiation, can be found in various international publications (ICRP 1991, 1993, 1997, IAEA 1996, 1999, EC 1996, 1997).

The following dose limits for occupational exposure have been adopted in international standards (IAEA 1996):

(a) an effective dose of 20 mSv per year averaged over five consecutive years; and
(b) an effective dose of 50 mSv in any single year.

In addition, there are separate dose limits for exposure of specific tissues (eyes, hands, feet, and skin), and for apprentices and students of age 16 to 18. Provision is also made for a temporary change in the dose limitation requirement mentioned in (a) in special circumstances.

The occupational dose limit currently imposed on the mining industry by the National Nuclear Regulator is 50 mSv in a year, but this is being reviewed as part of the drafting of new regulations on safety standards and regulatory practices.
Table 10.1 Basic principles of radiation protection

| Primary aim: | “to provide an appropriate standard of protection for man without unduly limiting the beneficial practices giving rise to radiation exposure” |
| Practices: | human activities that increase the overall exposure to radiation |
| Intervention: | human activities that can decrease the overall exposure to radiation |
| • Justification of a practice: | no practice involving exposures to radiation should be adopted unless it produces sufficient benefit to the exposed individuals or to society to offset the radiation detriment that it causes |
| • Optimization of protection: | in relation to any particular source within a practice, the magnitude of individual doses, the number of people exposed, and the likelihood of incurring exposures where these are not certain to be received should all be kept as low as reasonably achievable, economic and social factors being taken into account (ALARA) |
| • Individual dose and risk limits: | the exposure of individuals resulting from the combination of all the relevant practices should be subject to dose limits, or to some control of risk in the case of potential exposures |
| • Justification: | the proposed intervention should do more good than harm, i.e. the reduction in detriment resulting from the reduction in dose should be sufficient to justify the harm and the costs, including social costs, of the intervention |
| • Optimization: | the form, scale, and duration of the intervention should be optimized so that the net benefit of the reduction in dose, i.e. the benefit of the reduction in radiation detriment less the detriment associated with the intervention, should be maximized (Dose limits do not apply in the case of intervention) |

10.5 Occupational radiation exposures in the mining industry

Table 10.2 gives examples of situations in the South African mining industry where experience has indicated significantly enhanced occupational exposures to natural radiation sources.

Table 10.2 Situations of radiological significance in the South African mining industry

<table>
<thead>
<tr>
<th>Type of situation</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Where the concentrations of uranium and/or thorium in the ore are typically more than about 25 times the average levels in the earth’s crust, i.e. more than about 1 Bq/g, especially in underground mines because of the build-up of the radioactive gas radon-222</td>
<td>Gold mines</td>
</tr>
<tr>
<td>Where uranium, thorium, or mineral products containing these elements are extracted from the ore</td>
<td>Extraction of uranium as a by-product of gold or copper</td>
</tr>
<tr>
<td>Where uranium, thorium or their decay products become adventitiously concentrated during the process</td>
<td>Radium sulphate scales formed during • the production of sulphuric acid from the roasting of pyrite, and • oil and gas extraction</td>
</tr>
</tbody>
</table>

The three most significant types of exposure that need to be considered are:

• exposure to alpha radiation from the short-lived decay products of radon-222 (radon daughters) through the inhalation of air in underground workplaces
• exposure to gamma radiation external to the body, such as from the rock face, from large ore stockpiles, or from localized radionuclide concentrations in surface plants; and
• exposure to alpha radiation from the inhalation of ore dust, such as in underground workplaces and in dry processing operations in surface plant

Other types of exposure, such as ingestion intakes or skin contamination, are not normally significant but may need to be considered in certain work situations.
The distribution of radiation doses received by workers during 1999, according to submissions made by mining and minerals processing facilities to the National Nuclear Regulator, are shown in Table 10.3.

Table 10.3 Distribution of radiation doses received by workers in 1999

<table>
<thead>
<tr>
<th>Type of Facility</th>
<th>Number of Workers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-5 mSv</td>
</tr>
<tr>
<td>Gold mining</td>
<td>130 986</td>
</tr>
<tr>
<td>Copper mining</td>
<td>4 576</td>
</tr>
<tr>
<td>Mineral sands</td>
<td>2 871</td>
</tr>
<tr>
<td>Phosphates</td>
<td>290</td>
</tr>
<tr>
<td>Other minerals processing</td>
<td>2 084</td>
</tr>
<tr>
<td>Total</td>
<td>140 807</td>
</tr>
</tbody>
</table>

Gold mining accounts for the majority of exposed workers. It is also the only type of facility where a significant proportion of the workforce receives radiation doses exceeding 5 mSv per year (or about twice normal natural background). A survey of 21 gold mines conducted by the Chamber of Mines in 1993 and 1994 (Wymer and van der Linde 1995) revealed that most of the dose received by workers (71% overall) was attributable to exposure to radon daughters. Exposure to external gamma was the next most significant (25%) and exposure to dust the least significant (4%).

Radon-222, a gaseous decay product of uranium-238, is released into the mine atmosphere mainly by diffusion through ore. It may also be released from water percolating through the ore body. Because it is an inert gas, it is not retained in the respiratory system and contributes little to radiation dose. It has a half-life of 3.8 days, long enough to have a chance of escaping from the rock but short enough for its four immediate daughter products, which have particularly short half-lives (less than half an hour), to increase in concentration rapidly when a source of radon is present. These radon daughters are metallic ions and will very quickly attract to themselves molecules of water and other atmospheric gases to form very small particles, which in turn attach to natural aerosol particles of diameter typically about 0.3 µm. When inhaled, most of the radon decay products attached to aerosols, together with the unattached particles, will lodge in the lungs and airways. There will usually be insufficient time for the natural clearance processes to have removed them before the short-lived daughters have decayed and thus deposited their energy into the lung tissue. The consequence of this is that, for exposure to radon daughters, the stochastic health effect of concern is lung cancer.

Because almost all of the radiation dose arises from radon daughters, rather than from radon itself, the radiation hazard associated with underground air depends critically on the degree of ingrowth of radon daughters. This in turn depends on the age of the ventilating air as it flows through the mine. In relatively fresh (young) air, the ratio of the concentration of the daughter products to that of radon is low; it approaches unity in old (stagnant) air. The determination of this ratio (which, when expressed in terms of the available alpha radiation energy, is called the equilibrium factor) provides useful information about the source of radon and the effect of ventilation as a means of control. It also allows the conversion of the measured radon concentration to a radon daughter concentration, which is essential for calculating the radiation dose (see Appendix 10.2).

In ore bodies containing concentrations of thorium, a similar situation may arise from the inhalation of radon-220 (sometimes referred to as thoron), a decay product of thorium-232 which — like radon-222 — is also gaseous and decays rapidly through a series of short half-life daughters. However, because the half-life of radon-220 is less than one minute, there is much less chance of it escaping from the ore and it is unlikely to be a problem in most South African mines.

Further information on radon in mines can be found in publications by the IAEA (1983, 1989).
10.6 The legal framework

In common with the situation elsewhere in the world, the South African approach to the regulatory control of work activities involving radiation was focused originally on exposure to artificially produced radiation such as that associated with nuclear power and the use of fabricated radioactive sources in science, medicine and industry. It is only during the past ten years that regulatory control has been extended to include exposure to natural sources of radiation associated with the mining and processing of raw materials, and the implementation of the regulatory process is not yet complete.

Occupational exposure to radiation in mining is regulated in terms of two laws, the National Nuclear Regulator Act, 1999 (Act No. 47 of 1999) and the Mine Health and Safety Act, 1996 (Act No. 29 of 1996), both of which fall under the Minister of Minerals and Energy. At present, there is considerable overlap in this legislation. Section 6 of the National Nuclear Regulator Act addresses this by requiring the Minister, after due consultation, to make regulations regarding the conclusion of co-operative agreements that will avoid unnecessary duplication and omissions regarding safety requirements and the issuing of conflicting instructions. The NNR is required in terms of section 6 to conclude such co-operative agreements with every relevant organ of state. These regulations and co-operative agreements have yet to be established.

Details of regulatory responsibilities are given in Appendix 10.3.

10.7 Monitoring of exposure levels

Monitoring of radiation exposure levels is conducted for two main purposes. Firstly, it is necessary to acquire the data needed to establish the significance of the various types of radiological hazard and to determine the appropriate control measures. Secondly, there is a requirement to assess the doses received by individual workers. Further information on monitoring at mines is provided by the IAEA (1989).

10.7.1 Monitoring for operational control

Physical measurements of the parameters relevant for radiation protection, for example radon concentrations in underground air, as part of an initial hazard assessment will enable management to identify the sources of radiation exposure that are significant enough to require control. Such measurements also provide the diagnostic information needed for the management of radiation protection. They provide a method of quickly detecting departures from normal operating conditions and signal the need for corrective action. A well-conceived programme will also facilitate the prediction and understanding of trends and of the significant sources of exposure as the mining operation develops.

During the initial hazard assessment, comprehensive surveys of external gamma radiation, airborne radioactive dust, and radon and its daughters should be carried out. In uranium plants, particularly in the final product areas, surface contamination should also be measured to determine whether there are likely to be any problems caused by the resuspension of dust. The results of the initial hazard assessment, in particular the dose rates, the concentrations of radionuclides and their fluctuations over time, will determine the nature of the ongoing operational monitoring programme in terms of the parameters to be measured and the frequency of measurement.

10.7.2 Monitoring for the assessment of occupational exposures and doses

The main purpose of the dose assessment programme is to:

- demonstrate compliance with the individual regulatory limits
- demonstrate that doses are as low as reasonably achievable; and
- provide information to be incorporated into the dose records

Exposures to radon daughters may be determined by fixed workplace monitoring, by individual monitoring or, quite commonly, by a combination of the two. Workplace monitors should be
positioned where the samples are likely to be representative of the air breathed by workers. Individual dose assessment based on workplace monitoring should take account of the occupancy times at different locations. Individual radon monitoring of workers is generally more expensive than workplace monitoring, but may be necessary where conditions vary widely and where there is a possibility of exposures approaching or exceeding regulatory limits. It is often more convenient and cost-effective to routinely monitor the concentration of radon rather than of its daughters. In this event, it will be necessary to conduct a limited number of radon daughter measurements as well, so that a representative estimate of the equilibrium factor can be established for dose calculation purposes.

Where external gamma radiation exposure is significant enough to require monitoring (more than, say, 10% of the dose limit), it is usual to provide workers with individual dosimeters, which are inexpensive and reliable, and which can provide integrated dose measurements over periods of one to three months.

In those few areas where exposure to radioactively contaminated dust needs to be monitored, dust sampling devices may be deployed either at fixed locations or on a personal basis. Personal air sampling for gravimetric purposes is already adopted in South African mines, and is likely to be more the reliable method where a worker is exposed to widely varying dust concentrations.

10.7.3 Monitoring methods

A detailed description of radiation monitoring methods used generally in mining situations is provided by the IAEA (1989). The methods most commonly used in the South African mining industry are summarized below.

**Radon-222 and daughter products**

Most mines measure radon-222 daughters in underground mine air directly by a portable radiation spectrometer developed especially for the South African mining industry as part of a SIMRAC project (van der Linde and Roberts 1996). The instrument, known as the ML98, measures individual short lived radon daughters, as well as long lived alpha emitters in dust and external gamma radiation. The instrument has been designed for use in the harsh environment of South African mines and is certified by the SABS as intrinsically safe.

For personal monitoring, integrated measurements of radon gas concentrations are conducted over one month periods using passive track-etch detectors worn on the body. When alpha particles from the decay of radon impinge upon a film of plastic contained within the detector, they cause damage tracks in the material. The tracks are made detectable by chemical etching. The number of tracks is equal to the number of alpha particles that have reached the plastic, and can thus be related to the average concentration of radon over the wearing period. The detectors, and a film processing and counting service, are available locally.

Although passive track-etch radon gas monitors are convenient and relatively inexpensive, they suffer from the disadvantage that the equilibrium factor needs to be determined separately in order to calculate the dose from radon daughters. The ML98 radon spectrometer is commonly used for this purpose on a spot sampling basis. A track-etch detector capable of measuring radon daughters directly was developed as part of a SIMRAC project (van der Linde and Roberts 1996), and others are available from overseas. These are active dosimeters, in that a known volume of air is drawn through a filter by a battery powered pump and the alpha particles emitted by the radon daughters attached to the dust trapped on the filter are recorded on a nuclear track film. These devices have not yet found wide acceptance in South African mines.

**External gamma radiation**

Portable detectors that measure dose rates in µSv per hour directly are readily available for workplace monitoring. For personal monitoring, the thermoluminescent dosimeter (TLD) is the device most suitable for the temperature and humidity conditions in mines. It is deployed for periods of up to 3 months. TLDs, and a processing service, are available locally.
Radioactive dust monitoring

Alpha radiation from dust samples collected from the workplace atmosphere is measured in the laboratory using an alpha counter. Depending on the time that elapses between the sampling and the counting, and whether the dust contains uranium or thorium, the alpha radiation detected may or may not include a significant contribution from short-lived decay products. This needs to be considered when using the results to calculate the inhalation dose.

10.7.4 Biological monitoring

The use of biological monitoring to assess the exposure of workers has limited applicability in mining and minerals processing operations, and is generally restricted to workers in uranium extraction plant. The solubility characteristics of uranium concentrates depend strongly on the specific extraction and post-extraction conditions. Uranium contained in non-calcined or low temperature calcined yellowcake is likely to be more biologically transportable, and in this case routine urine analysis may be appropriate for workers handling such materials.

Workers suspected of having an accidental high intake of radioactivity through the inhalation or ingestion of dust containing radionuclides at high concentrations should have a urine analysis done within 24 hours of the suspected intake. Other appropriate bioassay methods, such as faecal assay, should be employed if indicated by the result of the urine analysis, to evaluate the intake and the consequent dose. Where the results of urine monitoring following a suspected high accidental intake indicate a consistently high uranium (or thorium) concentration, a measurement of the activity content of the thorax should be made with a whole-body counter.

10.8 Health surveillance

Health surveillance of workers exposed to radiation should form part of the mine’s normal health surveillance programme. No specific radiation-related medical examinations are required for workers exposed to radiation at mines, because there are no diagnostic tests that yield information relevant to exposure at doses below the threshold for deterministic effects. Health surveillance should therefore follow general occupational medical practice for determining fitness for work.

Health surveillance is the responsibility of the occupational health practitioner, whose functions include the assessment of the health of workers, ensuring the initial and continuing compatibility of the health of workers and the conditions of their work, and the maintenance of confidential medical records in accordance with regulatory requirements.

10.9 Engineering and administrative control measures

10.9.1 Basic principles

Engineered control measures such as good design, installation, maintenance, operation, administrative arrangements, and instruction of personnel should be used to the maximum extent practicable before the use of personal protective equipment is considered. Adequately designed and properly controlled ventilation systems are the most effective methods of minimizing exposure to airborne radioactive substances in underground mines and processing plants. Further information on engineering control methods on mines is provided by the IAEA (1983).

10.9.2 Control of radon underground

Ventilation is particularly critical to the control of radon in underground workplaces, and is the only practical means of limiting the build-up of radon daughters. Situations that need particular consideration include those where the heat load — and thus the amount of ventilation required for cooling — is moderate, where the air has to travel large distances underground before reaching the workplace, where the air passes through worked-out areas, and where workplaces are ventilated in series rather than in parallel.
The degree of dust control required to provide adequate protection of workers against non-radiological dust hazards will normally be sufficient to protect against radiological hazards.

10.9.3 Control measures in ore processing plant

In addition to dust control measures, attention should be given to good design, operating and general housekeeping measures, including procedures for the clean-up of spills of concentrated radioactive material, to minimize the spread of radioactive contamination. Particular care is needed to protect workers carrying out maintenance operations, where they may become exposed to scales and sediments in which radionuclides have become highly concentrated.

10.9.4 Personal protective equipment

Except in the case of temporary and unforeseen situations, or for particular repair and maintenance operations, reliance on personal respiratory protective devices should be avoided. They should not be considered as a substitute for good engineering control measures. Further guidance on the use of personal respiratory protective devices is given by the IAEA (1983, 44).

Depending on the risk of radioactive contamination, overalls, head coverings, gloves, and impermeable footwear and aprons should be provided to workers whose personal clothing or skin is likely to become contaminated.

10.9.5 Personal hygiene

- Where necessary, suitable washing, showering, changing, and laundering facilities should be provided to prevent the spread of contamination
- Appropriate attention should be given to measures for the prevention of potential intake of radioactivity through eating, drinking and smoking, including the instruction of workers in this regard
- Precautions should be taken to prevent the possible contamination of wounds in areas where concentrated radioactive materials are present

10.9.6 Job rotation

In mines having high levels of radiation exposure, when no other practical means of control are available, job rotation may be considered, in consultation with the workforce, in order to reduce the exposure of individual workers. Job rotation should not be used as a substitute for the development and use of other radiation control methods.

10.10 Guide to information resources


The time periods noted on the figure are the half-lives of the radionuclides named.

**Figure 10.1** Uranium-238 decay chain
The time periods noted on the figure are the half-lives of the radionuclides named.

Figure 10.2 Thorium-232 decay chain
Appendix 10.2 Units of measurement in radiation protection

The unit of radioactivity (or ‘activity’) is the becquerel (Bq), defined as one nuclear disintegration per second and having the dimension s⁻¹. The ‘activity concentration’ of radioactivity in a material is usually expressed in units of Bq.g⁻¹.

The fundamental measure of dose in radiation protection is the energy absorbed per unit mass of tissue or organ (the absorbed dose). The stochastic effects of radiation depend on more than just the absorbed dose, however. They depend also on the type and energy of the radiation (dealt with by a ‘radiation weighting factor’) and on the distribution of dose within the body (dealt with by a ‘tissue weighting factor’). The doubly weighted absorbed dose, called the ‘effective dose’, then becomes the overall measure of radiation detriment or harm. The ‘effective dose’, often referred to simply as the ‘dose’, has the dimensions joule per kilogram (J.kg⁻¹), and is given the special name sievert (Sv).

Since the sievert is a very large dose, effective dose is often expressed in µSv or mSv. If the dose is due to an intake of radioactive material into the body, the material gives rise to doses to different tissues in the body at different rates. It is then necessary to take the time integral of the dose rate for each tissue over the period of interest (usually 50 years for adults and to age 70 years for children). The overall radiation detriment, taking all tissues into account, is then known as the ‘committed effective dose’.

Radon in air is conveniently measured in terms of its concentration (Bq.m⁻³). However, the real quantity of interest is the concentration of alpha energy available from its short-lived daughters, as this is what determines the dose to the lung. This quantity is expressed as the ‘potential alpha energy concentration’ (PAEC) of the short-lived daughters, expressed in units of joule per cubic metre of air (J.m⁻³). If the short-lived daughters of radon-222, at a concentration of 1 Bq.m⁻³, are allowed to grow into equilibrium with their parent, then the PAEC will be 5.56 x 10⁻⁹ J.m⁻³. At equilibrium the activity concentration of each daughter becomes equal to that of the parent radionuclide (radon-222).

The PAEC of any mixture of radon daughters in air can also be expressed in terms of the so-called ‘equilibrium equivalent concentration’ (EEC). The EEC is defined as the concentration of radon in equilibrium with its daughters that would have the same PAEC as the actual (non-equilibrium) mixture, and is thus expressed in units of Bq.m⁻³. The ratio of the EEC to the actual radon concentration will vary between 0 and 1, depending on the degree of ingrowth of daughters into the mixture, and is known as the equilibrium factor, F. In underground workplaces, F usually varies between 0.2 (young air containing relatively low concentrations of radon daughters) to 0.8 (old air containing relatively high concentrations of radon daughters). A value of 0.4 is often taken as a representative value.

The exposure of an individual to radon progeny over a given time period is defined as the time integral of the PAEC over that period, and is expressed in units of J.h.m⁻³ (or, more conveniently, mJ.h.m⁻³). If the PAEC is constant, then the exposure is simply the PAEC multiplied by the exposure time in hours.

The dose received by workers exposed to radon-222 daughters can be determined directly from the exposure. A potential alpha energy exposure of 1 mJ.h.m⁻³ will give rise to a committed effective dose of 1.4 mSv.

The dose received by workers can also be determined from the time-weighted average radon concentration, which is more readily measurable, provided that the equilibrium factor and the exposure time are known:

- A radon-222 concentration of 1 Bq.m⁻³, if in equilibrium with its daughters (F = 1), would represent a radon daughter PAEC of 5.56 x 10⁻⁹ J.m⁻³ (see above)
- Multiplying by 0.4 (the assumed equilibrium factor ) gives an actual PAEC of 2.22 x 10⁻⁹ J.m⁻³
- Multiplying by 2 000 (the assumed annual exposure time in hours), gives an exposure of 4.44 x 10⁻⁶ J.h.m⁻³
- Multiplying by 1.4 to convert to dose, gives an annual dose of 6.36 x 10⁻⁶ Sv

Thus, a radon concentration of 1 Bq.m⁻³, at an equilibrium factor of 0.4 and an annual exposure time of 2 000 hours, gives an annual dose of approximately 6 µSv.
Appendix 10.3 Regulatory responsibilities

Minister of Minerals and Energy

In terms of the National Nuclear Regulator Act, the Minister appoints the NNR board members and chief executive officer and, in addition to making regulations on co-operative governance agreements, must also make regulations on safety standards and regulatory practices. These regulations will establish, among other things, the criteria for determining which activities must be regulated and the general safety requirements that must be satisfied. These regulations are presently being drafted. In the meantime, Government Notice No. R.848 issued by the Minister in terms of the now-repealed Nuclear Energy Act, 1993 (Act No. 131 of 1993) remains in force. This notice excludes radioactive material from the scope of regulation provided that the radionuclide concentrations are all below 0,2 Bq.g\(^{-1}\); it also permits the NNR to exempt an activity from regulatory control if the radioactive material contains less than 10 000 Bq of radioactivity at a concentration of less than 100 Bq.g\(^{-1}\), or if the activity gives rise to a radiation dose of less than 1 mSv.

In terms of the Mine Health and Safety Act, the Minister of Minerals and Energy may, after consulting the Mine Health and Safety Council, make regulations on a wide range of health and safety matters on mines, prohibit or restrict work on mines for health and safety reasons, and declare health hazards and measures to be taken in respect thereof. These regulatory powers relate to any health hazard including exposure to radiation.

National Nuclear Regulator

In terms of the National Nuclear Regulator Act, the NNR is responsible for exercising regulatory control over mining and minerals processing facilities to protect persons, property and the environment against nuclear damage. This regulatory control is exercised through the granting of nuclear authorizations, the imposition of conditions of authorization, and the implementation of compliance inspections.

In the absence of regulations on safety standards and regulatory practices, all regulatory requirements are currently determined by the NNR and incorporated into the conditions of authorization. The authorization holder is required in all cases to carry out an assessment to identify and quantify the risks. Based on the results of the risk assessment, the authorization holder must then establish and submit to the NNR a radiation protection programme embodying accounting and record systems, controls, surveillance programmes and reporting procedures as required in terms of the conditions of authorization. The areas generally covered by occupational health requirements include:

- radiation dose limitation
- radiation protection capability, including the availability of competent, qualified and trained staff
- control procedures with respect to designated areas and persons working therein
- health surveillance
- radiation dose monitoring
- quality assurance
- notification of occurrences

Mine Health and Safety Inspectorate

The Mine Health and Safety Inspectorate ensures that the provisions of the Mine Health and Safety Act are complied with and enforced. These provisions include the identification of health and safety hazards at mines, and the elimination, control and minimizing of the associated risks. Exposure to ionizing radiation is a recognized health hazard in mines and is therefore included in the scope of the Act. Specific health and safety hazards are addressed through regulations and guidelines for codes of practice, which are drawn up in consultation with the tripartite institutions established in terms of the Act (the Mine Health and Safety Council and the Mining Regulation Advisory Committee).
Pending a co-operative agreement between the NNR and the Mine Health and Safety Inspectorate, radiation hazards have not yet been specifically addressed in any regulation or guideline, although a considerable amount of drafting work has been done. In terms of a future co-operative agreement, it is envisaged by the Mine Health and Safety Inspectorate that its trained regional inspectors, with professional support from the Head Office Radiation Section, will take on responsibility for inspection and enforcement functions with respect to radiation hazards at mines to ensure worker safety in line with their general inspection duties.
CHAPTER 11

Ergonomics

Ergonomics is mentioned specifically in the Mine Health and Safety Act but, generally speaking, the nature and scope of the subject are not well understood. This chapter gives an overview of ergonomics, why it is important to recognize ergonomics related hazards during risk assessment and the importance of correctly designed equipment and workplaces. Shiftwork is addressed briefly as is computer work environments. Guidance is provided on how to set up an ergonomics programme and a checklist will assist the interested reader to identify potential problem areas.

Prof. J.A. van Tonder
Consultant

Jan van Tonder holds a D.Phil degree in Psychology and is a registered Industrial and Counselling Psychologist. Since 1989 he has been an Extraordinary Professor in the Department of Human Resource Management at the University of Pretoria and, since 1999, has been Extraordinary Professor in Bio- and Industrial Engineering. He has consulted in a private capacity since 1994.

P.C. Schutte
Physiologist

‘Schu’ Schutte holds a Masters degree in Industrial Physiology and has extensive experience in the Physiology, Occupational Hygiene and Ergonomics fields. He is currently employed in the Mining Technology Division of the Council for Scientific and Industrial Research (CSIR).
Glossary

**Anthropometry:** science of measurement of the body’s mass, size, shape, and inertial properties

**Biomechanics:** application of the principles of mechanics to the study of biological systems

**Circadian rhythm:** the various bodily functions of humans fluctuate in a 24-hour cycle, called the diurnal or circadian rhythm

**Cumulative trauma disorders:** any class of pathologies affecting soft tissues (muscles, tendons, and nerves) created from excessively frequent use of a particular joint or tissue, especially in combination with awkward positioning, inadequate or no rest periods, or excessive loads. Also called repetitive strain/stress injury, repetitive motion injury, and overuse syndrome

**Environmental stresses:** environmental stimuli that represent potential adverse impacts on the health of workers. Stresses may include chemical and physical agents as well as ergonomic and psychological stress

**Ergonomic hazard:** source of potential harm or a situation with a potential to cause loss

**Ergonomic risk:** chance that harm from a particular ergonomics hazard will occur. It is measured in terms of consequences and likelihood

**Ergonomics:** the science and practice of designing workplaces and systems to fit people

**Overuse syndrome:** see Cumulative trauma disorders

**Repetitive strain injury:** see Cumulative trauma disorders

**Work-related musculoskeletal disorders:** all anatomically located disorders of the musculoskeletal system (both upper extremity and low back and limbs) as well as non-specific symptoms and syndromes where association with work has been found


11.1 Introduction

The mining industry in South Africa has undergone significant changes in the past twenty years with increased mechanisation and development of new technologies. Despite changes, many jobs continue to be labour intensive, physically demanding and repetitive, and human-centred design principles have often been neglected in the design and development of new equipment and technologies.

With the promulgation of the Mine Health and Safety Act (Act 29 of 1996) the concept of “ergonomics” was legislated into occupational health and safety. For the first time in South Africa specific reference was made to ergonomics in legislation, i.e. the application of ‘ergonomic principles’. However, the responsibility was limited to the manufacturers and suppliers of mining equipment (Section 21(1) (c)). Unfortunately, this section in the Act does not include the workplace and work procedures and no regulatory guidelines are provided as to what is actually meant by “ergonomic principles”.

Section 21(1)c of the Act reads as follows:

21. Manufacturer’s and supplier’s duty for health and safety

(1) Any person who .........

(c) designs, manufactures, erects or installs any article for use at a mine must ensure, as far as reasonably practicable, that ergonomic principles are considered and implemented during design, manufacture, erection or installation. (Emphasis ours).

The applied science of ergonomics was formally established in the late nineteen-forties but there still seems to be confusion as to what the term really means. From this chapter the reader will gain a better understanding of ergonomics and how it relates to occupational health and safety issues in the mining industry. Some guidelines are also given to identify ergonomic hazards and associated preventive strategies will be outlined.

Ergonomics covers a wide field and can only be addressed superficially in this chapter. The focus is on health-related issues in the mining industry. One cannot deal with ergonomic hazards without considering environmental factors and the well-being and health of the human operator. However, environmental stressors (Occupational Hygiene factors) will not be discussed as they are comprehensively addressed elsewhere.

11.2 The Nature and Scope of Ergonomics

11.2.1 Definition of ergonomics

The term “ergonomics” is derived from the two Greek words *ergon*, meaning work, and *nomos*, meaning law. Literally translated, ergonomics means “The Laws of Work”. ‘Ergonomics’ and ‘human factors’ are often used synonymously. Both describe the interaction between the operator and the job demands, and are concerned with trying to reduce unnecessary stress in the workplace. The term ‘human factors’ is preferred in the United States, while the term ‘ergonomics’ is preferred in Europe, the United Kingdom, Australia and South Africa.

The International Ergonomics Association defines ergonomics as “the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimise human well-being and overall system performance”.

As a science, ergonomics studies human capabilities, limitations and other characteristics for the purpose of developing human-system interface technology. As a practice, ergonomics applies human system interfaces to the design, standardization, and control of systems. Ergonomics promotes human reliability and improved health and safety. It ensures that equipment, tasks and the physical work environment are designed to take account of the capabilities and limitations of people.
In the present context, a succinct definition would be that ergonomics seeks to design equipment, tools, workstations and tasks to be compatible with human capabilities and limitations with the purpose of providing work conditions that assure safety, health, well-being and efficiency.

11.2.2 The objectives of ergonomics

The goals of ergonomics are to decrease the risk of injury and illnesses (especially those related to the musculoskeletal system), to improve worker performance, to decrease worker discomfort and to improve the quality of work life. The benefits of well-designed jobs, equipment, work methods and workplaces include: enhanced safety and health performance; improved quality and productivity; reduction in errors; heightened employee morale; reduced compensation and operating costs; and the accommodation of diverse populations. The ultimate goal of ergonomics is to improve and maintain the well-being of the individual worker. At the same time the well-being of the organization will also be improved and maintained. Although ergonomics is an evolving science, proper application of its principles can achieve benefits that are significant and immediate.

11.2.3 Interdisciplinary nature of ergonomics

Ergonomics draws on various fields in the human sciences and technology, including anthropometrics, biomechanics, physiology, psychology, toxicology, mechanical engineering, industrial design, information technology and industrial management. It has gathered, selected and integrated relevant knowledge from these fields.

Ergonomics differs from many other fields by its interdisciplinary approach and applied nature. The interdisciplinary character relates to different human facets while its applied nature results in the adaptation of the workplace or environment to fit people, rather than the other way around.

11.2.4 Ergosystem

A useful concept in understanding the occupational application of ergonomics is that of an ‘ergosystem’. An ergosystem consists of three primary interacting components, namely human, machine or technology, and environment.

The most general approach to ergonomics is to consider a person interacting with technology (man-machine system). Typical examples are persons driving a vehicle, using a computer, speaking over a telephone and using a lift. The interaction occurs by means of displays, whereby the machine or technology provides information to the user and controls whereby the user passes information to the machine (Figure 11.1). There is therefore a complete information flow loop with a proper functioning of all the parts. In order to ensure successful, safe and effective use there should be no delays in the information flow (Galer, 1987).

Tasks are not performed in a vacuum. The interaction between human and technology always takes place in a certain workspace, which is located in a specific physical and psychological environment (Figure 11.2). The characteristics of the workspace and the environment will affect the task performance of the human.

The workspace is described in terms of the size and layout of workbenches, control desks, consoles and other e.g. mining equipment. Factors like size and layout will have an effect on the body position, body posture and reach distances of the expected user population, and consequently on comfort and efficiency.

The environment can be described in terms such as temperature, lighting, noise and vibration, presence and effect of chemical and biological agents, as well as in psychological terms such as teamwork, management structure, shift conditions and psychosocial factors.
The human-technology-workspace-environment model (Figure 11.2) is useful in identifying the factors that will have an effect on comfort, task performance and safety. Applied consistently, this model will ensure that no potential ergonomic factors are omitted. It is, however, primarily a descriptive aid and does not spell out specifically how and in which sequence a system should be analysed and designed. This systems approach is a formal analysis method which has been used successfully in a large number of ergonomics investigations.

Figure 11.1: Communication between human and machine viewed as an information flow loop (after Galer 1987)

Figure 11.2: Human-technology-workspace-environment model
11.3 Ergonomics-related Hazards in the Workplace

11.3.1 Basic ergonomic considerations

The crux of ergonomics is that the human can only, and to a limited extent, adapt to poorly designed human-machine systems and, therefore, the systems must be designed and adapted to fit the human restrictions.

In the application of ergonomics in the workplace there are two primary considerations. In the first instance, ergonomics provides the guidelines and specifications according to which tools, machines, work procedures and workplaces are to be designed and developed for effective, efficient and safe use by the operator. Safe also implies that they do not constitute a health risk. This first role is the proactive approach to effective ergonomics which designers and developers of mining equipment should be applying to comply with the requirements of the Mine Health and Safety Act.

The second important, but reactive, role is the use of criteria to assess whether existing tools, equipment, workplaces and work procedures comply with ergonomic requirements to ensure health, safety and efficiency.

In considering human abilities and limitations there are five critical sets of factors that must always be considered:

- Anthropometrics
- Biomechanics
- Human sensory issues
- Human physiological well-being
- Human cognitive issues

11.3.1.1 Anthropometrics

Anthropometry literally means the measurement of humans. Although one can measure humans in different ways, anthropometry focuses on the measurement of bodily features such as shape and size (“static anthropometry”), body motion and use of space (“functional anthropometry”).

The world’s population can be divided into subpopulations of different average physical dimensions. Anthropometric surveys have shown that South African populations of different ancestries and social class differ significantly in average stature. Difference in stature is important in the design of equipment and work environments, reach distances in driving of vehicles, locos and the operation of equipment, or the postures at workbenches. An anthropometric database can provide useful information for optimising the human-machine-equipment or system interface. Information on the anthropometry of South African mineworkers is available in Chamber of Mines Research Report, No 3/1981. More recent information for the South African population is documented in the South African Military Standard RSA-MIL-STD-127. The basic human body requirements for technology design are given in the International Organization for Standardisation document ISO 7250:1996(E).

11.3.1.2 Biomechanics

Biomechanics deals with the mechanical aspects of body movement and is basically the application of the principles of mechanics to the study of biological systems. Biomechanics thus utilises knowledge from anatomy, physiology, and mechanical engineering. The portion of biomechanics dealing with ergonomics (industrial or occupational biomechanics), is defined as “the study of the physical interaction of workers with their tools, machines, materials so as to enhance the worker’s performance while minimising the risk of musculoskeletal disorders” (Chaffin and Andersson, 1991).

As with anthropometrics some individuals will, due to factors such as muscle volume associated with physical size, life style, gender and socio-economic circumstances, have greater muscle power than others. Muscle power relates to the ability to lift and handle material, equipment and heavy tools.
Occupational biomechanics assessments are used to describe quantitatively the musculoskeletal loading during work to determine the degree of risk associated with an occupationally-related task.

11.3.1.3 Human sensory system

This refers to the human sensors such as vision, hearing, smell, taste, balance and the kinaesthetic sense. Vision and hearing are of particular interest in the mining industry.

11.3.1.4 Human physiological homeostasis

This refers to the need of the human body to be in a state of physical well-being. Environmental stressors such as heat, barometric pressure, noise, vibration, toxic substances often affect physical well-being. Work procedures requiring a considerable amount of energy can place additional stress on the human physiological system. These factors are common in the mining environment.

11.3.1.5 Psychological (Cognitive) system

Body systems do not operate independently. If one system is adversely affected it can influence the others. For instance, during exposure to vibration it is not only the limb or body segment vibrated that is affected, so too are other systems as well as the psychological well-being of that person. Effects on psychological well-being will be manifested in mental fatigue, stress and motivational level which can result in poor decision making, errors and a predisposition to accidents.

When exposed to stress, the human body will attempt to counter it. If the body cannot adapt to or cope with the physical or mental stress because it has reached its limitations, health problems may occur. The most common reaction of the body to physical stressors beyond its limits is pain, and pain is the first indication of a series of events that can eventually result in a person becoming unfit for duty.

In practice it is essential that the design of optimal working conditions with regard to human well-being, performance, and safety and health, should take the following aspects into consideration:

- The physical size of people and its implications for the fit of the person at the workplace and within the facility
- The cardiovascular system and its limitations on work as measured by work physiology
- The major musculoskeletal system and its limitations on manual material handling
- The minor musculoskeletal systems and their limitations on fine work, manipulation and dexterity
- The environmental factors such as lighting, noise and thermal comfort, and their impact on human performance
- The cognitive capabilities of people and their impact on processing information and “human error”

11.3.2 Ergonomics Risk Factors

According to the Mine Health and Safety Act a “risk” is the probability that injury or damage will occur. A risk has three elements to it i.e. the hazard involved, the probability that something can go wrong and the resultant impact or severity.

Reference is often made to “ergonomic hazards” or “ergonomic risk factors” in the workplace. However, as ergonomics strives for a healthy and safe workplace, the hazards actually result from the absence of ergonomic considerations. These conditions are more correctly called “ergonomic risk factors” rather than “ergonomic hazards” or “ergonomic problems”. Table 11.1 summarises a number of the major ergonomic risk factors.
Table 11.1 Ergonomic risk factors.

<table>
<thead>
<tr>
<th>ERGONOMIC RISK FACTORS</th>
<th>Causal factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Awkward posture of:</td>
<td>Tool handles, control grips.</td>
</tr>
<tr>
<td>• Hand/wrist</td>
<td>Working overhead or work surface/benches too high</td>
</tr>
<tr>
<td>• Arm/elbow</td>
<td>Height of work surface, benches and desks, work layout</td>
</tr>
<tr>
<td>• Shoulders</td>
<td>Height of work surface &amp; manual handling</td>
</tr>
<tr>
<td>• Back</td>
<td>Visual angle to view work area</td>
</tr>
<tr>
<td>• Head/neck</td>
<td>Foot control angle, leg room at benches and desks</td>
</tr>
<tr>
<td>• Knee/ankle</td>
<td></td>
</tr>
<tr>
<td>Exertion of forces</td>
<td>Tool handle size and force needed to operate</td>
</tr>
<tr>
<td>• Grip (power vs pinch)</td>
<td>Lifting, lowering and carrying loads, pulling loads.</td>
</tr>
<tr>
<td>• Manual material handling</td>
<td>Work in confined spaces</td>
</tr>
<tr>
<td>• Crouching</td>
<td>Computer work, fixed work posture, holding equipment</td>
</tr>
<tr>
<td>• Static strain</td>
<td></td>
</tr>
<tr>
<td>Work procedures</td>
<td>Machine-paced work tempo</td>
</tr>
<tr>
<td>• Work pace</td>
<td>Insufficient rest and recuperation period</td>
</tr>
<tr>
<td>• Rest periods</td>
<td>Duration and type of work shift</td>
</tr>
<tr>
<td>• Shift work</td>
<td></td>
</tr>
<tr>
<td>Repetitions</td>
<td>Keyboard work, other repetitive work</td>
</tr>
<tr>
<td>• Number</td>
<td>Times cycles are repeated, not sufficient rest</td>
</tr>
<tr>
<td>• Frequency</td>
<td></td>
</tr>
<tr>
<td>Contact stress</td>
<td>Uneven, abrasive and slippery surfaces</td>
</tr>
<tr>
<td>• Surface</td>
<td>Small diameter tool handles</td>
</tr>
<tr>
<td>• Diameter</td>
<td>Thin, sharp and square edges</td>
</tr>
<tr>
<td>• Edges</td>
<td></td>
</tr>
<tr>
<td>Environment</td>
<td>Environmental stressors in the work environment that affect the physical and</td>
</tr>
<tr>
<td>• Noise</td>
<td>psychological well-being of the worker.</td>
</tr>
<tr>
<td>• Vibration</td>
<td></td>
</tr>
<tr>
<td>• Heat</td>
<td></td>
</tr>
<tr>
<td>• Radiation</td>
<td></td>
</tr>
<tr>
<td>• Air quality</td>
<td></td>
</tr>
</tbody>
</table>

11.3.3 Synergism of risk factors

In the workplace the worker may be exposed simultaneously to more than one ergonomic or other risk factor. Such factors may act independently but the effects may also be additive.

In this regard it is important to take notice of the synergistic effect. Synergism simply means the simultaneous and combined effect of two or more factors where the combination is greater than the sum of their individual effects.

In industry vibration for example, in conjunction with other stressors such as heavy manual work, poor posture leads synergistically to cumulative trauma disorder. Van Niekerk et al (1998) state in this regard:

“It is concluded that vibration stress is an important contributor to the development of musculoskeletal disorders in workers using handheld vibrating tools. The heavy manual work needed to control the power tool and to manipulate the work piece is also a contributing factor.”

While many situations can be the cause of ergonomic hazards, individual differences in susceptibility do exist and one individual’s response may not be the same as that of another.

11.4 Work-related musculoskeletal disorders and manual material handling

11.4.1 Work-related musculoskeletal disorders

Musculoskeletal disorders are injuries and problems of the muscles, tendons, ligaments, joints,
nerves, vessels and supporting structure involved in locomotion. They are usually manifested by pain, numbness, tingling, swelling or loss of function, and are primary located in the upper limb, back and, to a lesser extent, the lower limbs.

The term “work-related musculoskeletal disorders” (WMSD) refers to the musculoskeletal disorders to which the work environment and performance of work contribute significantly, or that are made worse or longer lasting by work conditions. WMSD are known by a variety of terms across the world e.g., “cumulative trauma disorders” in the United States of America, “repetitive strain injuries” in Canada and Australia, and more recently in Australia “occupational overuse syndrome”. Lately, WMSD has gained popularity, worldwide, as the preferred designation for this group of disorders. Examples of WMSD are given in Table 11.2.

**Table 11.2 Examples of work-related musculoskeletal disorders (based on Kuorinka and Forcier, 1995)**

<table>
<thead>
<tr>
<th>Anatomical structure involved</th>
<th>Example of possible work-related musculoskeletal disorder (WMSD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tendons</td>
<td>• Tendonitis/peritendonitis/synovitis of most joints, in particular shoulder, elbow and hand-wrist</td>
</tr>
<tr>
<td></td>
<td>• Epicondylitis</td>
</tr>
<tr>
<td></td>
<td>• De Quervain’s disease (stenosing tenosynovitis)</td>
</tr>
<tr>
<td></td>
<td>• Trigger finger</td>
</tr>
<tr>
<td></td>
<td>• Gamekeeper’s thumb</td>
</tr>
<tr>
<td>Nerves</td>
<td>• Median nerve entrapment: Carpal tunnel syndrome (CTS) (entrapment at the wrist) and Pronator teres syndrome (entrapment at the elbow)</td>
</tr>
<tr>
<td></td>
<td>• Ulnar nerve entrapment: Cubital tunnel syndrome (entrapment at the elbow) and Guyon canal syndrome (entrapment at the Guyon canal)</td>
</tr>
<tr>
<td></td>
<td>• Radial tunnel syndrome (radial nerve entrapment at the elbow)</td>
</tr>
<tr>
<td></td>
<td>• Thoracic outlet syndrome (TOS) (neurogenic TOS = entrapment of the brachial plexus at different locations)</td>
</tr>
<tr>
<td></td>
<td>• Cervical syndrome (radiculopathy) (compression of the nerve root)</td>
</tr>
<tr>
<td></td>
<td>• Sciatica</td>
</tr>
<tr>
<td>Circulatory/vascular structures</td>
<td>• Hand-arm vibration syndrome (involves vascular and nerve damage)</td>
</tr>
<tr>
<td></td>
<td>• Hypothenar hammer syndrome</td>
</tr>
<tr>
<td></td>
<td>• Raynaud’s syndrome</td>
</tr>
<tr>
<td>Joints (cartilage and bone)</td>
<td>• Osteoarthritis of most joints/degenerative joint disease</td>
</tr>
<tr>
<td></td>
<td>• Arthrosis of the hip</td>
</tr>
<tr>
<td>Muscles</td>
<td>• Tension neck syndrome</td>
</tr>
<tr>
<td></td>
<td>• Trapezius myalgia</td>
</tr>
<tr>
<td>Bursa</td>
<td>• Bursitis of most joints</td>
</tr>
<tr>
<td>Neurovascular related</td>
<td>• Brachial plexus compression injuries</td>
</tr>
</tbody>
</table>

Risk factors which are known, on the basis of epidemiological evidence, to be associated with the development or aggravation of musculoskeletal disorders include personal characteristics (e.g. gender, age, body mass, physical limitations), psychosocial and work-related aspects.

Factors that commonly contribute to WMSD are tasks requiring repetitive, forceful, or prolonged exertion of the hands, frequent or heavy lifting, pushing, pulling or carrying heavy objects and prolonged awkward postures. Vibration and cold may also contribute. Multiple risk factors will have a higher probability of causing a musculoskeletal problem and the level of risk depends on the intensity, frequency and duration of the exposure plus the individual’s capacity to cope.

Information on the job activities and tasks typically associated with common WMSD of the upper extremities is given in Table 11.3.
Table 11.3 Job activities and tasks typically associated with common work-related musculoskeletal disorders

<table>
<thead>
<tr>
<th>Disorder</th>
<th>Typical Job/Task Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carpal tunnel syndrome</td>
<td>Buffing, grinding, polishing, sanding, assembly work, typing, packing, scrubbing, hammering, repetitive or forceful grip and prehensile tasks especially in extremes of flexion, extension and ulnar deviation, video display terminal (VDT) work.</td>
</tr>
<tr>
<td>Cubical tunnel syndrome</td>
<td>Resting forearm near elbow on a hard surface or sharp edge or reaching over obstruction, repetitive or static elbow flexion.</td>
</tr>
<tr>
<td>DeQuervain’s syndrome (“tennis elbow”)</td>
<td>Buffing, grinding, polishing, sanding, pushing, pressing, sawing, use of pliers, use of small tools, “turning” control such as on motorcycle, inserting screws in holes, forceful hand wringing.</td>
</tr>
<tr>
<td>Epicondyritis (tennis elbow)</td>
<td>Turning screws, small parts assembly, hammering, repetitive wrist extension and repetitive grasp, VDT work.</td>
</tr>
<tr>
<td>Neck tension syndrome</td>
<td>Belt conveyor assembly, typing, small part assembly, load carrying in hand or on shoulder.</td>
</tr>
<tr>
<td>Pronator (teres) syndrome</td>
<td>Soldering, buffing, grinding, polishing, sanding.</td>
</tr>
<tr>
<td>Shoulder tendonitis (rotator cuff syndrome or tendonitis, supraspinatus tendinitis, subacromial bursitis, subdeltoid bursitis, partial tear of the rotator cuff)</td>
<td>Punch press operation, overhead assembly, overhead welding, overhead painting, belt conveyor assembly, work with the arms away from the body, electrical work, packing, construction work, reaching, lifting, carrying load on shoulders.</td>
</tr>
<tr>
<td>Tendinitis, Tenosynovitis, (tendovaginitis)</td>
<td>Punch press operation, assembly work, wiring, packaging, use of pliers, buffing, grinding, polishing, sanding, punch press operation, sawing, cutting, use of pliers, “turning” control such as on motorcycle, inserting screws in holes, forceful hand wringing.</td>
</tr>
<tr>
<td>Thoracic outlet syndrome (Brachial plexus compression injuries)</td>
<td>Work with arms overhead or in front of the body, mechanical stress applied to the brachial plexus, truck driving, material handling, office workers, carrying heavy loads with extended arms.</td>
</tr>
<tr>
<td>Guyon tunnel syndrome (Biker’s finger)</td>
<td>Repeated/prolonged pressure on the outside of the palm, prolonged flexion of and extension of the wrist, carpentry, brick laying, use of pliers, soldering, hammering.</td>
</tr>
<tr>
<td>Trigger finger (or thumb)</td>
<td>Operating trigger finger, using hand tools that have sharp edges pressing into the tissue or whose handles are too far apart for the user</td>
</tr>
<tr>
<td>White finger (Raynaud’s syndrome, vibration syndrome)</td>
<td>Working with chain saws, jackhammers, using vibrating tool that is too small for the hand, often in a cold environment.</td>
</tr>
</tbody>
</table>

The relationship between occupational factors and low back pain is often difficult to determine as objective evidence of low back pain is often lacking and exact exposure is usually difficult and sometimes impossible to quantify. Further complicating the situation is the fact that exposure to several occupational risk factors often occurs in the same job. For example, a truck driver may have to load and unload his truck (lifting), sit for many hours in an unchanged posture (static loading), and be exposed to whole-body vibration. The most frequently mentioned risk factors for lower back pain include heavy physical work, static work posture, frequent bending and twisting, lifting, pushing and pulling, and whole-body vibration.

The diagnosis of WMSD requires expertise in evaluating workers in light of the biomechanical, personal and work organizational factors that cause such a condition. Ergonomics is important in preventing WMSD and the following concerns should be addressed at the work area to minimise the risk of developing these disorders:
• Cramping of the worker
• Twisting and turning
• Repeated reaching motions
• Misalignment of body parts
• Manual material handling

More information on WMSD can be obtained from the web pages of the Occupational Safety and Health Administration (OSHA) of the US Department of Labour (http://www.osha-slc.gov/SLTC/ergonomics/) and the US-EU Ergonomics page (http://www.osha-slc.gov/us-eu/ergonomics/ergonomics2.html).

11.4.2 Manual material handling (MMH)

Manual material handling refers to the lifting, lowering, pushing, pulling, holding and dragging of loads without the help of mechanical devices or tools. These activities often require static and dynamic efforts that place great strain on the human musculoskeletal system. MMH is a major hazard due to the injuries that can arise. These include cuts and bruises, hernias and back injuries. In the mining industry where MMH is performed, mostly underground in restricted areas and with the body often in an unnatural posture, this aspect is particularly important and should receive specific attention.

A frequently-asked question is what can a person be reasonably expected to handle? There is not any straightforward answer due to the great diversity of people, different strengths and physical conditions, size and shape of objects to handle. The International Labour Organization (ILO) has provided guidelines, which are generally accepted as the norm for lifting tasks (Table 11.4).

<table>
<thead>
<tr>
<th>AGE (years)</th>
<th>MEN</th>
<th>WOMEN</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 – 20</td>
<td>23 kg</td>
<td>14 kg</td>
</tr>
<tr>
<td>20 – 35</td>
<td>25 kg</td>
<td>15 kg</td>
</tr>
<tr>
<td>35 – 50</td>
<td>21 kg</td>
<td>13 kg</td>
</tr>
<tr>
<td>50+</td>
<td>16 kg</td>
<td>10 kg</td>
</tr>
</tbody>
</table>

The American National Institute for Occupational Safety and Health (NIOSH) has developed a comprehensive index to calculate the risk involved in manual handling tasks: *Work Practices Guide for Manual Lifting* was revised in 1991, to reflect new findings and the NIOSH recommendation for lifting and lowering tasks is 23 kg, which corresponds closely with that of the ILO.

Manual-handling tasks will always exist in the workplace and it is often lifting a small load that triggers a problem.

Some considerations to counter the effects of MMH are:

• Workers must be trained in correct load-handling procedures
• If the worker is uncertain whether he can handle the load, he/she must get help
• Use leg lift instead of back lift
• Work must be done between knuckle and shoulder height
• Do not twist and rotate the body when handling a load, use the feet to turn
• Avoid stretching with a load in the arms
• Avoid awkward body postures
• Keep load close to the body
• Use a firm grip on the load
• Balance the load especially where it has an awkward shape
• Use mechanical assistance, hoists, conveyors, trolleys etc., wherever possible
• Where possible design the workplace to push and pull rather than lift and lower
• Keep walkways clear of obstacles
• Provide small ramps instead of stairs where possible
• Ensure the underfoot surface is not uneven or slippery
• Minimize heights between surfaces where loads are handled
• Consider the physical condition of the worker

A comprehensive guide with recommendations to address MMH activities has been prepared by Mital, et.al. (1997) and more information is available from the NIOSH web page (http://www.cdc.gov/niosh/).

11.5 Equipment and Workplace design

In the mining industry in South Africa literally thousands of different tasks are performed in different settings and environments. The ergonomic recommendations for the dimensions of workstations are to some extent based on anthropometric data, but behavioural patterns of people and specific requirements of the work itself must also be considered. Poor ergonomics in human-machine work systems can result in accidents and injuries, but can also result in health-related problems if the lack of consideration for human abilities and limitations result in stresses and strains on the body. Two reports, one dealing with the ergonomic design of trackless mining machines (Mason, et.al., 1998) and the other with the ergonomics of locomotive design in gold and platinum mines (Smith, et.al., 2001) are available.

11.5.1 General guiding principles and considerations with regard to workplace design

• Know and understand the tasks of the operator. Identify and analyse the task to be performed, especially to identify potential ergonomics risk factors
• “Fit the task to the human and not the human to the task”. The human is fitted to the task only if very specific characteristics are required and selection takes place through training programmes
• Identify the user population. Design for the correct anthropometrics and biomechanical abilities of the user population. Design for a range and not for the average. Use adjustability to fit different sizes
• Consider population expectancy or stereotypes which may differ from country to country, as these may be the cause of errors and accidents. It becomes especially important if equipment is being imported from countries where the stereotypes differ from that of the South African population.
• Use standards and other verified scientific information and ergonomics data
• Do not design for extremes of postural reaches. Work activities should be at about the midpoint of limb ranges
• Avoid unnecessary stretching and turning. Controls should be within functional reach.
• Avoid unnecessary repetitive actions or static muscular postures, especially with the arms above shoulder level
• Design for adequate rest pauses during a work period. Consider the work pace especially if set by the system, e.g. conveyor belts
• Consider comfortable viewing postures (viewing angles). In the sitting position, 15° below horizontal and 10° below horizontal while standing are the best for attention, scanning and ability to see detail as well as lessening stress on the neck and shoulder muscles
• Design for maintainability and emergency situations
• Height of the work surface, e.g. workbenches must be related to the task. Variable height work surfaces for different tasks should be considered
• Design for functional comfort and ease but not for luxury
• Consider the principles for MMH

11.5.2 Seated/standing work operations

Work should be arranged so that it may be done, at the worker’s choice, in either a seated or standing position. Correct height of work surfaces is important. Standing work is preferable when the operator has to move frequently and/or when knee room is limited, where force has to be applied, where there is limited front and rear space and a large number of controls and displays needs attention. Height adjustable seating is essential.

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The seat, work surface, and/or desk should be designed as a unit to achieve the preferred body posture, namely trunk erect, body weight appropriately supported, elbows at the side of the body, and forearms approximately horizontal.

11.5.3 General guiding principles with regard to display design

A display is a device that allows the operator to monitor the status of a system. Deciding on the applicable type of display is one of the most important decisions a designer can make and this must be part of the task analysis process. It is commonly assumed that a display is a device relating to sight, but in practice displays can make use of auditory, tactile and smell senses. Visual displays are, however, favoured and therefore sometimes over-emphasised in system design.

The cardinal principle in the design of visual displays is to establish precisely what information the user requires in his task and to display no more or no less in a form which is visible, legible and intelligible. The nature and design of displays should ensure unambiguous perception.

The nature and number of displays should be compatible with the characteristics of the information. General guiding principles concerning the design of displays include:

- “Importance” principle: the most important and emergency displays should be placed in the primary vision area
- Frequency of use: frequently-used displays should be placed in the primary area
- Grouping: related displays should be grouped together. Borders could be used to emphasize grouping
- Sequence of use: displays should be placed in sequence of use
- Intelligibility: the information displayed must be clearly understandable
- Legibility: it must be easy to read the display
- Visibility: account should be taken of the visual angle, size, contrast and prominence
- Unambiguity: displays should not be confusing. Rate and direction of change of display of information must be compatible with the rate and direction of change of the primary source of that information
- Expectancy: displays must operate according to the common expectations of the user population. For example, a red display is generally associated with a danger situation
- Type: digital or analogue. Analogue is generally used to check the status of a system, while a digital display gives very precise information
- Coding: light, colour and symbols must be done in such a manner that all users will interpret the information in the same way
- Information processing: too much information or information displayed too fast may overload the operator
- Auditory displays: must be limited and clearly different to avoid any confusion. They must also be at a sound level and frequency clearly audible above background noises

11.5.4 General guiding principles with regard to control design

Controls are human-machine interface devices that allow an operator to change the status of a system. Examples are steering wheels, hand wheels, cranks, levers, push buttons, joysticks and switches. Controls are usually used in conjunction with displays, the latter allowing the operator to see and regulate the amount of change he has activated.

General guiding principles regarding controls (ISO 6385-1981) include:

- Controls should be selected, designed and laid out in such a way as to be compatible with the characteristics (particularly of movement) of that part of the body by which they are operated
- Type, design and layout of controls should correspond to the control task, taking into account human characteristics, including learned and innate responses
- Travel of controls and control resistance should be selected on the basis of the control task and of biomechanical and anthropometrical data
- Control movement, equipment response, and display information should be mutually compatible.
• Function of the controls should be easily identifiable to avoid confusion
• Where controls are numerous they should be laid out so as to ensure safe, unambiguous and quick operation. Critical controls should be visually and tactiley identifiable
• Critical controls should be safeguarded against inadvertent operation

11.5.5 Display and control integration

Controls and displays are the means by which people operate machinery. In difficult circumstances such as underground, poor control and display design could lead to hazardous operation. The integration of the control with its specific display needs careful consideration to ensure that no errors of observation and/or interpretation occur. The most important considerations in this respect are:

• Control-display compatibility: The direction of movement on the display should be compatible with the movement on the control. This movement should also conform to the common expectations of the particular user population
• Control-display movement ratio: Describes how much a control must be moved to adjust a display. No fixed relationship exists and is dependent on the task requirements. For accuracy, a relatively high number of rotations on a control is needed for a small amount of change in the display, e.g. searching for frequency on a radio
• Control-display layouts: Two aspects should be considered here. The first is that the organisation of the control-display must be such that it is obvious which control belongs to which display. Secondly, labels must be placed to be clearly associated with their respective controls. The usual approach is to place them above the controls. This ensures that the hand does not cover labels once the hand is on the control

11.6 Shiftwork and related issues

11.6.1 Shiftwork and extended work hours

The term “shift” is defined as the hours of the day that a worker is required to be in the workplace. Workers may have permanent hours, with their shift at the same time every work day. Many workers have rotating hours, with the time of day of the work changing in a scheduled way. Some workers are employed to work irregular hours, with shift starting times and/or durations varying in an erratic or unpredictable way.

The problems that shift workers experience relate to both the phase-displacement of their work-sleep periods and adverse negative working conditions that may be combined with shift work. The effects of phase-displacement lead to disruption in the physiological “circadian” rhythms. Circadian rhythms occur in many physiological functions, such as body temperature, blood pressure, heart rate, hormones, etc., as well as in cerebral functions. Research has shown that it is generally difficult to make quick and large changes in the timing of the biological clock, i.e. in circadian variation.

Shift workers who are chronically exposed to night or rotating shift work have biological, social and cultural problems. In the long run, sleep deprivation, besides having an influence on the de-synchronization of circadian rhythms and on the “shift-lag” syndrome, can cause persistent and severe disturbances of sleep itself, chronic fatigue and psychoneurotic syndromes (such as chronic anxiety and depression), which often require treatment with hypnotic or psychotropic drugs (Costa, 2001).

Sleep disturbances, chronic fatigue and oscillatory fluctuations of vigilance and performance can also be important contributing factors to “human error” and the accidents that result. Moreover, sleepiness or fatigue due to a too-early starting hour on morning shifts, or in the case of prolonged duty periods, can also favour higher frequencies of errors and accidents during day shifts (Costa, 2001).

Long-term exposure to shift work or extended hours may have deleterious effects on the health of individuals. Evidence from studies of shift work indicate a higher incidence of gastrointestinal
disorders (peptic ulcers, heartburn, nausea), cardiovascular disease (palpitations, hypertension) and complaints associated with stress such as anxiety and depression, for example.

Work-related fatigue may arise in situations requiring concentration for extended periods during work hours, performing strenuous physical work (especially in unnatural body postures), working in temperature extremes, working in noisy environments or being exposed to vibration (hand-arm or whole body vibration). Fatigue is a functional state which in one direction grades into sleep, and in the opposite direction grades into a relaxed, restful condition. People with practical concerns prefer a more operational definition such as “fatigue is a state of declining alertness which eventually ends in sleep”.

In a fatigued condition workers feel tiredness or dullness in their bodily parts, are inhibited from doing work and are forced to give up. Generally, sensation manifests itself in three ways: sensation of bodily drowsiness, sensation of weakened cognitive processes and motivation, and physical complaints.

11.6.2 Design of shift systems

Scheduling the work of employees to eliminate or minimise the potential health and safety risks is a complex issue. Because there are no “optimal shift systems”, a reasonable compromise must be found between workers’ needs and business demands. Many guidelines are available to assist with the design of shift systems. Examples are the Night Work Convention (No 171) adopted by the International Labour Organization, and publications by Knauth (1993 and 1997) and Kielblock (1995).

Some useful suggestions for shift pattern design are the following:

- Clockwise (forward) rotation (morning to afternoon to night) is preferable to counter clockwise (afternoon-morning-night) rotation
- Minimise the occasions on which employees are required to work more than 10 hours in a period.
- Minimise the use of nightshifts
- Minimise consecutive night shifts (only 1-3 night shifts in succession where possible) in order to limit reductions in performance levels caused by circadian disruption, fatigue and reduced alertness
- Continuous night work without rotation should be avoided
- Avoid rapid shift changes such that at least a 24 hour break is provided before rotating to a new shift
- Ensure employees have regular time (at least 24 hours) free of work in a 7-day period

Workers’ fitness for shift- and nightwork should be evaluated by occupational health physicians before assignment, at regular intervals, and in the case of health problems. It appears reasonable to consider exemption from nightwork for people suffering from severe disorders that can be either directly related to shift- and nightwork, or can be worsened by irregular working hours because of their interference with sleep, diet or drug treatment. Examples of such conditions are: clinical sleep disorders, severe gastrointestinal diseases, ischaemic heart disease and severe hypertension, insulin-dependent diabetes, severe nervous disorders and women in pregnancy (Costa, 2001).

11.6.3 Fatigue and sleep disorders

Closely associated with shift work are sleep disorders and fatigue. These factors are closely linked in the human physiological and psychological systems. Fatigue is often the reason given for human physical and mental performance not being at the required level. Many industrial, vehicle and other accidents are attributed to operator fatigue.

Human fatigue refers to two sets of conditions. One is exhaustion as found after a day’s physically demanding work and the other is a psychological experience of mental fatigue. This latter condition is not only due to mentally demanding work but can also be the result of boredom and/or sleep deprivation.
Fatigue, especially mental fatigue, is a complex phenomenon deeply imbedded in the neuro-physiological system of the human and not yet fully understood. In medical terms it is not a distinct entity. It refers, generally speaking to a group of phenomena associated with impairment, or loss of efficiency and skill, and the development of anxiety, frustration or boredom. In common usage, it is not unlike the word ‘unconscious’ which has become a convenient category used to classify certain phenomena that are not clearly understood, yet are none the less real.

The kind of fatigue caused by hard muscular work is termed “acute fatigue”. This results in a loss of efficiency, which is temporary and is overcome by rest. Chronic fatigue, which will not improve by rest or sleep, is largely a psychological problem characterized by boredom, loss of initiative and progressive anxiety. One of the explanations of this condition, is an outcome of conflict and frustration within the individual.

The intricate relationship between the human physiological homeostasis, neuro-hormone balances, sleep deprivation and fatigue unfortunately has not yet been explained. In an unpublished research project it was found that levels of a neuro-hormone “melatonin” in subjects display a positive correlation with accident tendencies on mines. The production of melatonin is affected by sleep deprivation and to control or prevent fatigue an adequate, not excessive, amount of sleep is necessary per day. One of the disadvantages of shift work is that workers do not have adequate sleep and chronic fatigue could result.

Shift work, fatigue, sleep disorders and neuro-hormone dysfunctions and their role in accident causation is an area that requires further research especially in the mining industry where shift work is commonplace.

11.7 Ergonomics risk assessment

11.7.1 Risk assessment process

Risk assessment is part of the proactive occupational health and safety planning approach that emphasises prevention. Generally the following steps are necessary to carry out a risk assessment:

- Identify hazards
- Estimate the risk from each hazard, e.g. the likelihood and severity of harm
- Decide if the risk is tolerable, and
- Prepare risk control action plans (if necessary)

The methodology of risk management (including risk assessment) is well-documented and addressed in this Handbook. A practical guide to the risk assessment process is available from SIMRAC, while the Australian/New Zealand Standard on risk management (AS/NZS 4360:1999) also deals with the subject in detail.

As most of the physical and biological hazards are covered elsewhere in this Handbook, this section addresses occupational surveillance, as a form of hazard identification, as it relates to the practice of Industrial Ergonomics and the prevention of musculoskeletal disorders.

Surveillance is a “continuous analysis, interpretation, and feedback of systematically collected data, generally using methods distinguished by their practicality, uniformity, and frequently their rapidity, rather than by their accuracy or completeness”. Occupational surveillance provides the data needed to identify, control, and prevent work-related injuries and illnesses.

Effective occupational surveillance systems include the following components: data collection, analysis of the data (i.e. to evaluate their meaning), and some action or response to ensure that surveillance activities are translated into preventive action.

Many surveillance programmes begin with efforts to document the number of work-related musculoskeletal disorders that have occurred in recent history (i.e. establish a baseline). Data can be obtained from a review of existing medical records. If existing records are incomplete or unreliable, questionnaires or worker surveys may be used to determine how many workers are experiencing
symptoms potentially caused by work activities. Additionally, because prevention depends on identification and elimination of hazardous working conditions, hazard surveys may be used to identify jobs at risk.

Worker surveys may be oral (i.e. administered by an interviewer) or written; and they may rely heavily on pictures or charts. Examples of worker surveys include the “body part discomfort scale” (Corlett and Bishop, 1976), the Nordic Musculoskeletal Questionnaire, and the computerised “discomfort assessment system” (Saldana et al., 1994). Common features of surveys include the use of body part diagrams where workers can indicate the location of symptoms, questions about the onset and duration of symptoms and the nature of job activities, and the use of rating scales to indicate severity of pain or discomfort. Worker surveys should be conducted when there is evidence from any data source of increased musculoskeletal injury, or at the commencement of new jobs or tasks.

Ideally, actions to prevent ergonomics-related hazards should proceed before injuries and/or symptoms develop.

The first step in a hazard survey is to establish whether functional job descriptions are available. A functional job description typically identifies essential functions, or fundamental job duties, and the physical and mental abilities needed to perform these functions. If functional job descriptions are available, they can provide useful information for identifying potentially stressful jobs or jobs requiring unique skills or special endurance.

The next step in the identification of ergonomic risk factors in the workplace is a walk-through survey. Investigators observe job activities to detect obvious risk factors, interview workers and supervisors to obtain job information not apparent from observation, and use checklists to score job features against a listing of risk factors.

Examples of checklists that might be used for ergonomic hazard identification are a generic checklist compiled by the Occupational Safety and Health Administration of the Department of Labour in the United Sates of America (http://www.osha.gov/), and the NIOSH checklist for qualitative assessment of lifting hazards. An example of a checklist for use in the mining industry is given in Appendix 11.1.

Hazard surveys should be conducted whenever a job, task or process is changed substantially, when new jobs are introduced, and periodically (especially after new cases of musculoskeletal disorders are reported) to detect whether trends exist across jobs that use similar equipment, tools or processes.

11.8 Computer work environments

Pain in the neck and shoulder muscles due to a forward bent neck is a problem that is manifesting itself more regularly. Computer keyboard users that cannot touch-type are experiencing severe neck pain and headaches. These are due to the extended manner in which the neck has to be craned to identify the keyboard keys. This is often aggravated by the head being tilted upwards for the eyes to focus on the visual display unit of the computer. It is erroneously believed that a computer screen should be read with the line of sight horizontal. This requires a backwards arching of the neck, especially with a computer user with bifocal spectacles. The ideal height for the computer screen is a viewing angle of 10 to 15 degrees downwards from the horizontal line of sight.

ISO 9241 provides extensive information on human-computer interaction including task design, hardware (screens, input devices), software and the work environment.

11.8.1 Fitting the task to the human and fitting the human to the task paradigms

The ergonomics approach is to fit the task to the human. However, it is not always possible to design all workplaces or systems to fit all possible users and pose no ergonomic risks for them. There are situations where particular work conditions or circumstances require workers with special skills or abilities and in this case a psychologist and/ or physiologist may be required to fit the human to the task.

On the psychological side, knowledge is drawn from the behavioural sciences to select those workers who need to possess certain traits and mental skills in order to perform specific tasks. The special
skills for selection as a test pilot or astronaut are generally well-known and, in the same vein, not all people are suited nor psychologically equipped to do underground mine work, to be a member of a mine proto-team or to be a member of a shaft-sinking group. In the same context but from an anatomical and physiological point of view, aircraft fighter pilots are selected for their special mental skills and physical abilities. This is a typical example of fitting the human to the task.

The South African Mining Industry has been and is still conducting research on selecting and acclimatising workers to be able to withstand the harsh (e.g. hot) environment of underground mining. This process is also fitting the human to the task.

11.8.2 Operator job specification

Through a task analysis the characteristics needed in individuals to perform tasks successfully may be identified. These should be recorded as an “Operator Job Specification” (also known as a “Man specification”). This document, if properly designed, will give valuable information on the educational, training, mental and physical requirements the task requires from the worker. Such documents are of particular use for occupational health practitioners responsible for pre-employment and pre-placement medical examinations.

11.9 Implementing an ergonomics programme

A strategy to implement ergonomics in the mining industry was developed as part of the SIMRAC research programme (De Koker and Schutte, 1999). The strategy involves four groups of role players, namely the State, Employers, Employees and Manufacturers/Suppliers of mining equipment, on the basis of participatory ergonomics. The specific involvement proposed for role players entails reviewing of existing legislation addressing ergonomics and the drafting of an ergonomics implementation plan in the case of the State, the establishment of formal ergonomics programmes on mines by employers, the active participation and involvement in the ergonomics programmes by employees, and the use of ergonomics design guidelines and specifications suitable for the local user population and mining conditions ("cultural and environmental calibration") by Manufacturers/Suppliers of mining equipment.

A comprehensive and well thought-out ergonomics programme is part of modern organisational and management practice in many industrial settings. The introduction of ergonomics programmes in various industries has proved to be instrumental in increasing worker comfort, safety and health. From a business viewpoint a corporate ergonomics programme also makes a great deal of sense.

Hendrikse (1994) suggests the following steps for the development and implementation of an ergonomics programme (Figure 11.3):

• Define the programme goals, priorities and objectives. Also define the budgets, resources and limitations
• Select a qualified ergonomics resource in order to achieve the programme goals and objectives.
• Conduct a professional ergonomics assessment to identify priority problem areas
• Utilise the ergonomics resource to train supervisors, safety personnel and engineers in the principles of ergonomics
• The ergonomics consultant should, together with safety personnel and engineers, conduct systematic workplace assessments
• Develop and implement practical and cost-effective engineering solutions where possible or plan other preventative activities, e.g. adjustment of procedures
• Evaluate the programme, as well as the impact of the changes implemented. Conduct a cost/benefit analysis of the solutions
• Refine the solutions on an ongoing basis
The key ingredients of any successful ergonomics programme are top management commitment and the support of people from all other levels in the organisation. Top management must approve and support such a programme and it should be part of an organisation’s mission. The active involvement of employees on all levels must be accomplished during each phase of the programme. This concept of participatory ergonomics, which can be defined as “the involvement of people in planning and controlling a significant amount of their own work activities, with sufficient knowledge and power to influence both processes and outcomes in order to achieve desirable goals” (Wilson, 1994), has proved to be very successful to introduce ergonomics in industrial settings. It is, therefore, recommended that the same approach be followed at mines.

11.10 Conclusion and recommendations

The South African mining environment, especially underground, presents the designers and manufacturers of mining equipment with unique challenges. As mining equipment grows in sophistication, it is imperative to incorporate ergonomic principles in its design from the conceptual phase. This approach, is not only a legal requirement, but will facilitate efficiency and effectiveness of operation and maintenance of the equipment.

Ergonomics is a discipline that spans a wide field. Considering the variety of jobs in the different mining environments in South Africa, there are no specific guidelines to counter all the
ergonomics-related hazards that exist. However, the introduction of sound ergonomics principles in 
mining will enhance human performance reliability, with a concomitant reduction in health and safety 
risks.

For the successful integration of ergonomics into the South African mining industry, which is still 
labour intensive, the application of ergonomic programmes and the development of guidelines under 
the auspices of the Mine Health and Safety Act are of paramount importance.

11.11 Guide to information resources


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Safety and Health.


Appendix 11.1 Ergonomics checklist

The screening for risk factors for work-related musculoskeletal disorders should involve the following:

- Walk-through observational surveys of the work facilities using the Ergonomics Risk Checklist to identify risk factors
- Interviews with workers and supervisors to obtain information and other data not so apparent during the walk-through survey
- Task analysis and measurements in the workplace (to be conducted by suitably qualified ergonomists)

1. Ergonomics Risk Checklist

A “yes” response indicates that an ergonomic risk factor may be present which requires further investigation.

**Manual Material Handling**

- Is there lifting of loads, tools, mining equipment?
- Is there lowering of loads, tools, mining equipment?
- Is there overhead reaching for loads, tools, mining equipment?
- Is there bending at waist to handle loads, tools, mining equipment?
- Is there twisting at the waist to handle loads, tools, mining equipment?

**Physical Energy Demands**

- Do tools and mining equipment used weigh more than 5 kg?
- Is reaching more than 55 cm?
- Is bending, stooping, or squatting a primary task activity?
- Is lifting or lowering loads a primary task activity?
- Is walking or carrying loads a primary task activity?
- Is stair or ladder climbing with loads a primary task activity?
- Is lifting or lowering loads a primary task activity?
- Is pushing or pulling of loads a primary task activity?
- Is reaching overhead a primary task activity?
- Is operating equipment or tools above shoulder height a primary task activity?
- Is shovelling a primary task activity?
- Is barring a primary task activity?

**Other Musculoskeletal Demands**

- Do manual tasks require frequent, repetitive motions?
- Do work postures require frequent bending of neck, shoulder, elbow, wrist or finger joints?
- Does worker kneel (one or both knees)?
- Is the worker unable to change body position often?
- Does the work involve forceful, quick, or sudden motions?
- Is finger-pinch gripping used?
- Do job postures involve sustained muscle contraction of any limb?
- Does worker stand continuously for periods of more than 30 min?

**Environment**

- Is the temperature too hot or too cold?
- Is the workplace poorly lit?
- Is there glare?
- Is it a noisy environment?
- Is the worker working with vibrating hand tools or equipment?
- Is the worker subjected to whole-body vibration?
**General Workplace**

- Are the walkways uneven?
- Is the floor surface free of obstacles and flat?
- Is the workplace at a gradient?
- Is the ceiling height less than 2.5 m?
- Is there inadequate clearance or accessibility to perform the task?
- Is housekeeping poor?

**2. Methodology for task and workplace analyses**

The assessment of tasks and workplaces to identify potential risk factors that contribute to the development of musculoskeletal disorders should be based on the following:

- Workstation measurements (e.g. working surface heights; reach distances, ceiling heights, gradient)
- Observing the workers performing tasks (time-activity analysis)
- Measuring of environmental factors such as temperature, noise, illumination levels (Relevant ISO and South African standards can be used to assess environmental factors)
- Determination of physical energy demands
- Evaluation of manual material handling tasks (NIOSH Work Practice Guide to Manual Lifting can be used to determine recommended weight limits)
- Questionnaire to determine the amount of perceived exertion (Modified Borg Scale)

**Appendix 11.2 Ergonomics in the Mine Health and Safety Act (Act No. 29 of 1996)**

**Section 21: Manufacturer’s and supplier’s duty for health and safety**

21.(1) Any person who —

(a) designs, manufactures, repairs, imports or supplies any article for use at a mine must ensure, as far as reasonably practicable —

(i) that the article is safe and without risk to health and safety when used properly; and

(ii) that it complies with all the requirements in terms of this Act;

(b) erects or installs any article for use at a mine must ensure, as far as reasonably practicable, that nothing about the manner in which it is erected or installed makes it unsafe or creates a risk to health and safety when used properly; or

(c) designs, manufactures, erects or installs any article for use at a mine must ensure, as far as reasonably practicable, that ergonomic principles are considered and implemented during design, manufacture, erection or installation.

(2) Any person who bears a duty in terms of subsection (1) is relieved of that duty to the extent that it is reasonable in the circumstances, if —

(a) that person designs, manufactures, repairs, imports or supplies an article for or to another person; and

(b) that other person provides a written undertaking to take specified steps sufficient to ensure, as far as reasonably practicable, that the article will be safe and without risk to health and safety when used properly and that it complies with all prescribed requirements.

(3) Any person who designs or constructs a building or structure, including a temporary structure, for use at a mine must ensure, as far as reasonably practicable, that the design or construction is safe and without risk to health and safety when used properly.
(4) Every person who manufactures, imports or supplies any hazardous *substance* for use at a *mine* must —

(a) ensure, as far as *reasonably practicable*, that the *substance* is safe and without *risk to health and safety* when used, handled, processed, stored or transported at a *mine* in accordance with the information provided in terms of paragraph (b);

(b) provide adequate information about —

(i) the use of the *substance*;

(ii) the *risks to health and safety* associated with the *substance*;

(iii) any restriction or control on the use, transport and storage of the *substance*, including but not limited to exposure limits;

(iv) the *safety precautions* to ensure that the *substance* is without *risk to health or safety*;

(v) the procedure to be followed in the case of an accident involving excessive exposure to the *substance*, or any other emergency involving the *substance*; and

(vi) the disposal of used containers in which the *substance* has been stored and any waste involving the *substance*; and

(c) ensure that the information provided in terms of paragraph (b) complies with the provisions of the Hazardous Substances Act, 1973 (Act No. 15 of 1973).
It is not widely appreciated that diving is a primary hazard in the offshore diamond mining industry. This chapter identifies diving hazards and details their physiological and pathological effects. The prevention of diving-related problems and their management and treatment are addressed succinctly. A list of references is provided to assist the interested reader in identifying sources of further information.

Dr A. Kayle
Medical Practitioner

Allan Kayle is an internationally recognised authority in diving-medicine and related activities. He has published extensively in his field of expertise.
Glossary

**ACOP:** Approved Code of Practice

**Acute Decompression Illness (ADI):** acute inert gas tissue bubble formation or arterial gas embolism (AGE) resulting in post dive illness

**Alluvial:** relating to soil washed from one place and deposited elsewhere by flowing water

**ATA:** atmospheres absolute — an indication of diving depth

**Barotrauma:** pressure-induced injuries associated with diving

**Bell:** metal structure to enable persons to go underwater without being drowned or wetted

**CPR:** cardio-pulmonary resuscitation

**Decompression:** return to normal atmospheric pressure after being submerged for lengthy periods

**Embolism:** a clot

**Hookah:** a specific rudimentary means to supply a diver with air. This method is totally inappropriate and is life threatening in an emergency

**HSC:** (UK) Health and Safety Commission

**HSE:** (UK) Health and Safety Executive

**Hypoxia:** reduced oxygen partial pressure — potentially fatal

**IMCA:** International Marine Contractors Association

**msw:** metres of sea water — an indication of diving depth

**Narcosis:** state of stupor, insensibility or coma
12.1 Introduction

The inshore and offshore diamond mining and petroleum industries expose divers to hazardous working environments. Although numerous legislated safety requirements exist, the primary responsibility for diver safety must ultimately rest with the diving contractor. This requires strict procedural planning, clearly defined company operating manuals and meticulous attention to detail by working divers. Any temptation by the contractor to reduce costs by providing sub-optimal safety conditions, insufficient numbers of trained personnel or inadequate equipment and maintenance is unacceptable.

Ocean floor alluvial diamond mining involves gravel dredging by airlift or bucket line, depending on the character of the gravel, seawater depth and diving technology and training. Airlift dredging equipment vacuums the sea bottom gravel to the surface processing plant and exposes the diver to zero visibility, moving underwater boulders, entrapment and injury. Depths are usually limited to 28 metres of seawater (msw) using a 200 mm airlift hose.

The offshore petroleum diving industry involves much greater depths and dive times and requires the use of a permanently on-site mother support ship or oil platform, diving bells and deck decompression chambers, helium/oxygen breathing mixes, highly-specialised backup personnel and very advanced technology. In South Africa, the relevant codes of safe practice are as yet rudimentary. Much of the offshore oil work is therefore contracted to giant companies such as Comex utilising internationally recognised diving safety protocols as prescribed, for example, by the British Health and Safety Executive (HSE).

12.2 The legal framework

Safe commercial diving work in South Africa is legislated by two governmental bodies, the Department of Minerals and Energy and the Department of Labour. They co-operate and liaise within the framework of the Council for Diving Work and receive input as required from the Institute for Maritime Medicine, the South African Bureau of Standards and several diving companies and authorities. Both bodies are currently upgrading their safety legislation in line with approved international standards.

The Department of Labour (The Occupational Health and Safety Act and its extension to the Diving Regulations 1991) has controls involving:

- Training of divers
- Designated medical examiners and medical certificates of fitness
- Diving supervisor
- Operations manual
- Control of diving operations
- Decompression
- Compression chambers and bell
- Plant and equipment
- Council for Diving Work
- Rules, syllabi and examinations
- Diver registration and applications
- Fees, offences and penalties

These Diving Regulations 1991 are currently being revised for republication in 2001.

The Department of Minerals and Energy (The Mine Health and Safety Act, 1996 — Act 29 of 1996) provides legislation for diver health and safety at work and, like the Department of Labour, appoints health and safety inspectors who investigate accidents, deal with complaints and ensure, by on-site examination, that diving premises and projects meet approved standards.

Any new legislation is proposed by the Council for Diving Work and then enforced by law. Very recently proposed new developments, yet to be promulgated, involve upgraded aspects of:
Diving at work
Health and safety at work
Duties of employers and contractors to employees and members of the public
Duties of employees
Saturation and bell diving regulations in line with HSE, Health and Safety Commission (HSC), International Code of Practice for Offshore Mining (IMCA D014) as provided by the International Marine Contractors Association (IMCA), and Approved Code of Practice (ACOP) for inshore commercial diving work.

The South African Bureau of Standards specifies standards relating to the design, construction and testing of air cylinders and containers (SABS 019). Specifications regarding diver breathing equipment are provided by their reference BS EN 250. The SABS is currently involved in an upgraded draft, South African Standards (DSS), encompassing gas cylinder design, construction and testing to international standards.

12.3 Identification of diving hazards

There is a very wide spectrum of diving hazards which can result in an even wider range of possible diver morbidity or mortality. The three commonest hazards by far — difficulty in middle ear equalising on descent, external ear canal infections and fungal skin infections — affect virtually all divers at one time or another but are invariably relatively minor and readily treated. Details of most commercial diving fatality statistics are extremely poor internationally. Most database records have not been maintained or are non-existent. Only in the North Sea have commercial diving fatalities been reported to a central agency allowing very approximate international figures to be derived by the UK Department of Energy. The trend in international diving mortality rates now appears to approximate those in the construction industry or better. It would appear that the increased regulation controlling diving operations has contributed to improved safety, but probably this is not the only factor.

Aside from the three common diving problems, all other hazards are potentially far more threatening in terms of life or functional loss but are very much less common. The incidence of reported acute decompression illness per 1000 divers in the South African diamond mining sector between 1988 and 1997 is shown in Table 12.1.

Table 12.1 Annual incidence rate of acute decompression illness per 1000 SA divers (actual numbers in brackets)

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Injury</td>
<td>0.16  (3)</td>
<td>0.05  (1)</td>
<td>0</td>
<td>0.14  (3)</td>
<td>0.11  (2)</td>
<td>0.28  (4)</td>
<td>0.99  (15)</td>
<td>1.71  (26)</td>
<td>0.65  (10)</td>
<td>0.14  (2)</td>
</tr>
<tr>
<td>Fatality</td>
<td>0.05  (1)</td>
<td>0.05  (1)</td>
<td>0.07  (1)</td>
<td>0.07  (1)</td>
<td>0.07  (1)</td>
<td>0.07  (1)</td>
<td>0.07  (1)</td>
<td>0.07  (1)</td>
<td>0.07  (1)</td>
<td>0.07  (1)</td>
</tr>
</tbody>
</table>

Particulars of the hazards encountered by divers are listed in Table 12.2
### Table 12.2 Diving hazards

<table>
<thead>
<tr>
<th>Causes</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure-induced injuries in gas-filled body and equipment spaces</td>
<td>Pulmonary barotrauma of descent</td>
</tr>
<tr>
<td>(barotrauma)</td>
<td>Pulmonary barotrauma of ascent</td>
</tr>
<tr>
<td></td>
<td>– arterial gas embolism</td>
</tr>
<tr>
<td></td>
<td>– pneumothorax</td>
</tr>
<tr>
<td></td>
<td>– mediastinal emphysema</td>
</tr>
<tr>
<td></td>
<td>– interstitial lung tissue damage</td>
</tr>
<tr>
<td>Middle ear barotrauma of descent and ascent</td>
<td></td>
</tr>
<tr>
<td>Inner ear barotrauma of descent</td>
<td></td>
</tr>
<tr>
<td>Mask/helmet barotrauma of descent</td>
<td></td>
</tr>
<tr>
<td>Sinus barotrauma of decent and ascent</td>
<td></td>
</tr>
<tr>
<td>Gut barotrauma of ascent</td>
<td></td>
</tr>
<tr>
<td>Dive suit barotrauma of descent and ascent</td>
<td></td>
</tr>
<tr>
<td>Decreased tissue solubilities of inert gases at decreased pressures</td>
<td>Acute decompression illness</td>
</tr>
<tr>
<td>Hypoxia</td>
<td>Deficiency of adequate oxygen partial pressure in the breathing mix</td>
</tr>
<tr>
<td>Toxic effects of inhaled and metabolic gases at increased partial</td>
<td>Oxygen toxicity</td>
</tr>
<tr>
<td>pressures</td>
<td>Carbon dioxide toxicity</td>
</tr>
<tr>
<td></td>
<td>Carbon monoxide toxicity</td>
</tr>
<tr>
<td></td>
<td>Nitrogen narcosis</td>
</tr>
<tr>
<td></td>
<td>High pressure neurological syndrome (HPNS) with helium or hydrogen</td>
</tr>
<tr>
<td>Equipment risks</td>
<td>Hookah</td>
</tr>
<tr>
<td></td>
<td>Inadequate or absent life/communication line or harness</td>
</tr>
<tr>
<td></td>
<td>Airlift dredge</td>
</tr>
<tr>
<td></td>
<td>Airlift suction nozzle</td>
</tr>
<tr>
<td></td>
<td>Tools — air grinder, Cox gun, Broco torch, pneumatic drill and chisel,</td>
</tr>
<tr>
<td></td>
<td>welding machine</td>
</tr>
<tr>
<td></td>
<td>Incorrect tools</td>
</tr>
<tr>
<td></td>
<td>Explosives</td>
</tr>
<tr>
<td></td>
<td>Electrical — surface supplied, battery or live anodes</td>
</tr>
<tr>
<td>Environmental hazards</td>
<td>Zero visibility during dredging</td>
</tr>
<tr>
<td></td>
<td>Entrapment by kelp, moving rocks, engine cooler intake or shipwrecks</td>
</tr>
<tr>
<td></td>
<td>Collision with ship hull and propellers</td>
</tr>
<tr>
<td></td>
<td>Marine animals</td>
</tr>
<tr>
<td>Chronic ailments</td>
<td>External ear canal infections</td>
</tr>
<tr>
<td></td>
<td>Skin infections</td>
</tr>
<tr>
<td></td>
<td>Joint problems — dysbaric osteonecrosis</td>
</tr>
</tbody>
</table>

#### 12.4 Prevention of diving hazards

Several factors are essential in minimising diver morbidity and mortality. These are diver fitness, safe diving practice, emergency medical support, and skilled surface reaction, rescue and resuscitation in an emergency.

##### 12.4.1 Diver fitness

The first prerequisite is that the diver is fit to dive. An annual diving medical by an approved diving physician is mandatory, as is a medical after any illness or injury that bars diving. The objective of the medical is to assess diver fitness and any impairment or disability.
12.4.2 Safe diving practice

Avoidance and management of the vast majority of diving hazards depend almost totally on meticulous safe diving practice in terms of training, dive planning, equipment, communications, expert supervision, emergency medical backup and fully-kitted and ready standby divers. An alpha dive flag, indicating the presence of submerged divers, should always be flown at the dive site to alert passing boats that dive work is in progress. In shallow water, diving must only be done at high tide to obviate diver injury by the boat hull at low tide. All diving operations must have an adequate medical oxygen supply immediately available and pre-fitted with a pressure-reduction valve and face mask preferably equipped with a demand valve to ensure 100 per cent oxygen delivery.

Especially hazardous, but still in common use, is the hookah. This form of air supply can only be condemned. Failure means immediate cessation of the life support air supply and instantly forces the diver to abandon any work and commence an emergency free ascent to the surface, foregoing any possible decompression requirements and running the risk of pulmonary barotrauma, arterial gas embolism and acute decompression illness.

12.4.3 Emergency medical support

The names and telephone numbers of the particular designated emergency advanced medical support team should be permanently fixed in clear view and in transparent weatherproof material at the surface site telephone or radio. These details must never be placed in a drawer or other hidden place. It is also essential that the medical support personnel be informed in advance that diving work will be commencing. The exact dive site and nearest roads and landing strip must be clearly described. This will enable site planning in advance by the rescue team and facilitate the decision to rescue by land, boat, helicopter or fixed wing aircraft.

12.4.4 Reaction, rescue and resuscitation

In order to ensure an effective surface reaction in an emergency it is absolutely essential that communication between the diver and support crew is reliable, that emergency underwater assistance can be provided at a moment’s notice and that effective primary first aid is immediately available. Without these, a diver, with poor or zero visibility and trapped by kelp, wreckage or moving underwater rocks, or injured by electrical, explosive, equipment or tool accidents, will either drown or may die at the surface due to inadequate aid.

12.5 Management of diving illnesses

12.5.1 Acute decompression illness and pulmonary barotrauma

The old term Decompression Sickness (DCS) which was divided into Type 1 and Type 2 DCS has been abandoned in favour of Acute Decompression Illness (DCI) which now includes both inert gas (nitrogen or helium) tissue bubble formation and Arterial Gas Embolism (AGE) following pressure/volume-related lung tearing. DCI may occur immediately postdive or be delayed for more than 24 hours. Predisposing factors for these conditions are listed in Table 12.3.

If any of the additional signs and symptoms also present soon after diving, the diver must be considered to have sustained a lung-tearing injury during ascent:

- Chest pain
- Breathlessness
- Bloody sputum
- Hoarseness
- Cough

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Table 12.3 Predisposing factors for DCI and AGE

<table>
<thead>
<tr>
<th>Predisposing factors for inert gas bubble formation (DCI)</th>
<th>Predisposing factors for arterial gas embolism (AGE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Missed decompression stops or incomplete decompression</td>
<td>Breathholding during ascent due to:</td>
</tr>
<tr>
<td>Bounce diving using a surface recompression chamber</td>
<td>Panic</td>
</tr>
<tr>
<td>Repetitive dives</td>
<td>Free ascents</td>
</tr>
<tr>
<td>Exposure to heat postdive</td>
<td>Skip breathing during ascent</td>
</tr>
<tr>
<td>Excessive exercise postdive</td>
<td>Unco-ordinated buddy breathing during ascent</td>
</tr>
<tr>
<td>Exposure to cold predive and during diving</td>
<td>Aborted ditch and recovery training</td>
</tr>
<tr>
<td>Increased age</td>
<td>Apparatus difficulties causing a higher than normal</td>
</tr>
<tr>
<td>Obesity</td>
<td>demand valve delivery pressure</td>
</tr>
<tr>
<td>Increased carbon dioxide</td>
<td>Water, foreign body or vomit inhalation</td>
</tr>
<tr>
<td>Alcohol excess</td>
<td>Laryngospasm</td>
</tr>
<tr>
<td>Rapid ascents</td>
<td>Lung disorders, e.g. asthma, respiratory infections</td>
</tr>
<tr>
<td>Physical injury</td>
<td></td>
</tr>
<tr>
<td>Altitude postdive</td>
<td></td>
</tr>
<tr>
<td>Prolonged limb flexion postdive</td>
<td></td>
</tr>
<tr>
<td>Previous decompression illness</td>
<td></td>
</tr>
<tr>
<td>Patent foramen ovale</td>
<td></td>
</tr>
</tbody>
</table>

12.5.1.1 Presentation of acute decompression illness

1. Joint or limb pain
2. Changes in higher brain function — personality changes, confusion to coma
3. Sensory changes involving vision, hearing, touch, taste or smell
4. Motor changes — weakness, incoordination, loss of balance, paralysis
5. Other — e.g. rash, restlessness, loss of appetite, undue fatigue, chest pain, breathlessness, cough, coughing blood, vomiting, headache, abdominal or back pain.

Table 12.4 Treatment of acute decompression illness and pulmonary barotrauma

Act now! Do not wait for things to worsen
Contact a dive physician or emergency diver rescue service as well as the nearest recompression facility (Appendix 12.2)

Administer continuous 100% oxygen preferably via a demand valve or else a face mask. Do not be concerned about possible oxygen toxicity breathing pure surface oxygen for a few hours.

<table>
<thead>
<tr>
<th>Diver conscious</th>
<th>Diver unconscious</th>
</tr>
</thead>
<tbody>
<tr>
<td>Place flat on the back</td>
<td>Place in the left lateral rescue position</td>
</tr>
<tr>
<td>Keep calm and reassure</td>
<td>Monitor breathing and carotid pulse</td>
</tr>
<tr>
<td>Give 500 ml water then 150 ml per hour</td>
<td>Assess coma every 15 minutes on the Glasgow scale — full consciousness scores 15; very deep coma scores 3 (Appendix 12.1)</td>
</tr>
<tr>
<td>Give 1000 mg Vitamin C tablet</td>
<td>Be ready for rescue breathing or CPR</td>
</tr>
<tr>
<td>Give 10 mg Valium tablet if diver very agitated</td>
<td>Set up a Ringer’s lactate drip at 60 drops per minute</td>
</tr>
<tr>
<td>Transport flat on the back to a recompression facility or bring a one-man chamber to the diver</td>
<td>Transport in the left lateral rescue position to a recompression facility</td>
</tr>
<tr>
<td>If air transport is essential it must be pressurised or very low flying. Reduction of atmospheric pressure will worsen the diver.</td>
<td></td>
</tr>
</tbody>
</table>

If a pneumothorax occurs, a pneumothorax must first be drained by a doctor prior to recompression.

Do not recompress a suspected pneumothorax! A life-threatening tension pneumothorax may occur. A pneumothorax must first be drained by a doctor prior to recompression.
12.5.1.2 Management of inhaled gas problems

All diving gases are potentially toxic and can kill when their tissue partial pressures are excessive. The conditions are:

- Oxygen toxicity
- Carbon dioxide toxicity
- Carbon monoxide poisoning
- Nitrogen narcosis
- Helium or hydrogen high pressure neurological syndrome (HPNS)
- Only oxygen can kill when its tissue partial pressure is too low. This is hypoxia.

The toxic effects of all these gases as well as hypoxia have much in common (Table 12.5). They all cause abnormal changes in higher cerebral function, the senses and motor activity. This can make recognition of the precise causative gas problem difficult, but the problem can generally be explained by considering four dive conditions:

- Open or closed circuit breathing device
- Free flow or demand system
- Adequacy, availability and composition of the breathing mix
- Dive depth

For example, at a dive depth of 20 msw and using a surface-supplied open circuit demand air supply, nitrogen narcosis, oxygen toxicity and helium toxicity do not come into question. The problem then becomes one of hypoxia, carbon dioxide or carbon monoxide toxicity. Ensuring excellence of compressor filtration and regular air analysis of the compressed air supply will exclude carbon monoxide and dioxide from the air supply. The problem then becomes hypoxia, usually in addition to metabolic carbon dioxide toxicity due to inadequate ventilation.

### Table 12.5 Common features of all diving gas problems

| Changes in higher cerebral function | Irritability, anger, fear, apathy, laughter, irresponsibility, hysteria, hallucinations, stupor, sullenness, uneasiness, illusions, confusion, amnesia, automatism, unconsciousness |
| Changes in the senses | Visual: Blurring, double vision, tunnel vision, blindness, dazzle Auditory: Deafness, ringing in the ears (tinnitus), loss of balance, nausea, vomiting, vertigo Touch: Numbness, itching, pins and needles, burning Taste: Loss of taste or abnormal taste awareness Smell: Loss of smell or abnormal smell awareness |
| Changes in motor activity | Weakness, loss of balance, inco-ordination, tremor, abnormal gait, twitching, paralysis, slurred speech |

In addition to the above common features, the individual gases also have specific effects which may assist in toxicity recognition, but these are unreliably present. The toxic levels vary for each gas and have been provided in Atmospheres Absolute (ATA) in Table 12.6.
### Table 12.6 Specific gas toxicity effects

<table>
<thead>
<tr>
<th>Gas problem</th>
<th>Causes</th>
<th>Special features</th>
<th>Toxic levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypoxia</td>
<td>Breathhold diving, Exhausted air supply, Wrong mix, Low rebreather flow, Inhaled foreign body, vomit or water, Pulmonary barotrauma, Pulmonary DCI (chokes), Circulatory failure — shock, heart failure, Haemorrhage, Hypothermia, Carbon monoxide</td>
<td>Blue lips and tongue — cyanosis, With severe hypoxia, unconsciousness may be sudden</td>
<td>Below 0.1 ATA</td>
</tr>
<tr>
<td>Oxygen toxicity</td>
<td>Pure oxygen rebreathers, High percentage oxygen mixes, Pure oxygen decompression schedules, Oxygen therapeutic tables, Saturation diving</td>
<td>Twitching, Very pale, Vertigo, Vomiting, Convulsions</td>
<td>Above 2 ATA</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>Air supply contamination, Scrubber failure, Poor helmet or chamber ventilation, Breathhold diving, Inhaled foreign body, vomit or water, Dense breathing mix at depth and hard dive work, Tight harnesses and suits limiting ventilation, Circulatory failure aemorrhage, Hypothermia</td>
<td>Rapid deep breathing, Flushing and sweating, Throbbing headache, Depression of breathing with increasing toxicity, Sudden loss of consciousness</td>
<td>Above 0.02 ATA</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>Air pollution, Oil flashing in the air compressor</td>
<td>Cherry red lips, “Healthy” red cheeks</td>
<td>Above 0.001 ATA</td>
</tr>
<tr>
<td>Nitrogen narcosis</td>
<td>Deep dives on air</td>
<td>Over-confidence, Inordinate well-being, Inappropriate action, Impaired memory and concentration, Tunnel vision or blurring, Hallucinations, stupor</td>
<td>Below 50 msw</td>
</tr>
<tr>
<td>High pressure neurological syndrome (HPNS)</td>
<td>Rapid descents using a helium or hydrogen mix</td>
<td>Fine tremors, Dizziness, Impaired consciousness, Stupor, coma</td>
<td>Below 150 msw</td>
</tr>
</tbody>
</table>

12.5.1.3 Treatment of inhaled gas problems

Nitrogen narcosis quickly disappears on ascent from depth. Oxygen toxicity requires an immediate switch to surface or chamber air. HPNS requires an immediate halt in descent and a slower descent rate. Hypoxia, carbon monoxide and carbon dioxide toxicity require the protocol in Table 12.7 if the diver is at the surface.

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Table 12.7 Treatment of hypoxia and carbon dioxide or monoxide toxicity

<table>
<thead>
<tr>
<th>Diver conscious</th>
<th>Diver unconscious</th>
</tr>
</thead>
<tbody>
<tr>
<td>Place flat on the back</td>
<td>Place in the left lateral rescue position</td>
</tr>
<tr>
<td>Keep calm and reassure</td>
<td>Monitor breathing and carotid pulse</td>
</tr>
<tr>
<td>Maintain a 100% oxygen atmosphere preferably via a face mask demand valve.</td>
<td>Assess coma every 15 minutes on the Glasgow scale — full consciousness scores 15; very deep coma scores 3 (Appendix 12.1)</td>
</tr>
</tbody>
</table>

If carbon monoxide poisoning exists or is suspected, transport the diver, breathing continuous 100% oxygen, for emergency hyperbaric oxygen therapy in a chamber.

12.5.2 Management of major trauma

Effective primary treatment of major wounds, whether due to propeller, marine animal, explosive or other trauma, requires emergency control of haemorrhage and shock. This is provided in the protocol in Figure 12.1.

Figure 12.1 Management of major trauma
12.6 Management of marine animal stings

Sea-stingers use one of two methods to envenom their victims. They cause either surface or penetrating stings. Some can be lethal and these all kill by causing respiratory paralysis. The common surface stingers comprise jellyfish, bluebottles and fire coral. The penetrating stingers use barbs or spines and inject venom through the skin into underlying tissues. This group includes cone shells, sea-urchins, crown-of-thorns starfish, stingrays and the various scorpionfish (lion fish, scorpionfish proper, stonefish). Surface stings cause acutely painful rashes or welts while barbs and spines cause penetrating wounds.

12.6.1 Treatment of marine animal stings

In many cases the diver does not know the precise species of stinger involved. Sudden violent pain may be the only clue to having been stung. The primary practical aspect is that all surface stings should be treated with vinegar (10% acetic acid) while all penetrating stings are treated by heat application as described in Table 12.8.

Table 12.8 Treatment of marine animal stings

<table>
<thead>
<tr>
<th>Skin surface stingers</th>
<th>Penetrating stingers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Get the victim out of the water and lay flat on the ground. The diver is in extreme pain!</td>
<td>A wound, with or without spines, is present</td>
</tr>
<tr>
<td>Welts or rashes are present at the sting site</td>
<td></td>
</tr>
<tr>
<td>Pour vinegar liberally over the stings and any pieces of tentacle and wait a few minutes</td>
<td>Irrigate the wound with cold sea water (or saline) while heating fresh water to 50°C</td>
</tr>
<tr>
<td>Scrape off inactivated tentacles with a knife — drying them with powder makes it easier</td>
<td>Immerse the limb in hot water (as hot as bearable without scalding!) for 30-60 min. Add more hot water to maintain temperature</td>
</tr>
<tr>
<td>Apply more vinegar as a cloth-soaked poultice</td>
<td>Wounds on the head and trunk should be treated with hot water compresses for 1 hour</td>
</tr>
</tbody>
</table>

If no rapid improvement occurs summon urgent medical help

Later:
Apply a topical antibiotic/steroid cream
Keep the wound dry
Further diving will aggravate any infection

Later:
Clean and dress the wound properly
Lacerated stingray wounds may need suturing
Broad-spectrum antibiotics should be given

12.7 Management of chronic diver ailments

Commercial divers are especially liable to three chronic ailments:

• otitis externa (swimmer’s ear)
• fungal skin infections
• dysbaric osteonecrosis

12.7.1 Otitis externa

This bacterial infection of the external ear canal is virtually always caused by water-loving bacteria of the *Pseudomonas* species, most commonly *Pseudomonas aeruginosa*. These bacteria are found in all water bodies — lakes, dams and the sea — and are also common contaminants in the moist and humid confines of decompression chambers. Divers are exposed to ear infection in the sea and during decompression chamber schedules. In addition to *Pseudomonas*, a simultaneous fungal infection with *Candida* and *Aspergillus* species often occurs. Inadequate therapy allows the condition to become chronic, often because the usual antibiotics and eardrops commonly used to treat ear infections in non-divers are invariably ineffective in divers. *Pseudomonas* is very resistant to antibiotic therapy with the exception of garamycin and ciprofloxacin.
Cause

Damaging the integrity of the delicate lining of the ear canal allows bacterial access and infection. This commonly follows the use of foreign bodies such as cotton buds, finger nails or other objects to remove earwax. Exposing the injured membrane to contaminated water then results in infection.

Presentation

Earache and sometimes deafness commence within 24-48 hours of diving. There is usually no history of equalising difficulty. Tugging on the earlobe typically aggravates the pain intensely and helps to distinguish otitis externa from other causes of earache.

Prevention

- Do not attempt to remove wax with cotton buds or other foreign bodies
- Instil 5 drops of 5% glacial acetic acid in propylene glycol into each ear after every dive
- Decompression chambers must be dry, clean and well aired when not in use and those used in saturation diving must be thoroughly washed every day with an antiseptic solution such as Panacide

Treatment

- Stop diving until the ear is better
- Consult a doctor — an ear swab should be taken and a culture made
- The use of ciprofloxacin in a dose of 500 mg twice daily for at least 5 days is recommended
- The simultaneous use of ciprofloxacin and hydrocortisone drops (Ciprobay HC Otic) is also recommended
- If a concomitant fungal infection is also present, the use of an anti-fungal agent such as fluconazole (Diflucan), one tablet weekly, is indicated.

12.7.2 Fungal skin infections (see Chapter 13 for diagnosis and management)

Fungal skin infections thrive under humid, sweaty conditions and, within the damp confines of rubber dive suits and boots, conditions are optimal for fungal growth. Infections commonly found in divers are:

- Athlete’s foot
- Dhobie itch
- Tinea versicolor

Athlete’s foot

_Tinea pedis_, or Athlete’s foot is a fungal infection of the feet, commonly between the fourth and fifth toes and on the soles. The skin between the toes becomes dead white (maceration) and grey blisters often appear and spread to the sole of the foot. Peeling or painful cracking of the skin can follow as well as secondary bacterial infection. Sharing of showers and dive boots predisposes to cross-infection.

Dhobie itch

This yeast fungal infection, caused by _Candida_ species, affects the skin in the groins and between the buttocks. It also occurs in other sweaty areas such as the axillae and beneath the breasts. The affected skin has clearly-defined edges, often with nearby satellite rashes, and is reddened, moist and itchy. Bathing in warm water aggravates both redness and itch.

_Tinea versicolor_

This chronic, asymptomatic fungal skin infection is caused by the fungus _Malassezia furfur_. The condition is very common. Numerous pale yellowish spots occur all over the body, especially the trunk. After sunbathing, the skin tans everywhere except for these spots which then become much more obvious. They also fluoresce under UV light.
12.7.3 Dysbaric osteonecrosis

This chronic and potentially disabling condition results in localised areas of bone death.

Causes

It is thought to be caused by nitrogen embolisation and obstruction of bone blood vessels in divers. Osmotic gas pressure effects in the bone medulla, fat embolisation, haemoconcentration and increased coagulability may be involved. There are two types, one affecting the juxta-articular ends of bones, mostly at the shoulder and hip joints, and the other the shafts of long bones. The former are of greater significance as they can result in collapse of bone ends, joint deformity and permanent osteoarthritis. In the early stages there are no symptoms but flattening of the articular surfaces, thinning of joint cartilage and bony spur formation are present. This progresses to massive bone destruction and joint collapse. The shaft lesions usually heal like a fracture without further problems.

Diagnosis

Diagnosis of dysbaric osteonecrosis (DON) is radiological, involving X-rays, Technetium 99m scans and magnetic resonance imaging (MRI) which can detect very early lesions. The Decompression Sickness Registry (1981) showed that the incidence of DON increased with age and experience, affected 4.2% of a general population of 4980 divers, did not occur in those who had never dived deeper than 30 msw, and involved 15.8% of 190 divers who had dived deeper than 200 msw. Routine screening of deep divers is essential to detect early asymptomatic juxta-articular lesions and remove these people from hazardous exposure before joint collapse occurs.

Treatment

Prevention is the best treatment. This involves using the safest possible decompression tables and ensuring adequate hyperbaric oxygen treatment for all DCI symptoms. Active treatments involve joint immobilisation, osteotomy of the femur and joint replacement.

12.8 Guide to information resources


HSE

Approved codes of practice http://www.hse.gov.uk/spd/spdacop.htm
Diving information sheets http://www.hse.gov.uk/spd/spdinfo.htm
First aid http://www.hse.gov.uk/spd/divicaid.htm
Diving at work regulations 1997 http://www.hse.gov.uk/spd/divequal.htm
Inland/Inshore diving http://www.hse.gov.uk/spd/divequ2.htm


Scubadoc — USA
http://www.gulftel.com/scubadoc/chrbon.htm
http://www.gulftel.com/scubadoc/dysostref.htm
Appendix 12.1 Glasgow coma scale

<table>
<thead>
<tr>
<th>GLASGOW COMA SCALE (SCORE 3-15)</th>
<th>SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Eye opening</strong></td>
<td></td>
</tr>
<tr>
<td>Spontaneous</td>
<td>4</td>
</tr>
<tr>
<td>To speech</td>
<td>3</td>
</tr>
<tr>
<td>To pain</td>
<td>2</td>
</tr>
<tr>
<td>None</td>
<td>1</td>
</tr>
<tr>
<td><strong>Verbal response</strong></td>
<td></td>
</tr>
<tr>
<td>Oriented</td>
<td>5</td>
</tr>
<tr>
<td>Confused</td>
<td>4</td>
</tr>
<tr>
<td>Inappropriate words</td>
<td>3</td>
</tr>
<tr>
<td>Incomprehensible words</td>
<td>2</td>
</tr>
<tr>
<td>None</td>
<td>1</td>
</tr>
<tr>
<td><strong>Motor response</strong></td>
<td>6</td>
</tr>
<tr>
<td>Obeys commands</td>
<td>5</td>
</tr>
<tr>
<td>Localises to pain</td>
<td>4</td>
</tr>
<tr>
<td>Flexion to pain</td>
<td>3</td>
</tr>
<tr>
<td>Abnormal flexion</td>
<td>2</td>
</tr>
<tr>
<td>Extension to pain</td>
<td>1</td>
</tr>
<tr>
<td>None</td>
<td></td>
</tr>
</tbody>
</table>

Appendix 12.2 Recompression chambers in Southern Africa

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>INSTITUTE</th>
<th>TYPE</th>
<th>TELEPHONE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretoria</td>
<td>Institute for Aviation Medicine</td>
<td>10-man multiplace 100 msw</td>
<td>(012) 664-5964</td>
</tr>
<tr>
<td>Pretoria</td>
<td>SA Police Special Task Force</td>
<td>3-man multiplace 60 msw</td>
<td>(012) 353-9338</td>
</tr>
<tr>
<td>Johannesburg</td>
<td>Medical Rescue International — DivEvac</td>
<td>1-man monoplace 21 msw</td>
<td>(011) 403-7080</td>
</tr>
<tr>
<td>Simon’s Town</td>
<td>SA Navy</td>
<td>14-man multiplace 100 msw</td>
<td>(021) 787-3818</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(021) 787-3819</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(021) 787-3820</td>
</tr>
<tr>
<td>Richard’s Bay</td>
<td>Portnet</td>
<td>3-man multiplace 60 msw</td>
<td>(035) 905-2377</td>
</tr>
<tr>
<td>Durban</td>
<td>SA Navy</td>
<td>6-man multiplace 60 msw</td>
<td>(031) 460-6110</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(031) 460-6911</td>
</tr>
<tr>
<td>East London</td>
<td>Port Rex</td>
<td>6-man multiplace 60 msw</td>
<td>(043) 722-2415</td>
</tr>
<tr>
<td>Port Elizabeth</td>
<td>SA Navy</td>
<td>6-man multiplace 60 msw</td>
<td>(041) 505-1348</td>
</tr>
<tr>
<td>Kariba Zimbabwe</td>
<td>Zimbabwe Defence Force</td>
<td>8-man multiplace 60 msw</td>
<td>09263 61 2567</td>
</tr>
</tbody>
</table>
Appendix 12.3 Recommendations to the council for diving for safe diving practice in the inshore diamond diving industry

From a safety perspective, three essentials are required for a successful result in an emergency:

- Reaction
- Rescue
- Resuscitation

Reaction

In order to react immediately to an emergency it is essential that the diver and surface supervisor are in constant communication and that the supervisor is at all times aware of the diver’s depth, working conditions and available air supply. The only really acceptable way of doing this requires a pneumofathometer, hard wire telephone, air bank manifold and a fully-gauged and piped surface control panel. This means that all divers must wear a full face helmet such as a Kirby Morgan helmet with a back-up diver cylinder in case of surface-supply failure. It also means that hookah systems and scuba equipment must be outlawed for commercial divers.

A medically in-date diving supervisor registered with the Department of Labour is required. He must be fully-qualified by a dive school approved by the Department of Labour, experienced in zero visibility underwater work, certified up-to-date annually in first-aid and CPR competence, and capable of handling diving and emergency contingencies related to the work speedily and efficiently. He must be totally responsible for all life-support systems and all aspects related to the safety of the diver, including pre-dive, post-dive, surface and submerged conditions.

Rescue

Rescue must be immediate once reaction to an emergency commences. Two medically in-date commercial divers registered with the Department of Labour are required as a minimum for any single diver work. They must be fully-qualified by a dive school approved by the Department of Labour and certified up-to-date in first-aid and CPR competence. One of these divers must be highly experienced and fully capable of ensuring the supervisor’s safety should the need arise for the supervisor to dive. One of these divers must be fully-equipped and ready to dive immediately should the need for diver aid arise.

Resuscitation

Two aspects are involved in diver resuscitation. Immediate primary first aid and CPR assistance to the rescued diver is the first need. It also requires the on-site presence of a medical oxygen supply equipped with a demand-system face mask as provided, for example, by Diver Alert Network (DAN). This provides 100% oxygen to the diver as opposed to about 40% oxygen with a standard freeflow oxygen mask.

The second aspect is the urgent summoning of advanced medical help. To achieve this the telephone number and address of the nearest emergency life support facility must be found and documented. This facility must be notified that diving work is being performed and the precise location, nature and site of the work provided to this facility in advance, so that emergency road, aircraft or helicopter access can be discussed and planned in advance. The telephone number of the nearest decompression facility must be determined and documented. This facility must also be informed in advance that diving work is being performed to ensure that the necessary medical personnel can be easily contacted if needed.
CHAPTER 13
Occupational Skin Disorders

This chapter covers the important topic of occupational skin disorders that have been largely unrecognised and underreported, much less researched, in the mining industry. The introduction summarises local and international information on skin diseases in the mining industry and research needs are discussed. The relevant legal framework and compensation issues are briefly outlined. The clinical approach to skin diseases summarises the conditions most likely to be encountered in the industry.

Risk assessment of skin hazards addresses the complexities of assessing skin exposure risk and the deficiencies of applying recognised exposure levels to occupational skin diseases. The skin barrier function in identifying hazards is highlighted. Personal protective equipment is discussed with particular emphasis on skin protection. General principals relevant to all PPE are addressed with additional sections on gloves and barrier creams. Rehabilitation and accommodation of mineworkers with impairment and disability due to skin disease gives the reader a general guide to occupational skin diseases with emphasis on those that need special consideration.

Prof. G. Todd
Specialist Dermatologist
Gail Todd is Head of the Department of Dermatology at the University of Cape Town and Groote Schuur Hospital. She has a special interest in occupational skin diseases and is the chairperson of the National Occupation Skin Disease Initiative.

Dr. H. Carman
Specialist Dermatologist
Dr Hilary Carman is a consultant dermatologist in private practice. She worked for 3 years at the Rand Mutual Hospital, the specialist referral hospital for mine workers, until its closure in 1999.
Glossary

Dermatophytes are fungi that grow in the horny layer of the skin.

Dermatitis is used to describe inflammatory skin disease.

Dermatosis is used to describe any skin condition, including inflammatory skin disease.

Emollients are topical creams, lotions or ointments that are used to keep the skin soft and hydrated.

Hyperkeratosis refers to a thickened horny layer as seen in corns and calluses.

Lichenification is the term used to describe the clinical signs of chronic eczema, namely thickened skin with pigmentary changes and increased skin markings.

Occupational skin disease is defined as any abnormality of the skin induced or aggravated by the work environment.

Stratum corneum is the technical term for the horny outer layer of the skin.

Tinea is the term used to describe dermatophyte fungal skin infections.

Vesicles are collections of fluid in the skin that look like small blisters.
13.1 Introduction

Any abnormality of the skin induced or aggravated by the work environment is defined as an occupational skin disease. While legislation applies particularly to the workforce involved in mining and other activities, a mine workforce also includes managerial, laboratory, administrative, maintenance and construction personnel. All these workers are potentially exposed to skin hazards from air conditioners to solvents. This chapter will assist the identification of skin diseases in any of these jobs although conditions relating to mining are emphasised.

There is little published information on skin diseases in the mining industry. Identified irritants are listed in Table 13.1 and allergens are listed in Table 13.2.

Table 13.1. Skin hazards relevant to mining: Irritants

| Shotcrete (fresh), cement |
| Alkaline and acid concrete accelerating agents |
| Concrete solutiser |
| Moulding agent |
| Wood impregnating materials |
| Lubricants (greases, oils) |
| Solvents (trichlorethylene, white spirits, thinners, benzene) |
| Acids and alkalis |
| Anticorrosives |
| Diesel fuels, paraffin |
| Bitumen, tar |
| Polyurethane (rock strengthening) |
| Phenol formaldehyde resin (ground stabilisation) |
| Ammonium nitrate (explosives) |
| Dust (rock, coal, iron pyrites, cement, wood) |
| Humidity |
| Heat |
| Cold |
| Sand, soap, detergents, handcleaners |
| Hand-operated tools |
| Radiation — non-ionising UV (welding, open cast mining), ionising (uranium/radon gas, C14) |

Table 13.2. Skin hazards relevant to mining: Substances causing skin allergy

(“Found in standard allergen series”)

| Acrylates (concrete wetting agent, adhesive) |
| Polyurethanes and catalysts (rock strengthening) |
| Preservatives (skin protection creams, technical oils) |
| Antimycotics (fungal treatments) |
| Oils and greases (hydraulics, machines) |
| Rubber (especially in PPE) |
| Plants (lichens, liverworts, fungi) |
| Insects (mites, fleas, mosquitoes, cockroaches) |
| Explosives |
| Potassium dichromate, 0-5% (cement, anticorrosion) |
| 2-Mercaptobenzothiazole, 1-2% (rubber, anticorrosion) |
| Carba mix, 3% (rubber — PPE) |
| Epoxy resin, 1% (adhesives, epoxy cement) |
| Mercapto mix, 1% (rubber — PPE) |
| IPPD, 0.1% (black rubber — PPE) |
| Thiuram mix, 1% (rubber — PPE) |
| Nickel sulphate, 2.5-5% (hand tools, cement) |
| Cobalt chloride, 1% (cement) |
| Coconut oil diethanolamide, 0.5% (hydraulic fluid) |
| Dinitronaphthalen, 1% (explosive) |
| Dinitrotoluene, 2% (explosive) |
| Ethylene glycol dinitrate, 0.1-0.5% (explosives) |
| Nitroglycerine, 0.5-2% (explosive) |
| Zinc bis-diethylthiocarbamate, 1% (rubber — PPE) |

The extent and diversity of mining operations in South Africa expose the 400,000 mineworkers to a wide range of environmental conditions from hot, dry, high solar radiation open mines of the Northern Cape to hot, humid, underground mines of the Witwatersrand Basin. As there has been minimal research on the prevalence of skin diseases, there are no reliable data to assess the impact of
occupational skin diseases on worker health and productivity. Estimates are possible only from compensation claims and mine healthcare records, since published data on skin diseases in South African mines deal mainly with epidemics of unusual infections such as yaws and sporotrichosis, extreme physical conditions such as heat or systemic diseases such as systemic sclerosis.

13.1.1 Compensation data on skin diseases in mining in South Africa

Rand Mutual Assurance estimates that only 2% (1,000/50,000) of yearly occupational disease claims under the Compensation for Occupational Injuries and Diseases Act (COIDA) are for dermatitis (Table 3), of which 80% are compensated. Claims lacking proof of exposure or medical evidence of dermatitis are rejected. Similarly, one large mining group recorded only 3 compensated skin claims amongst 35,000 miners over a 3 year period.

Table 13.3 Compensated occupational dermatitis claims in the South African mining industry*

<table>
<thead>
<tr>
<th></th>
<th>Cases</th>
<th>% of all injury and disease claims</th>
<th>% of all disease claims</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>100</td>
<td>0.2</td>
<td>1.3</td>
</tr>
<tr>
<td>1998</td>
<td>79</td>
<td>0.16</td>
<td>1.1</td>
</tr>
<tr>
<td>1999</td>
<td>182</td>
<td>0.36</td>
<td>2.4</td>
</tr>
</tbody>
</table>

*Rand Mutual Assurance Data

13.1.2 Skin diseases in South African mines

The commonest skin disease among miners referred for clinical management in Gauteng is dermatitis. Of the 211 working and retired miners referred to a mutual benefit scheme dermatologist in 1996, 63 (30%) presented with dermatitis. The dermatitis was chronic, unremitting and often continued for years after the patient had left the working environment.

During the period April 1997 to December 1999, of 237 mine employees (83 gold mines, 76 platinum mines and 68 coal mines) referred to the mine dermatologist, 149 (63%) were diagnosed with dermatitis. The remainder had infectious conditions and a wide range of dermatology disorders, mostly unrelated to their occupations.

Of 62 mineworkers with dermatitis evaluated for possible occupational causes, 38 worked underground and 24 were surface workers on the gold, platinum and coal mines. The median length of service was 13 years (platinum miners: 10 years, gold miners: 14 years, coalminer: 14.5 years). The average duration of dermatitis was two years, affecting predominantly the hands, followed by the feet and generalised eruptions. Patch tests were positive in 15 of 56 (27%) workers tested. In five workers, a link was found to a workplace allergy to rubber components (conveyor belt 2, personal protective equipment 3, rubber control lever 1). Other reactions were to ubiquitous chemicals where no specific workplace exposure could be confirmed, viz. formaldehyde, nickel, cobalt chromate, colophony, cliquinol or fragrances. Positive skin prick tests in 50% of the evaluated dermatitis patients suggests that atopy plays a role.

13.1.3 International surveillance data from the mining industry

Until recently, occupational dermatitis was not reportable under the United Kingdom Reporting of Disease and Dangerous Occurrences Regulations. However, data from 1979/1980 analysing off work periods by disease, showed that in males, mining and quarrying were the highest risk occupation for industrial dermatitis, followed by mechanical engineering, construction and vehicle manufacture. On average, 36.7 days per 100 men years were lost in North East England collieries between 1978 and 1984 due to skin disease. Bacterial infections (36%), dermatitis (25%) and fungal infections (11%) accounted for most skin problems. Dermatitis was recurrent and accounted for longer absences from work. Foot dermatitis was especially troublesome with a median absence of 14 days. A greater percent of these workers had recurrent absences, which extended to 6 weeks in 21% of the group.
In contrast to the UK, surveillance data and compensation records from the USA in the early 1980s suggested that mining was not a high risk occupation for occupational skin disease as it accounted for a rate of only 4 cases per 10 000 employed workers. Agriculture, forestry and fishing (35.9), manufacturing (14.8), construction (8.8), services (5.8), and transportation (6.5) were identified as the high-risk occupations.

Data from the Federal Republic of Germany also showed a low prevalence of occupational skin disease in miners. Respiratory diseases (64.6%), noise (17.4%) and physical damage (16.6%) accounted for most occupational disease amongst miners, with skin diseases contributing only 1.1% of the burden. This was in sharp contrast to occupations in other sectors where skin disease was a major cause of morbidity.

Different countries thus report different experiences of skin diseases in miners. However, because skin disease is a rare cause of death, and is underdiagnosed and underreported, health professionals, management and sufferers may underestimate its importance and the long-term disability it can cause. Occupational skin disease accounts for half of all occupational diseases in the USA and is a leading cause of work-related illness absence. The cost of occupational skin disease in the mining sector is thus potentially high for the worker, in respect of disability and for the industry, in days lost and medical compensation costs. Research on this subject in the South African mining industry is urgently needed.

13.2 Overview of legal framework and compensation issues
The laws applying to occupational skin diseases in mine workers are COIDA and MHSA. A practical approach to workers with suspected work related skin disease based on the COIDA Manual is detailed in appendix 13.2.

Sections dealing specifically with skin are limited, but provision exists for any condition caused or aggravated by the work environment to be submitted for compensation. In view of the wide range of work related skin diseases found in the mining industry, the need for patch testing as part of a submission, is a contentious issue. Patch tests are usually of little additional value even for dermatitis as many cases are caused by irritant exposure. Patch testing, when it is done, does not include all possible chemical hazards or skin reactions are incorrectly interpreted (see appendix 13.3).

Obtaining compensation for skin diseases is difficult, due to the perceived unimportance of the problem. Chances of acceptance are greatly facilitated by ensuring that all the necessary forms, including a dermatology report where indicated, are properly completed and forwarded together at the same time.

The following forms need to be completed.
W.Cl.1 — Employer’s report of disease
W.Cl.22 — First medical report
W.Cl.53 — Dermatological report with copies of relevant special investigations
W.Cl.26 — Progress reports as required
W.Cl.26 — Final report

13.3 Clinical approach and spectrum of conditions
Dermatological disease, while rarely causing serious illness, causes disability, misery and decreases worker efficiency. Workers themselves fear retrenchment and do not wish to give up bonus pay. They will work without complaint, although in much discomfort. This section attempts to provide a workable approach for recognising these problems and should be read in conjunction with appendix 13.1.
Occupational dermatoses can be the result of a single or repeated exposure to one hazard or the cumulative effects of a variety of different hazards occurring simultaneously or consecutively. All four categories of causation comprise skin irritants with the ability to cause direct skin damage and they can all act as hazard modifiers. For more details on specific skin diseases see appendix 13.3.

13.3.1 Mechanical hazards: — trauma, friction, pressure, vibration, pounding, abrasion, penetration

This is the largest category, as it includes trauma. Mechanical hazards are irritant and result in acute damage (redness, blisters, erosions, necrosis — burns, ulcers), chronic damage (Raynaud’s phenomenon, vibration syndrome, deformity, nasal perforation) or chronic adaptive skin protective reactive responses (skin thickening and hyperkeratosis as in corns, calluses and lichenification). Vibration injury is covered in Chapter 7.

13.3.2 Chemical hazards: — organic and inorganic compounds

Chemical hazards are either directly toxic to cells or cause indirect injury through metabolites or immune mechanisms. The effects (irritant/toxic or allergic) are local, causing skin damage (burns, ulcers, nasal perforation, pigmentation) and disease (dermatitis, urticaria) or systemic, secondary to percutaneous absorption (trichloroethylene).

Chemical irritants include water or mild soap as well as harsh acids, alkalis and solvents. Chemical allergens cause skin disease via stimulation of the immune response. The spectrum of skin changes range from nothing (subclinical damage) or dryness to erythema and frank eczema.

As there is individual variation in the sensitivity of the skin and its ability to recover, and as virtually every substance can affect the skin or be absorbed, NO substance should be excluded from a risk assessment.

13.3.3 Physical hazards: — temperature, radiation, electricity, humidity, airflow, occlusion

Physical hazards often act as hazard modifiers but they can cause direct effects.

Solar, non-ionising, ultraviolet radiation causes sunburn, skin ageing and cancer and, in combination with certain chemicals, can precipitate phototoxic or photo-allergic reactions. Chronic exposure to artificial light sources may produce similar effects. Ionising radiation causes radio-dermatitis and cancer. Uranium oxide (alpha, beta and minimal gamma radiation) is present in rock and is mined as a by-product of gold. The concentration varies from place to place with the highest level being 0,5kg/ton of ore. Workers are shielded from exposure by rock and water.

Temperature, humidity and airflow all act as irritants causing damage to the skin barrier. Reactions to heat include burns, miliaria, urticaria, erythermalgia, erythema ab igne, and cancers. Cold exposure causes frostbite, chilblains, urticaria and immersion foot. In dry environments, the stratum corneum becomes dehydrated (<50% relative humidity is associated with <10% horny layer hydration, the level at which skin irritation occurs) while excess hydration results in maceration of the skin.

Occlusion of the skin (rubber PPE) may cause damage to the protective skin barrier by over hydration of the horny layer and encourage infections (fungal foot infections). It may also lead to blocked pores, predisposing to acne (rubber masks, oils, greases) and miliaria.

13.3.4 Biological hazards: — viruses, bacteria, fungi, parasites, insects

The range of infections encountered in the skin is varied. These are immediately obvious (impetigo, folliculitis, boils, abscesses, candidiasis, dermatophytes etc) and respond promptly to treatment. The more chronic, indolent forms may be difficult to recognise (lumps, chronic sores or sinus tracts) and often need biopsy for culture and histology. Unusually severe, recurrent and persistent infections despite full appropriate treatment should alert one to underlying systemic immuno-deficiency conditions.
Foot problems are especially problematic for miners. Occlusive PPE, used in hot, humid working environments, predisposes to skin maceration and irritation and micro-organism growth. Although moist environments encourage dermatophyte fungal and yeast infections, wetness of the feet predisposes to bacterial infections characterised by malodour (10).

Rodents, bats, mites and cockroaches can inhabit mines. Rodent fleas and mites can result in insect bites. Bats are associated with histoplasmosis exposure that causes systemic fungal infections especially in the immuno-compromised. Cockroaches are increasingly recognised as a cause of type I allergic reactions in the general population.

13.3.5 Pre-existing conditions

There are pre-existing conditions that pre-dispose miners to certain occupational dermatoses.

- Atopic individuals, especially those with a family or personal history of eczema, are more at risk of developing contact dermatitis, as their skin barrier function is impaired. Individuals with dry skin will also be more at risk for the same reason
- Those with fair skin are at higher risk of solar damage
- Patients who are immuno-compromised, e.g. diabetics and those with acquired immunodeficiency syndromes, are more liable to develop severe skin infections
- Patients with underlying disorders of keratinisation such as psoriasis are susceptible to disease aggravation following skin damage or develop lesions at the sites of trauma (isomorphic or Koebner phenomenon)

13.4 Risk assessment of skin hazards

Risk assessment involves the identification of all potential hazards in the workplace, an evaluation of exposure potential for each hazard and a ranking of occupational risk. While the risk assessment approaches have been developed for respiratory or noise risk assessment, skin disease risk assessment is complex owing to a number of practical and technical problems.

- Ability to recognise and diagnose skin diseases by medical personnel is generally poor
- Knowledge among medical and occupational health personnel of skin function and the factors that affect it is inadequate, so that these factors are not addressed in occupational health programmes
- There are few reliable incidence data of occupational skin disease amongst miners
- Hazard effect modifiers (pre-existing skin disease, humidity, heat, dryness, occlusion, irritants etc) need identification and consideration in any risk evaluation
- Some knowledge of product chemistry is needed to identify unexpected exposures. For example, certain biocides release formalin but formalin will not be listed on the product label as it is not added by the manufacturer. Oxidation or degradation products, such as the potent skin sensitiser formed on exposure of the degreasing agent d-limonene to air, will likewise not be listed. Iron pyrites in gold ore produce sulphuric acid with water. Workers contaminated with the ore dust in humid, wet surroundings are exposed to this acid, as are those who sweat. Nitrous emissions from blasting dissolve in water to form nitric acid. Cross-sensitisers such as Balsam of Peru, turpentine, or pine need to be identified as hazards capable of causing ongoing disease when the primary sensitiser, colophony/rosin has been eliminated
- Simple, reliable techniques to measure and monitor skin exposure are not available
- There are no occupational exposure limits (OELs) for skin. Most material safety data refer to respiratory and oral exposure limits. This makes compliance monitoring difficult. For chemical toxicity, oral exposure limits are applied to skin contact exposures, which may be inappropriate
- A single exposure limit is not applicable to all skin surfaces. The palms, soles and forearms are less permeable than the face and scalp. The thick horny layer of the palms and soles may however act as a reservoir for substances increasing their chances of skin penetration. The nails are highly permeable to water and water-soluble compounds
- Exposure levels needed to sensitise an individual for the first time are much higher than those likely to precipitate disease in an already allergic individual
Material safety data sheets often list only officially recognised hazardous substances under product composition data. Skin irritants and sensitisers are not necessarily included in these lists. Recognised hazard and exposure limits refer to a single pure substance assessed under environmental conditions. In reality, skin exposure to a single pure substance in the workplace is unusual. It is, however, impractical to establish a set of unique hazard exposure safety limits for each combination. Skin disease is often the result of accumulated multiple insults. Risk assessment generally deals with the risk of acute effects rather than slow cumulative effects. Routes of skin exposure include contact with solid, liquid and vapour forms of the substances, all of which need to be evaluated in a risk assessment. Skin risk assessment is time-consuming as virtually every substance present in the workplace environment needs identification and assessment, not only those listed in statutory regulations. At least 20,000 chemicals are potential hazards for miners. Skin risk assessment depends on the knowledge and experience of the assessor allowing a subjective evaluation based on a systematic approach to ensure all potential hazards are considered.

13.4.1 The skin barrier function

To appreciate the complexities of risk assessment for skin exposure an understanding of the skin barrier function is important.

The skin has developed to function effectively as a living structure at a water-air interface. The barrier function of this interface is due to a specially formulated combination of fatty substances that are found between the specifically adapted cells of the horny outer layer of the skin. A thin surface layer of oil secreted by the skin oil glands helps to maintain this barrier intact. The skin may be damaged in many different ways and often there are multiple causes contributing to skin disease.

Absorption through the skin can occur in normal skin. Substances that dissolve in organic solvents and the solvents themselves easily penetrate the fatty layer of the skin barrier. Although the mechanism is not well understood, water and water-soluble substances can also penetrate the normal barrier but at a much slower rate. Areas not protected by the horny outer layer, such as the hair follicles, sweat ducts and mucosal surfaces offer less resistance to the penetration of most substances especially water-soluble compounds. Material safety data sheets have a skin warning for certain substances that are recognised to have significant skin absorption.

Damage to the skin barrier occurs easily. The fatty layer can be removed or damaged by detergents, organic solvents, soaps, and chemicals. Too much water damages the specially adapted cells by excess hydration, while an environment that is too dry dries them out and disrupts the barrier. Once the barrier has been damaged, substances from outside can more easily penetrate the skin. This can result in stimulation of the skin immune system and immune disease such as contact dermatitis and urticaria. Alternatively, systemic absorption is markedly increased and can result in systemic toxicity. Infective organisms can also gain access into damaged skin more easily.

Most people do not recognise that damage to the skin barrier occurs many times a day. Fortunately the skin barrier can regenerate, but this requires time. We become aware of the damage when the skin shows changes such as dryness, cracking and peeling. This represents early disease of the skin and is known as irritant dermatitis. Should damage occur faster than repair, a continuous state of disease will be evident as worsening dermatitis. Associated immune diseases, such as allergic contact dermatitis and urticaria and infections, occur more readily with damaged barrier function and often complicate the presentation of irritant dermatitis.

13.5 Personal protective equipment (PPE)

Common sense confirms that gloves and barrier creams are not all that are relevant to skin protection. All forms of PPE (masks, overalls, boots, gloves, helmets, goggles, ear plugs, skin guards, braces) protect against skin exposure. Because of this and because PPE is worn in close contact with the skin general principals applicable to PPE are discussed in this chapter.
PPE should be used as a last resort when all other means of engineering have failed to prevent exposure. They should be used for back-up, splash protection only. Workers should understand this and be fully informed of the limitations in their use especially as primary protection.

Before any PPE is selected, the precise task and reason for the choice must be established and discussed with the worker. This implies a complete hazard assessment of the task, including the ambient environment.

13.5.1 Personal protective equipment must not worsen or aggravate the exposure.

- Any piece of apparel worn in close contact to the skin that does not allow the free exchange or absorption of water vapour leads to skin maceration and irritant contact dermatitis (e.g. rubber boots)
- Any ill-fitting piece of PPE lessens the ability of the worker to function adequately because it is cumbersome, restricts movement, causes pain or leads to corns, calluses or mechanical skin trauma (e.g. boots and gloves)
- Where possible, PPE should be personalised. The fit should be correct and the items used by one worker only. This prevents the spread of skin infections such as fungi (dermatophytes, yeasts), bacteria (staphylococcus) and viruses (warts) from worker to worker that may occur with communal use. The potential spread of infections via body secretions should also be considered, especially in the event of undiagnosed dermatitis. The use of disinfectants and cleansers to overcome these problems is not reliable owing to human error and the lack of a universal product that will not result in damage to the equipment or dermatitis in the worker. Personalised PPE can be cleaned in accordance with the manufacturers instructions for each individual item
- Failed PPE can lead to skin disease. Examples of this are gloves used for mechanical protection in wet environments. When water penetrates into the gloves and the gloves are kept on, an environment similar to that of working with the hands immersed in water is created, leading to maceration and loss of barrier function. When soiled gloves are used, the soiling is kept in occlusive contact with the skin, increasing penetration and toxic possibilities. This also occurs when damaged gloves are used

Most personal protective equipment, especially gloves, have OELs for their use with pure substances. There are no OELs for combination substances.

- Gloves that are inappropriately used, such as latex rubber gloves for organic solvents, give a false sense of security. Although the gloves are believed to be protective, they are a time bomb! Certain solvents and chemicals penetrate the gloves easily and build up within the gloves without damage to the glove being obvious. This is known as the break through time. This leads to a higher concentration of the solvent and solutes inside the gloves, in direct contact with a moist macerated stratum corneum, increasing skin penetration and toxic effects. Any reputable supplier of PPE should be able to provide the break through time for a variety of solvents for each specific glove for example. Alternatively, the solvents or chemicals cause structural damage to the glove material altering its performance characteristics. The manufacturer should also provide the list of chemicals and solvents for which a glove can be safely used. PPE can itself cause skin disease. A good example of this is allergies developed to rubber in facemasks, rubber boots, skin protectors and a variety of different gloves

Use of damaged PPE, especially gloves (torn, leaking, structurally altered, beyond the break through time) is a work hazard.

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• Cleansing products used for PPE can lead to dermatitis, for example, allergies to chlorhexadine in disinfectants or irritant reactions to soap products in incorrectly maintained equipment

There is no single item of personal protective equipment that is applicable to every task or every exposure.

13.5.2 Barrier creams
Barrier creams are topical preparations that are marketed as rub on exposure protectors. They create a greater sense of false security. Given the limitations of all physical means of protection, obviously barrier creams offer little skin protection. They are NOT the universal, cheap solution for skin protection sought by management and occupational health care workers. The main function of barrier creams is to maintain skin hydration and preserve skin barrier function. The addition of chemicals to inactivate or bind specific substances, such as metals like nickel, to prevent their interaction with the skin, may have specific application. Barrier creams themselves may aid penetration of chemicals by allowing the chemicals to dissolve in the vehicle of the barrier cream, thereby increasing the contact reservoir and the toxic and penetration effects. The constituents of barrier creams (fragrances, preservatives, antibacterial agents, and colourants) can also cause allergic dermatitis.

13.5.3 Solar radiation protection
See the formulary — Appendix 13.4.

13.6 Rehabilitation and accommodation of mineworkers
The aims of rehabilitation and accommodation of workers are to give the worker with skin disease a chance to recover from the disorder, and to restore barrier function while investigating and eliminating the risk, pending the worker’s return to the job.

Rehabilitation and accommodation depends on the type of skin disease, its appropriate management and the ongoing risk of exposure. Apart from the guarded prognosis of contact dermatitis, most skin problems should resolve with minimum impairment and disability after appropriate treatment, allowing full return to work.

Several general principles apply to most skin disease.
• Skin hygiene is essential for preventing many skin diseases. Facilities with warm water and bland cleansers should be readily available to all workers to remove soiling as needed
• Keep the skin clean, healthy and supple with regular bland moisturisers
• Protect the skin from unnecessary exposure to irritants
• Personnel protective equipment must be appropriate for the task, maintained and kept clean for personal use only

13.6.1 Mechanical skin disorders
• Mechanical skin disorders are usually due to trauma (cuts, abrasions, lacerations, penetration) or friction and pressure (corns, calluses) and should resolve with removal of the irritant
• Vibration injury from pneumatic tools is reversible if recognised early and the worker given time to recover. Use light tools where vibration frequencies between 30 and 300 Hz and vibration acceleration are minimised
• Limiting work in cold, wet environments should prevent recurrences of Raynaud’s phenomenon and vibration injury but susceptible individuals should be accommodated where they will not be exposed regularly

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13.6.2 Skin infections

- Skin infections will respond to treatment appropriate for the organism that can be identified clinically and by taking scraping, swabs and biopsies for microscopy and culture
- The worker can continue with the same work once the acute symptoms have settled, without impairment and disability
- Prophylactic measures need to be put in place to prevent re-infection and to discourage organism growth. These measures include education about the precautions needed to prevent dissemination of the infection (walking barefoot in communal areas with fungal or wart foot infections), treatment or elimination of organism reservoir (wood for sporotrichosis, stagnant water for pseudomonas, nasal carriage for staphylococcus) and the need for dry, hygienic, non-occlusive environments (absorbent bland powders and clean cotton socks daily, cotton glove liners, vapour-permeable overalls, air-conditioning)

13.6.3 Contact eczema/dermatitis

- This will respond to removal from contact with the responsible agents (irritants and allergens) combined with appropriate treatment for eczema (usually topical steroids) and secondary complications such as infections
- Prognosis is guarded for patients with contact dermatitis as ongoing exposure to irritants and unidentified sources of allergen or cross-reacting substances is difficult to control
- The worker can continue with the same job provided that management and medical personnel recognise that the problem will recur with re-exposure, especially if insufficient time has been allowed for full recovery of the skin barrier function
- If the worker is to continue in the same work, the work environment (macro or micro) must be engineered to prevent ongoing exposure. This does not have to be high tech or expensive but includes the use of water absorbent socks, the choice of appropriate gloves, the provision of adequate ablution facilities or the use of simple tools to prevent direct skin contact
- The appropriate PPE may be issued for use as back-up protection against skin hazards only or under exceptional controlled circumstances for those situations where exposure cannot be avoided
- The necessary prophylactic measures need to be put in place to prevent other workers from being exposed
- In the event of ongoing skin disease, despite adequate protection, the worker will need to be accommodated in alternative work situations. This can only be successfully achieved if ongoing exposure from unsuspected sources (e.g. formaldehyde releasing preservatives in hydraulic and cutting oils, detergents and topical creams) is excluded. This requires a thorough knowledge of the sources of exposure to particular agents

13.6.4 Physical skin disorders

- Control of or removal and protection from extremes of temperature, humidity and airflow should result in resolution of the condition caused or aggravated unless permanent damage has already occurred (frostbite, burns)
- Radiation damage is essentially irreversible. Removal or protection from ongoing exposure will prevent worsening and may retard cancer development

Prevention should be the aim of any occupational health programme. The best philosophy to adopt is to focus more effort on the occupation and process changes and less on the treatment of the skin.

The findings from any case of occupational skin disease should be used to engineer alterations in the work environment so that the problem does not recur.
13.7 Impairment and disability

Impairment is the clinical assessment of loss or abnormality of physiological, psychological, immunological or anatomical structure or function.

Disability refers to an incapacity to earn the wage previously earned by the worker because of injury or disease. It depends on the job and the workers ability to compete in the open market.

Impairment is a medical term dealing with health status and does not necessarily imply disability that is a social or vocational term dealing with the ability to meet the demands of life.

Handicap refers to impairment, or a history of such an impairment that limits life activities. A worker with contact dermatitis is considered handicapped even though the symptoms of the condition resolved away from exposure and would thus have neither an impairment nor disability rating.

Because of the wide range of conditions that are considered work related skin diseases, it is not possible to discuss the assessment of impairment and disability in each case. Work related skin diseases affect predominantly the hands, feet and face. They thus limit the ability to work and, because skin diseases are visible, they affect social contacts. Disability is determined by limitation of manual skills, risk of spread of infections, psychological negative image, colleague acceptance and the job involved.

Most work related skin diseases can be managed without the need to remove the worker from his job permanently. Apart from those conditions where permanent damage to the skin occurs (burns, vibration syndrome and scleroderma), the only condition that has a guarded prognosis is allergic contact eczema. Although the worker recovers away from the work place and exposure to the substance, the impairment to the immune system is permanent resulting in handicap and disability.

There are no simple rules that allow one to quantify occupational skin disease impairment and disability.

13.8 Guide to information resources

Useful reference works on occupational skin disease


A reference work on occupational contact dermatitis, which contains a chapter on contact allergens in miners.


The most detailed and useful reference work for in depth information on all aspects of occupational skin disease management


A recent reference addition to the reference works on occupational skin diseases, which contains a 2 page chapter on miners.


A comprehensive, practical text on the management of occupational skin disease which is applicable to all occupations and branches of occupational health.


A dated but useful text on industrial skin disease.
Van der Walle HB, Piebenga WP. Skin and occupation. A pocket guide to work-related skin diseases. Kampert Drukwerk bv. Oss. 1999

A neat pocket book with colour photographs, which is an excellent guide to the management of occupational skin disease. The small print makes it difficult to read. Copies can be obtained free of charge from email: koerten.nl@yamanouchi-eu.com

Other useful reference works

Chemical hazards

Hazardous Chemicals Desk Reference. Editor Lewis JL. Van Nostrand Reinhold, New York

Comprehensive main reference work with a section on the hazards of each chemical. This publication is updated regularly and is currently in its 4th edition, published in 1997.

The Merck Index. Merck & Co. Inc. Rahway, USA

Information on chemicals, drugs and biologicals. This publication is updated regularly and is currently in its 12th edition, published in 1997.


Information on chemicals, drugs and biologicals. This publication is updated regularly and is currently in its 32nd edition, published in 1999.

Dermatology


A pocket guide approach to making a dermatological diagnosis based on the morphology of the skin lesions or the region of the body involved, even for those with little training in the field. It deals with common skin diseases and their management in South Africa.


A practical dermatology text relevant to Africa with handy summary points of importance alongside the main text, making it easy to use.


A major reference work on all aspects of dermatology.


A major reference work on all aspects of dermatology.
Appendix 13.1 Clinical approach to an occupational skin disease

This section is a guide to evaluating a worker with a skin complaint and identifying risk factors involved for suspected occupational skin disease.

Step 1  Occupational history
Take a detailed chronological employment history. This often requires a personal knowledge of the type of work being done and may include an evaluation of the work environment to establish the occupational connection and all possible aetiologic agents.

Note when the skin problem started and its relationship to work.

Relate symptoms to activities of daily living including work, hobbies, sport, and the home environment. Record in detail the facilities and products used for skin hygiene, in both the home and in the workplace.

Include a detailed history of PPE, its use and maintenance. Note whether it is for own or general use. Document cleaning methods and the products used. Check that the PPE is appropriate for the exposure for which it has been chose. Check the workers’ understanding of the use and maintenance of the equipment. The PPE may be the cause of the skin problem e.g. of rubber boot dermatitis; or may be aggravating the condition e.g. dust trapped in gloves or occlusion causing skin maceration and promoting growth of skin bacterial and fungal infections.

Step 2  Medical symptoms
Describe the skin problem fully. Remember that there are a wide range of skin conditions that are considered occupational.

Note any past dermatological problems, especially atopic eczema, psoriasis, or previous skin allergies.

Take a full and detailed history of all treatments used, systemic and topical. Note medications given by alternative healers, self-medication and those used prophylactically.

Step 3  List of hazards
List all potential hazards not only those in statutory lists of hazardous chemicals. These should include dusts, environmental and climatic conditions, physical (vibration, radiation, temperature) and chemical exposures. The composition of the chemicals and dusts should be ascertained, and where appropriate, the manufacturers noted and material safety data sheets obtained. This information allows one to identify substances that could cause skin disease.

Step 4  Examination
Identify the skin lesions. Describe in detail the various morphologies present, the distribution of the lesions relative to each other and on the body.

Try to establish a relationship between the distribution of the lesions and exposure to materials at work by doing a complete skin examination. The area of greatest disease is often the area of greatest contact with the offending product.

Occasionally this is not immediately obvious, such as with the transfer of airborne agents (volatile chemicals or dusts) to exposed skin surfaces or via direct hand contact to more susceptible areas of skin such as the eyelids and genitalia.

Cutaneous absorption may lead to systemic toxicity. Examine any patient with suspected systemic toxicity for signs of skin exposure.

The clinical manifestations of the more commonly encountered skin problems in the mining industry are detailed in appendix 13.2.
Step 5  
**Assessment**

In many cases a clinical history and examination are all that is needed to confirm a diagnosis of occupational skin disease. Occasionally, infective organisms may need to be identified and cultured or special investigation (patch tests (appendix 13.3), biopsy and histology) required. Each case must be judged on merit.

**Clinical criteria for occupational skin disease**

- Is the clinical appearance consistent with occupational dermatoses?
- Are there workplace exposures to explain the skin disease?
- Is the distribution of the skin disease consistent with cutaneous exposure in the job?
- Is the relationship between exposure and the skin disease onset consistent with occupational exposure?
- Do special investigations identify and confirm probable causative agents from the workplace?

Step 6  
**Treatment**

This is unique to each disease and specific details are given in appendix 13.2.
Appendix 13.2 Skin conditions and their management

Corns and calluses

Calluses and corns result from exposure to excessive and continuous pressure to the skin.

A callus appears as a yellowish thickening of the skin over an area exposed to pressure, commonly the ball and heel of the foot and the palms in those exposed to manual labour.

A corn results from a more concentrated pressure producing a central hard core in the thickened skin, usually on the upper surfaces of the toes.

Soft corns are painful white thickenings of the foot webspaces, the result of lateral pressure from footwear.

**Treatment:**

1. Remove the cause and relieve pressure to the area
   - Advise on appropriate footwear or gloves
   - Refer to an orthoptist, for prosthetic devices to correct foot abnormalities
   - Use foam rubber between the toes to relieve lateral pressure.

2. Remove thickened skin. (Treatment by a chiropodist is preferable.)
   - Apply salicylic acid 10% (keratolytic) and occlude with plaster for 24 hours
   - Soften lesions by soaking in warm water
   - Remove softened skin with a scalpel blade or abrasive e.g. pumice or scraper
   - Repeat above process daily as required.

Eczema/dermatitis

There are many causes of eczema but the clinical picture is essentially the same. The main complication of eczema is secondary infection with either bacteria, particularly *Staphylococcus aureus*, or viruses such as herpes simplex. These infections aggravate the eczema.

**Acute eczema**

- Itchy
- Vesicles, weeping and crusts (dry serum)
- Erythema and swelling

Excoriations and secondary infections may complicate the presentation.
Chronic eczema — Lichenification

Itchy
Thickened, dry, leathery skin
Accentuated skin markings
Pigmentary change (increased pigmentation usually)

Excoriations, secondary infection and features of acute eczema may complicate the presentation.

Contact eczema may be irritant or allergic. Irritant dermatitis does not involve an immune response but occurs following a single or repetitive cumulative damage by the same or multiple different irritants encountered in all activities of daily living. Irritants can be physical (hot, cold, dry, humid environments) mechanical (dust or fabric abrasion, occlusion) or chemical (water, detergents, soaps, solvents, alkalis and acids). An allergic reaction to a particular substance is less common. Skin lesions are initially confined to the sites of contact but spread to adjacent skin with time. The eczema may become generalised, sometimes quite suddenly (id reaction). The initial site of involvement on the body may provide a clue as to the aetiology. Patch testing may help to identify specific allergen triggers.

Atopic eczema occurs in individuals who have a tendency to produce IgE antibody responses. There is usually a personal or family history of asthma, hayfever or eczema. Stress, secondary infection, super-imposed allergic contact dermatitis, and exposure to irritants aggravate the condition. Dietary intolerance plays little role. Common sites of involvement are the face and the limb flexures. The course is chronic with acute exacerbations. Skin lesions often start in infancy or childhood and improve at puberty, but some patients continue into adult life with skin problems.

Seborrhoeic eczema is common but the cause is unknown. It may be related to sebaceous gland activity, is aggravated by stress and possibly by yeast infections of the hair follicles. It occurs in all age groups and is recurrent. Greasy, scaly, red, poorly defined lesions are found in areas with large numbers of sebaceous glands like the scalp, central face, eyelids, central chest and bodyfolds. The sudden appearance of severe seborrhoeic dermatitis in adult life may be a marker of early HIV infection.

Nummular eczema is a persistent patchy eczema of unknown aetiology. Some patients have associated atopic or contact eczema. Bacterial infection may have a role in aggravating the condition. Well-rounded discrete patches of wet, crusted eczema are commonly seen on the limbs. The condition runs a relapsing course, with a tendency to slow deterioration without adequate treatment, usually potent topical steroids and anti-bacterial measures.

Stasis eczema is usually seen on the lower legs in relationship to chronic venous stasis of the affected area. Any dependant area of the body can be affected, especially if immobility, oedema or venous and lymphatic drainage impairment aggravates dependency. Increased pigmentation of the affected area often results secondary to blood leaking into the skin. With chronic stasis, fibrosis of the area presents as tightly bound down skin.
Treatment:

(1) **General measures:**
- Suppress itch with systemic antihistamines, topical steroids and wet-wraps.
- Avoid irritants and trigger factors like heat, dryness, woollen and synthetic clothes, soaps, detergents, solvents.
- Advise on use of appropriate PPE for task involved.

(2) **Topical eczema care:**
- **Hygiene:**
  - Wash daily to remove old ointment, necrotic tissue, crust and bacteria. Use a soap substitute to limit the irritant effect of detergent.
- **Acute eczema phase:**
  - Use potent steroids to control the eczema.
- **Chronic eczema phase:**
  - Wean to less potent or diluted steroids, tars or emollients.
- **Moisturise:**
  - Apply appropriate, acceptable emollient liberally.

(3) **Specific measures:**
- Formal patch testing may be needed to identify specific allergens.
- Treat secondary infections as per identified organisms.
- Control stasis oedema with elevation, exercise and pressure garments.

**Folliculitis**

This is a common, inflammatory condition of any hair follicle. Infection is usually due to *Staphylococcus aureus*. Less commonly, gram-negative bacteria or fungi may be involved. Occlusion, pressure or friction of the skin, adhesive dressings, high humidity, and contact with tar or oils are all contributing factors. When due to these effects, the pustules may be sterile.

![Folliculitis](image)

**Folliculitis**

Papule or pustule with erythematous halo
Involves the hair follicles

**Treatment:**

(1) Keep the affected area clean and dry.
(2) Remove or control predisposing factors if possible, such as vapour impermeable PPE, humidity, tar and oil exposure.
(3) Treat infections identified by pus culture with appropriate oral or topical therapy dependent on the severity of the folliculitis.
(4) Eliminate reservoirs of infection. Advise on anti-staphylococcal measures to eliminate a *Staphylococcus* carrier state (see table) and *Pseudomonas* in stagnant water, if there are frequent recurrences.
Foot problems in mineworkers.

According to miners, feet problems are extremely common. Workers report that because of heat, humidity, heavy physical work, occlusive footwear, excessive sweating and prolonged open wet conditions underground, their feet are wet throughout their shifts. Excess moisture causes softening of the horny layer of the skin which appears a soggy white colour. The process favours micro-organism growth and loss of skin barrier function.

(1) Fungal infections (yeasts and dermatophytes) thrive especially in the moist web spaces.

(2) Bacterial infections of the hydrated, mace-rated soles cause a pitted, worm-eaten appearance and/or superficial erosions (pitted keratolysis). This is usually asymptomatic but may cause burning and discomfort. Salmon pink fluorescence is seen with UV light examination.

(3) Malodorous, “smelly” feet are a consequence of the micro-organism overgrowth.
(4) Loss of the skin barrier predisposes to irritant and allergic contact dermatitis.
(5) Ill-fitting boots cause corns and calluses.
Treatment:
The aim of treatment is to reduce over hydration and remove pressure.
(1) The feet should be well dried after washing and dusted with a bland, absorbent powder (Fuller’s earth, talc).
(2) Clean absorbent socks (preferably cotton) used daily will reduce the effects of occlusive boots.
(3) Specific complications are treated as they arise.

| Erythromycin (lotion or systemic) is the treatment of choice for pitted keratolysis. |

Fungal infections
tinea corporis (body), tinea cruris (groin), tinea faciei (face), tinea capitis (scalp hair), tinea manuum (hands), tinea pedis (foot), tinea unguium (nail)

Fungal infections
Itchy
Scaly
Vesicles and blisters may occur on active edge
Secondary infection may complicate the presentation
These common conditions are caused by infection of the scaly layer of the skin by dermatophyte fungi. They may infect any area of the body and itching is variable occurring predominantly with inflammatory presentations. The characteristic feature of the skin lesion is the well demarcated active edge, erythema, papules, vesicles, pustules, erosions, scaling or hair loss. Central healing may occur, although on the palms, soles and scalp there may be diffuse, fine scaling. The skin lesions tend to be asymmetric in distribution. Infection of the groin area may present with symmetrical well defined patches on both thighs, but seldom involves the scrotum.

Fungal infections of the nail start at the edge of the nail causing it to becomes deformed, crumbly, thickened and yellow to white in colour. Superficial infection of the nail presents as crumbly, white irregular areas on the nail surface.

Sweating, high humidity and tight or synthetic clothing and PPE may predispose the individual to fungal infections and promote recurrences. Repeated reinfection from reservoirs such as toenails is common. Consider predisposing causes such as diabetes, steroid therapy or immunodeficiency states for resistant, severe, multiple fungal infections.

Without treatment, fungal infections are chronic and slowly progressive. With optimal treatment the lesions disappear promptly but recurrence may occur, even in the absence of obvious predisposing factors.

**Confirm the diagnosis**

It is best to confirm the diagnosis before starting treatment. This is done by scraping broken hairs or scales from the active edge or crumbly nail onto a glass slide. After adding a drop of 20% potassium hydroxide the preparation is covered with a coverslip and heated gently. This dissolves the scale allowing branching hyphae (seen in the dermatophyte skin and nail infections) and spores (found in the broken off hair infections) to be seen under the microscope.

**Treatment:**

(1) **General:**

- Eliminate predisposing factors and prevent spread of infection between workers. Communal ablutions predispose to inter-worker spread. Advise worker not to walk barefoot especially in public places.
- Keep skin clean and dry. Promote good foot care. Advise the use of cotton socks and open shoes, where possible, for feet infections. Socks may be sterilised by boiling.
- Do not share PPE.

**The choice of footwear and the workers lifestyle are probably responsible for many recurrences, infection being spread readily in carpets and ablation facilities in communal and public institutions.**

(2) **Specific:**

**Topical agents:**

- A variety of topical agents are available including Whitfield’s ointment (salicylic and benzoic acid in a 1:2 ratio), undeconates, imidazoles and allylamines. The choice is determined by the area of the body involved and the cost. The newer antifungals are more effective and come in a wide variety of formulations but they are more expensive.
Nail infections: Combine nail avulsion and antifungal treatment

Chemical avulsion: Apply 40% urea and occlude with plaster for 24 hours. Scrape off loose debris, wash well and re-apply. Repeat daily until abnormal nail area has been removed.

Topical nail antifungal (limited infections): Amorolfin, Bifonazole, Tioconazole

Hair infections: Only oral therapy is acceptable

Oral agents: Griseofulvin 10mg/kg/day, Itraconazole 200-400mg/day, Terbinafine 250mg/day

Treatment period depends on the area of the body involved and the response to treatment

Deep fungal infections

Sporotrichosis

The fungus that causes this condition is found in organic material and is an occupational hazard of gardeners and farm workers. However, in older mine workings, props of contaminated timber may still be found. In the 1940’s, thousands of mineworkers developed sporotrichosis. Since then wood has been properly decontaminated. Miners are warned not to touch underground timber.

The infection starts as a red asymptomatic swelling at the site of inoculation. This gradually enlarges and the infections spreads up the lymphatics causing similar lesions. The diagnosis is made by biopsy and culture of tissue. Systemic antifungals are used for treatment.

Histoplasmosis

Bats may nest in caves and shallow, old mines. Their droppings contain spores that may be inhaled to cause fungal lung infections. Occasionally, skin nodules will develop as a result of generalisation of the disease.

Skin lesions may take various forms, including nodules and papules with a central umbilication. The diagnoses is made by biopsy and culture of tissue. Systemic antifungals are used for treatment.

Tinea versicolor (pityriasis versicolor)

This condition is caused by *Pityrosporum orbiculare* a yeast commensal. The rash occurs typically on the trunk, may be itchy, but is usually asymptomatic. Active infection is suggested by the presence of scale, which may be accentuated if the skin is stretched. High humidity and diseases associated with increased sweating are predisposing factors.

Investigation: Microscopy of skin scrapings reveals short unbranched hyphae and spores.
Treatment:

(1) Selenium sulphide application to **whole body** overnight, weekly x 3 weeks.
(2) Topical: Imidazole preparations.
(3) Oral: Imidazoles for severe or persistent infection.

**Griseofulvin is not effective.**

Repigmentation may not occur immediately after eradication of the organism. The absence of scale indicates adequate treatment.

**Miliaria (obstruction of the outlet of the sweat gland)**

Miliaria is due to obstruction of the sweat gland ducts with sweat retention and duct rupture. They occur as a direct result of heat and humidity often after prolonged exposure. The level of rupture determines the clinical picture. Heat tolerance can be compromised due to decreased sweating and can lead to heat exhaustion and collapse especially with widespread involvement and miliaria profunda. Individual susceptibility varies. Predisposing factors include poor acclimatisation, obesity, underlying dermatitis (especially seborrhoeic dermatitis) and tight non-porous clothing.

**Miliaria**

- Pinhead vesicles on normal skin — miliaria crystallina
- Pinhead vesicles, itch and redness — miliaria rubra
- Skin coloured papules — miliaria profunda

Treatment:

- Treatment is symptomatic and preventative
- Cooling is the aim of acute management
- Topical steroids lotions may control itch and inflammation
- Removal of the obstruction of the sweat duct occurs with natural desquamation, which may take several days or weeks (miliaria profunda)
- Environmental controls, acclimatisation, non-occlusive clothing, and good hygiene are preventative measures

**Pigmentation changes**

Changes in skin colour are caused by many different mechanisms.

Following inflammation of the skin, due to any cause, the colour of the skin may darken, especially in dark skinned people, and become brown-black in appearance (post-inflammatory hyperpigmentation). A decrease in pigmentation (post inflammatory hypopigmentation) or total loss of colour (post inflammatory depigmentation/ acquired vitiligo) can also occur.

Chemicals such as alkyl phenols (para tertiary amylphenol, para tertiary butyphenol, and menobenzyl ether of hydroquinine) if in contact with the skin, as fumes or as a liquid, may cause a loss of pigmentation (acquired vitiligo).
Some metals cause specific skin discolouration. A green colour to the tongue may be due to vanadium. Infections with pseudomonas can also appear green. A slate grey colour could be due to agyria (silver) or gold. Black could be due to coal dust, tar or foreign body tattoos (secondary to skin penetration).

**Scleroderma**

This has been reported in mineworkers who are exposed to silica dust and who have silicosis. Underground workers on gold and coal mines and workers involved in sandblasting and quarrymen are susceptible. The lungs and kidneys are primarily affected, but the skin especially of the face and hands can also be involved. Affected workers find that their hands become white and painful in the cold.

Patients should be removed from exposure and referred to a physician for specific management.

![Scleroderma](image)

**Scleroderma**

Pigment loss or increase
Thickened bound down shiny smooth skin

**Urticaria**

Urticaria can be acute (lasts less than 6 weeks) or chronic (lasts more than 6 weeks). The cause of the acute attack may be identified from the history, but in chronic urticaria it is difficult to identify the cause. An itchy recurring condition, due to an allergy to insect bites including fleas, mosquitoes, midges, mites and bed bugs is known as papular urticaria.

Varying numbers of lesions occur all over the body changing shape and position but never leaving scars. Swelling of the lips, tongue or mucosal lining of the respiratory tract may occur causing breathing problems.
Urticaria can be made worse by stress, certain medication (codeine derivatives, aspirin, non steroidal antiinflammatories), certain food (salicylate or histamine containing) and environmental agents.

Papular urticaria
- Grouped or linear urticarial papules
- Central red mark (bite site) or vesicle
- Scabs, increased or decreased pigmentation
- Crops of lesions

Scratching causes erosions, crusts or scabs and secondary infection. Healing leaves dark or white spots and/or scars, depending on the degree of infection and trauma related to scratching. The lesions may be seasonal, related to the life cycle and habits of the insect. The condition tends to settle spontaneously with time but it may recur on exposure to insects in a new environment (after moving house, visiting a friend, going on holiday, changing work environment).

Treatment:

**Urticaria**
1. Regular antihistamines will control most urticarias. The antihistamines may need to be varied or used in combination before control is achieved.
2. Manage any problem with breathing as an emergency.
3. Stop all non essential medications and simplify activities of daily living to bland essentials.
4. A diary of all activities of daily living may help identify precipitants in cases of chronic urticaria.
5. Extensive investigations, especially allergy tests are not indicated in most patients.

**Papular urticaria/insect bite allergy**
1. Eliminating ongoing exposure and contact with the insect (fumigation). Insect repellents (DEET, tar, thiamine 50 mg and/or garlic daily) are sometimes helpful.
2. Topical steroids are used on acute itchy lesions for a few days weaning to weaker preparations.
3. Treat secondary infections.
Appendix 13.3

Patch testing

Patch tests are used to identify substances causing allergic contact dermatitis. The need for patch testing should be judged on the merits of each case. Patch tests have no relevance in obvious cases of irritant contact dermatitis unless an element of concomitant allergic contact dermatitis is suspected.

While standardised commercial allergens are easy to use, the reading, interpretation and evaluation of the results requires expertise. If non-standardised allergens need evaluation, knowledge of the substances being tested, how they must be diluted (vehicle, concentration, and pH-neutralisation) and the appropriate method for testing can only be done by an expert. This will prevent irritant reactions and burns from being interpreted as allergic reactions.

Because of the paucity of experts in South Africa, patch testing is a skill that may need to be developed by occupational health workers in consultation with the local expert in their area.

Guidelines for patch testing:

- Never test in the setting of acute or severe dermatitis
- Do not test patients taking systemic steroids as the allergic reactions are suppressed
- Systemic antihistamines do not suppress the reaction
- Topical steroid use in the test area must have been discontinued at least 48 hours prior to testing, preferably longer if potent products have been used
- Avoid patch testing in patients who give a history of an immediate urticarial type skin reaction
- Never test unnamed or unidentifiable substances
- Control testing, to rule out an irritant effect, is essential for non-standard allergens giving a positive reaction

Standard allergen testing methodology:

Allergens are applied to the upper back or upper arms provided these areas are free of disease. The areas of allergen contact with the skin are marked on the skin to allow allergen identification. Any non-irritant marker can be used provided it remains visible for several days after being applied.

The area of allergen application must be kept dry. Limit sweating, excess steam exposure or immersion until the results have been read.

Each reaction should be evaluated for clinical and occupational relevance. Is it relevant to the current presentation or a manifestation of a past problem? Is it related to occupational exposure or due to some other activity of daily living?

Allergens

Standard allergens are available commercially. In South Africa, the European standard series is used routinely. Although this contains the most commonly identified allergens in Europe, there are no data to show that they are appropriate to South Africa, let alone mining. The choice of allergens to be tested is often not comprehensive or adequate, as not all known allergens are commercially available. Allergens listed in the limited published works on mining (1) are given in Table 13.2.

Own product (substances used in the home or the workplace) testing is usually required after an investigation has identified the potential hazards to ensure that all allergens are included.

Application method

The application method is dependent on the substance to be tested. Occlusive methods use aluminium or plastic chambers affixed to hypoallergenic tape as allergen containers. Semi-occlusive testing requires that the allergen is applied to the skin and covered with a semi-permeable tape. Open testing
requires that the substance be applied to the same area of skin for a specific time. Occlusive tests are suitable for standard allergen preparations or own products prepared in such a way as to exclude irritant reactions. The other two methods are more appropriate for own product testing.

**Application time**

This is dependent on the allergen. Most standard allergens are kept in contact with the skin for 48 hours.

**Reading the patch test**

The tests are read after 48, 72 and 96 hours of skin contact dependent on the allergen and the ability of the patient to return for repeat visits. If only a single reading is possible then 72 hours is chosen, otherwise the tests are read after 48 and 96 hours of occlusion.

<table>
<thead>
<tr>
<th>Morphology</th>
<th>Interpretation</th>
<th>Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>+/- Macular erythema</td>
<td>doubtful</td>
<td>unknown</td>
</tr>
<tr>
<td>1+ Oedematous, non-vesicular erythema</td>
<td>weak</td>
<td>allergy</td>
</tr>
<tr>
<td>2+ Erythema, oedema and vesicles</td>
<td>strong</td>
<td>allergy</td>
</tr>
<tr>
<td>3+ Spreading erythema, oedema and vesicles, progressing to bullae/ulceration</td>
<td>extreme</td>
<td>allergy</td>
</tr>
<tr>
<td>IR Glazed, burned, pustular or purpuric reactions</td>
<td>irritation</td>
<td>irritation</td>
</tr>
<tr>
<td>— Negative</td>
<td>negative</td>
<td>negative</td>
</tr>
</tbody>
</table>

(IR = Irritant reaction)

A negative patch does not necessarily mean that no allergy exists. The test could have failed because of improper antigen selection, testing at too low a concentration, use of an inappropriate vehicle, incorrect testing techniques or the presence of confounders such as steroid use.

A positive patch test does not necessarily imply allergy. An irritant reaction may be misinterpreted as a positive result.

A positive patch test does not necessarily imply clinical relevance, as it may relate to a prior problem or represent cross-reactivity.

While the process of patch testing is relatively simple, the interpretation of the results and the ability to advise workers appropriately requires an in-depth knowledge of the allergens and where they are found, skin management principles and associated aggravating factors.
Appendix 13.4

Formulary

References:

- **Handbook of Dermatology for Primary Care.** Saxe N, Jessop S, Todd G. Oxford University Press. Oxford, 1999

Topical therapy principles

Topical therapy is the mainstay of dermatology treatment. It must be used in the correct way and for the appropriate indications for the best results.

1. The patient’s preferences, work and home circumstances determine treatment choice.
   - Choose the most appropriate preparation for the body area and skin disease to be treated

<table>
<thead>
<tr>
<th>SKIN TYPE</th>
<th>SUGGESTED VEHICLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>wet, eroded</td>
<td>lotion or cream</td>
</tr>
<tr>
<td>dry, lichenified</td>
<td>ointment</td>
</tr>
<tr>
<td>face</td>
<td>cream or lotion</td>
</tr>
<tr>
<td>hairy areas</td>
<td>lotion or gel</td>
</tr>
<tr>
<td>body folds</td>
<td>lotion or cream</td>
</tr>
</tbody>
</table>

   - Strongly smelling preparations are often unacceptable to patients
   - Laborious treatments are unsuitable for those who work long hours with limited ablution facilities

2. Explain why the topical application is to be used and advise on side effects.
   - preservatives (found in water-based formulations) may cause allergic reactions

3. Wash regularly with bland soap or soap substitutes to remove old topical applications, body secretions, crusts, and colonising or infecting organisms.

4. Explain exactly how topical applications are done. Ideally the method of application for each preparation should be demonstrated by the caregiver.

5. Adequate quantities of topical medication (about 250g per week for whole body) are essential.

   **Give adequate quantities of ointment, cream or lotion.**

Antihistamines

Antihistamines, used principally for acute and chronic urticaria, fall into four chemical groups. If the condition fails to improve with one agent, a drug from another group, or a combination of the two, can be tried. These agents treat the symptoms of urticaria, the cause and aggravating factors need to be identified and avoided for long term remission. The sedating property of some antihistamines is useful in treating severe atopic eczema. One of the newer, less sedating agents is preferable for those who need to be alert to drive, operate machines etc.
**EXAMPLES OF SOME ANTIHISTAMINES**

<table>
<thead>
<tr>
<th>Group</th>
<th>Generic name</th>
</tr>
</thead>
<tbody>
<tr>
<td>alkylamines</td>
<td>Chlorpheniramine</td>
</tr>
<tr>
<td></td>
<td>Dexchlorpheniramine</td>
</tr>
<tr>
<td>aminoalkyl ethers</td>
<td>Clemastine</td>
</tr>
<tr>
<td>ethylenediamines</td>
<td>Mepyramine</td>
</tr>
<tr>
<td>phenothiazines</td>
<td>Alimenazine/</td>
</tr>
<tr>
<td></td>
<td>Trimeprazine</td>
</tr>
<tr>
<td></td>
<td>Promethazine</td>
</tr>
<tr>
<td>piperazines</td>
<td>*Cetirizine</td>
</tr>
<tr>
<td></td>
<td>Hydroxyzine</td>
</tr>
<tr>
<td></td>
<td>Oxatomide</td>
</tr>
<tr>
<td>other</td>
<td>*Acrivastine</td>
</tr>
<tr>
<td></td>
<td>Azatadine</td>
</tr>
<tr>
<td></td>
<td>Cyproheptadine</td>
</tr>
<tr>
<td></td>
<td>*Ebastine</td>
</tr>
<tr>
<td></td>
<td>*Fexofenadine</td>
</tr>
<tr>
<td></td>
<td>*Loratadine</td>
</tr>
<tr>
<td></td>
<td>*Terfenadine</td>
</tr>
</tbody>
</table>

*non-sedating antihistamines

**Topical steroid therapy**

The choice of a topical steroid preparation depends on the severity of the skin disease and the area to be treated.

| Very potent steroids should not be used on the face or in the body folds |

A good practical tip when using topical steroids is to start with a potent steroid to suppress inflammation. Once this has been achieved, remission should be maintained by weaning to a weak or diluted preparation or emollient.
### COMPARATIVE POTENCIES OF TOPICAL STEROIDS

<table>
<thead>
<tr>
<th>Group I WEAK</th>
<th>Cutaderm®, Dilucort®, Skincalm® Biocort®, Mylocort®, Procutan®, Stopitch®</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrocortisone 0.5%</td>
<td></td>
</tr>
<tr>
<td>Hydrocortisone 1%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group II MODERATELY POTENT</th>
<th>Aclostone®, Betnovate $\frac{1}{2}$ strength®, Celestoderm-V $\frac{1}{2}$ strength® Eumovate®,</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alclometasone</td>
<td></td>
</tr>
<tr>
<td>Betamethasone</td>
<td></td>
</tr>
<tr>
<td>Clobetasone</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group III POTENT</th>
<th>Diprosone®, Adco-betamethasone® Betnovate®, Celestoderm-V®, Lenovate®, Persivate®, Topivate®, Nerisone®, Cortoderm®, Synalar®, Cultivate®, Locoid®, Advantan®, Elocon®, Elomet®, Elica®</th>
</tr>
</thead>
<tbody>
<tr>
<td>Betamethasone dipropionate</td>
<td></td>
</tr>
<tr>
<td>Betamethasone valerate</td>
<td></td>
</tr>
<tr>
<td>Diflucortolone</td>
<td></td>
</tr>
<tr>
<td>Fluocinolone acetonide</td>
<td></td>
</tr>
<tr>
<td>Fluticasone</td>
<td></td>
</tr>
<tr>
<td>Hydrocortisone butyrate</td>
<td></td>
</tr>
<tr>
<td>Methylprednisolone</td>
<td></td>
</tr>
<tr>
<td>Mometasone</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group IV VERY POTENT</th>
<th>Diprolene®, Dermovate®, Dovate®, Nerisone Forte®</th>
</tr>
</thead>
<tbody>
<tr>
<td>Betamethasone dipropionate</td>
<td></td>
</tr>
<tr>
<td>(in propylene glycol)</td>
<td></td>
</tr>
<tr>
<td>Clobetasol</td>
<td></td>
</tr>
<tr>
<td>Diflucortolone</td>
<td></td>
</tr>
</tbody>
</table>

Prolonged use of (especially potent steroids) may cause any of the following side-effects including atrophy, acne, hypopigmentation, increased skin fragility and bruising, masking/promotion of fungal and bacterial infection, perioral dermatitis, rosacea, striae, telangiectasia, vasodilatation, and systemic absorption with suppression of the hypothalamic pituitary adrenal axis.

15g of topical product is needed for a single, full body application in an adult.
Topical steroids diluted in an appropriate ointment, cream or lotion base (vehicle) that will not interfere with the active ingredient provide larger quantities of the steroid at a reasonable price and improve the ease of topical applications.
Sun protection
Sun exposure should be avoided as far as possible.

Physical sun protection methods

- Outdoor activities should be limited when possible to early morning and late afternoon.
- Clothing (cotton gloves, large brimmed hats and overalls) that does not allow penetration of the sun’s rays but is comfortable and cool is preferable.

Topical sun protection methods

The SPF (sun protection factor), water resistance and the specific wavelength protection offered determine the choice of sun protection used under any set of conditions. The SPF refers to the increased time a person can spend in the sun before burning. If one burns after 30 minutes of sun exposure then, theoretically, using a SPF 15 topical cream one should be able to spend 30x15 minutes in the sun before burning. Products SPF rating should be verified by a standards surveillance body. Many of the topical preparations are not water-resistant thus repeated applications may be necessary with sweating and water immersion to ensure sun protection irrespective of the SPF rating. Broad-spectrum wavelength (UVA and UVB) protection is important for chronic daily sun exposure. Topical preparations should be used to supplement sun avoidance measures. These can be divided into two groups:

  a) **Physical sun blocks** contain zinc, titanium and sometimes iron. They act as physical barriers to light penetration. They protect against a broad spectrum of wavelengths. Sometimes patients find them cosmetically unsuitable as they leave a fine film on the surface of the skin.

  b) **Sunscreens or filters** contain chemicals that absorb light at specific wavelengths. They thus filter the light reaching the skin. The chemicals are used in combination to give a broad spectrum of protection but may cause irritant, allergic or photo-allergic reactions.

Combinations of physical and chemical filters are often used. They provide a broad spectrum of wavelength protection.

Oral sun protection agents

These are not of any significant clinical value, although beta-carotene has been used for the management of porphyria, with some success.

For patients with photosensitivity disorders or skin which burns easily, a minimum sun protection factor of 15 is advisable.
CHAPTER 14

Fitness to Work, Disability and Compensation

This chapter covers an approach to assessing fitness for work and assessing and managing work disability in employees. The concepts of minimum standards, unfitness for work, impairment and disability are defined. A structured, staged approach to fitness certification is presented as well as a stepwise approach to handling the unfit employee.

The two statutory compensation systems applicable to miners are described, one for occupational lung diseases under the Occupational Diseases in Mines and Works Act and one for all other diseases and injuries under the Compensation for Occupational Injuries and Diseases Act. Procedures are detailed for conducting medical benefit examinations under the former Act as well as for submitting occupational disease claims under both Acts.

Dr. G. Kew
Occupational Medicine Practitioner
Greg Kew has a postgraduate qualification in occupational health. He has worked as an occupational medicine practitioner on the mines and in a number of industrial settings. He is a part-time lecturer in the Department of Public Health, University of Cape Town. He has a particular interest in developing management systems for occupational health practice.

Prof. R.I. Ehrlich
Specialist in Public Health Medicine and in Occupational Health
Rodney Ehrlich has qualifications in economics, medicine, occupational health and epidemiology. He is associate professor in the Department of Public Health, University of Cape Town. He has published widely on occupational medicine and lung disease, and has served in an advisory capacity to the Departments of Health and Labour.
Glossary

Certification: Official documentation of fitness to work, or in case of compensation, of presence of occupational disease.

CCOD: Compensation Commissioner for Occupational Diseases (administers ODMWA)

COIDA: Compensation for Occupational Injuries and Diseases Act (Act 130 of 1993)

Compensation: Statutory provision for medical aid, for direct payment to individual or for death benefits as a result of an occupational injury or disease

Disability: Alteration of an individual’s capacity to meet personal, social or occupational demands or statutory or regulatory requirements because of impairment.

Fitness for work: Ability to meet the specific requirements of a task or job.

Impairment: A loss, loss of use or function, or derangement of any body part, organ system or organ function.

Medical benefit examination: Statutory examination to determine whether miner or ex-miner has a compensable lung disease in terms of ODMWA

ODMWA: Occupational Diseases in Mines and Work Act

Rehabilitation: Process of returning a physically or psychologically impaired employee to optimal functioning.
14.1 Introduction to determination of fitness to work

The concept “fitness to work” implies that an occupation has inherent health requirements that need to be met by a person in that occupation in order to minimise the risk of injury or illness. The concept of fitness is thus closely associated with the concept of risk.

Occupational risks fall into two categories:

• Risks associated with exposure to hazards in a particular occupation. These hazards include noise, heat, dust, ergonomic hazards, etc., with their associated adverse health effects on exposed employees
• Risks associated with failure to meet the capabilities (physical or psychological) required of a particular occupation. Certain occupations pose particular demands on the employee’s ability to perform the work in a manner that does not increase the likelihood of injury or illness to the employee or to co-workers

These two categories of risk imply four occupational categories:

• Those with specific health requirements, but low hazard exposure: e.g. bulk truck drivers, heavy passenger vehicle drivers, onsetters, banksmen
• Those with specific health requirements and high hazard exposure: e.g. rescue (“Proto”) teams, loco operators, scraper operators, drilling machine operators
• Those with low health requirements, but high hazard exposure: e.g. welding, “lashers”, underground maintenance staff
• Those with low health requirements and low hazard exposure: e.g. general surface workers, office and administrative staff

Medical evaluation of fitness to work has to cover both types of risk. A programme of examinations should ensure that minimum medical requirements are met by employees, and also that any adverse health effects from exposure to hazards in the workplace are detected at an early stage, enabling remedial action to be taken.

There has been considerable recent effort directed to the development of guidelines for a Code of Practice for Medical Surveillance and standards of fitness for work on a mine. A guideline document on the latter was published by the Department of Minerals and Energy in 2000. The key elements of these standards of fitness, taken from this guideline document, are reproduced in Appendix 14.1.

14.1.1 Minimum standards of fitness

The minimum standards of fitness for an occupation are the capabilities that are required to perform the occupation (inclusive requirements), as well as those abnormalities that the employee should not have in order for the job to be performed safely (exclusions).

Whilst it is incumbent on the employer to reduce or minimise the hazards to which employees are exposed, in certain circumstances inherent health and safety risks will remain. This is particularly so in the mining industry.

The rationale for conducting such examinations is to ensure that people who have a reasonable likelihood of suffering from the hazards of the job or of imposing additional risk on co-workers are excluded from those particular jobs. It is not intended to produce a “superhealthy” workforce by denying employment to those who have impairments or a medical history of illness.

Minimum standards of fitness need to be fair and defendable, and expressed in a way that is measurable to ensure consistent application. In the mining industry, all employees involved in risk work are required to undergo an initial medical examination and be certified fit for work by an occupational medicine practitioner prior to their engagement in risk work. This needs to be repeated at prescribed intervals. This process is legally prescribed in both the Occupational Diseases in Mines and Works Act (ODMWA) and in the Mine Health and Safety Act.
Historically this certificate of fitness has been known as the “Red Ticket”, a term derived from the red card issued to miners by the Medical Bureau of Occupational Diseases, authorising them to perform risk work for a prescribed period of time. At the end of the authorised period, the employee was required to undergo a periodic medical examination, to ensure that he/she continued to meet the minimum standards of fitness to perform risk work.

14.1.2 The legal requirements in respect of fitness to work

Various statutes and regulations, guidelines and guidance notes published in terms of these statutes govern fitness to work. The provisions relevant to work fitness and disability are summarised below. These statutes are covered in more detail in Chapter 1.

Mine Health and Safety Act 29 of 1996 (MHSA)

The MHSA provides for the protection of the health and safety of employees and other persons at mines and requires risk assessment, exposure measurement and risk control. Part of risk control is medical surveillance, which has two main objectives: to ensure that employees meet the minimum standards of fitness to work, and to identify early signs of occupational disease. It is a specific requirement of each mine to establish a Code of Practice for Medical Surveillance.

An employee may appeal against a finding of unfitness for work or a finding in an exit medical certificate (section 20 of Act). This appeal is directed to the Medical Inspector.

The Basic Conditions of Employment Act 75 of 1997 (BCEA)

The BCEA contains a number of provisions that relate to the issue of fitness for work such as paid sick leave, medical certificates, maternity leave, protection of employees before and after birth of a child and night work.

The above provisions do not apply to an inability to work caused by an accident or an occupational disease as defined in ODMWA, except in respect of any period during which no compensation is payable in terms of ODMWA.

Employment Equity Act 55 of 1998 (EEA)

The EEA provides for the eradication of unfair discrimination in the workplace (including discrimination against the disabled) and affirmative action in the workplace in respect of Blacks, women and disabled persons.

The EEA makes provision for two defences against an allegation of unfair discrimination, namely:

- that the employer acted in terms of an affirmative action policy; or
- that the inherent requirements of the job are such that the disabled person would not be able to do the job

Medical testing is also regulated. Medical testing of an employee is prohibited unless:

- legislation permits or requires the testing (such as prescribed by the MHSA or ODMWA); or
- it is justifiable in the light of medical facts, employment conditions, social policy, the fair distribution of employee benefits or the inherent requirements of the job

The concept of “inherent requirements of the job” can be regarded as equivalent to “minimum standards of fitness for the job”. These standards will be discussed in some detail in this chapter.

Labour Relations Act 66 of 1995 (LRA)

The LRA regulates unfair dismissal and unfair labour practices directed at employees, including disabled employees. In terms of the LRA, dismissal of a person solely on the grounds of disability is automatically unfair, and constitutes an unfair labour practice.
Conversely, the Act provides mechanisms for the fair dismissal of an employee who is incapable of doing his or her job because of poor health or injury. Such a dismissal must be both substantively and procedurally fair. Substantive fairness relates to the reason for the dismissal, i.e. the employee’s ill health or injury. Procedural fairness relates to the manner in which the case is conducted, prior to the decision to dismiss. The detail of these instructions is contained in the document Code of Good Practice: Dismissal, to which reference is made in the Act. (See Chapter 1 and also Guide to Resources at the end of this chapter).

14.1.3 Definitions

**Unfit for work**

This refers to failure to meet the specific requirements of an occupation. A person can be declared unfit because of a medical condition that excludes him/her from the relevant occupation, or because of demonstrable lack of capacity to perform the work.

**Impairment**

Impairment refers to deviation from the functional capabilities expected of an average healthy individual. Loss of hearing, visual acuity, lung function or joint motion are impairments. These are not necessarily disabilities, nor do they render a person automatically unfit. For example, significant loss of hearing acuity due to noise in the high frequencies may not produce any disability because the loss does not extend into the speech frequencies. This is taken into account in the formula for compensating noise induced hearing loss.

**Disability**

Work disability refers to an impairment that prevents the person from performing a task or occupation or limits the performance of the occupation or tasks. It thus overlaps with the concept of unfitness for work. The assessment of disability is complex and is determined by the purpose for which the assessment is being done. Legal, ethical and administrative factors all play a role.

Disability is usually classified with respect to extent and duration. In extent, disability may be total or partial. Total disability means that the person is unable to perform any form of recognised occupation. Partial disability implies that the person is unable to perform only certain specific tasks or occupations.

A person with a partial disability as legally defined, e.g. for compensation purposes, may or may not be unfit for their usual job. An example is an employee who loses a finger in an accident, but is still able to continue in his/her job. Hence the disability only renders the person unfit if it changes that person’s status in respect of the inclusion or exclusion requirements of that job.

Disability may be of temporary or permanent duration. Temporary disability may be brief, such as in the typical case of an injured employee who recovers within a few days to weeks, or may be long, such in the case of a person with an illness or injury with a prolonged convalescence (tuberculosis, major injuries). For occupational diseases and injury claims under the COID Act, conditions that cause a temporary disability for longer than two years are regarded as permanent. This is not so for claims against the private insurance industry, which may review long-term cases every one to two years, in order to ascertain whether the affected party has recovered sufficiently to reverse the status of disabled.

Permanent disability is irreversible and untreatable. Typical causes of permanent disability are amputations, spinal injuries, noise-induced hearing loss and silicosis.

The various combinations are as follows:

- Total temporary disability: employee on sick leave or accident leave
- Partial temporary disability: employee on “light duty” (if available); otherwise as for temporary total disability
• Total permanent disability: termination of job due to incapacity. This is discussed below
• Partial permanent disability: The outcome depends on whether the impairment renders the employee fit for his/her usual job. This is also discussed below

14.1.4 Principles of impairment and disability assessment

Medical practitioners may be called upon to evaluate impairment alone or impairment and disability. Impairment assessment is an objective quantification of loss of function or loss of body part, which is reproducible, whereas disability evaluation involves forming an impression of an individual’s capacity to meet personal, social and occupational demands. It is important that medical practitioners and the various stakeholders are able to clearly distinguish the two concepts in the process of medical adjudication.

The Compensation for Occupational Injuries and Diseases Act (COIDA) makes use of the concept of “disablement” and provides an administrative means of converting impairment to disablement. The example of converting impairment due to loss of hearing into disablement is covered later in the chapter. The Act also provides a table (Second Schedule) of fixed disablement percentages attributed to various anatomic losses.

In order to improve consistency in medical adjudication, and therefore the calculation of disability, impairment should be graded in a structured and objective manner. Various grading systems have been developed around the world for this reason. An example is the classification of impairment of lung function established by the American Thoracic Society, or the systems for evaluating various types of impairment developed by the American Medical Association. (See Guide to Resources).

A variety of South African guideline documents to assist the practitioner in the assessment of disability are available. Examples include guidelines on psychiatric disorders, spinal disorders and cardiac disorders. These and other relevant resource materials are listed under Guide to Resources at the end of the chapter.

14.2 Approach to the certification of fitness to work

The process of certification of fitness consists of the following three stages.

• Establishing the standards required for fitness for work
• Defining the elements of the medical examinations/surveillance
• Managing the outcomes of these examinations, including medical adjudication of cases of incapacity and disability among employees

14.2.1 Stage 1: establishing medical standards for fitness for work

Professionals involved in the planning of medical surveillance programmes frequently underestimate this stage. It comprises three steps:

• Risk assessment
• Occupational risk and exposure profiling (person-job specifications)
• Setting standards for medical surveillance

Step 1: Risk Assessment

The objective of risk assessment is to identify all relevant health hazards and the degree to which the various occupations are exposed to these hazards. (See Chapter 3). Risk is the product of both the hazard (the capacity to cause harm) and the extent of exposure. A clear understanding of these risks is essential prior to setting medical standards for these occupations. At the end of this risk assessment process, each occupation should have a clearly defined risk profile.
Figure 14.1 Process of assessing work fitness and management of disability
Step 2: Occupational risk and exposure profiling (person-job specifications)

This step includes the process of documenting the risks for each and every occupation on the mine. These documents usually comprise a page per occupation, and are kept in a file. Copies of this file are held at the medical station and the Human Resources department. These documents are sometimes referred to as “person-job specifications” for the various occupations, and should cover both the inherent requirements of the jobs and the expected hazard exposures. An example is included as Appendix 14.2 for illustration. (Note that the example provided there is not necessarily the typical profile of a loco operator).

Step 3: Setting standards for medical surveillance

Once these risk profiles are established, the occupational medicine practitioner should set medical standards for each of these occupations as determined by the risk profiles. The medical examinations required to identify the relevant exclusions (or inclusions) should be stated, with the relevant minimum standard required. For example, if a minimum visual requirement is listed, the exact minimum standard for that occupation should be recorded. The same process applies to minimum lung function, etc.

To assist occupational medical practitioners in this exercise, as well as to set national benchmarks, the Mining Occupational Health Advisory Committee (MOHAC) has published guidelines for the minimum standards of fitness to perform work in a mine. A summary of this document is provided in Appendix 14.1. The original is obtainable from the Department of Minerals and Energy (DME).

With the assistance of these guidelines and this handbook, the occupational medicine practitioner should be in a position to draw up a medical surveillance programme for each occupation on the mine. The risk assessment, risk profiles and the occupation-specific medical surveillance programme will then comprise the overall code of practice which is a mandatory document required by the Chief Inspector of Mines of the DME.

14.2.2 Stage 2: defining the elements of medical surveillance

Medical examinations may form part of routine structured medical surveillance or occur by referral for poor work performance, ill health or return to work. Examinations for poor work performance are dealt with in section 14.3.2 below. This section covers routine examinations.

**Initial medical** This is required for new work applicants. The findings of the initial medical examination are recorded on form GW 24/57, “Application for Examination for Certificate of Fitness”.

**Transfer medical** This may be required for employees being transferred between jobs.

**Periodic medical** This refers to the examinations of employees conducted at specified intervals. The contents of the examinations and their intervals are prescribed in the mandatory code of practice for medical surveillance.

The findings of the periodic examination are recorded on form GW 24/38, “Periodical Examination”.

Previously, these documents were sent to the Medical Bureau for Occupational Diseases, where the decision regarding fitness to perform risk work on the mine was taken. The current procedure is that the appointed occupational medicine practitioner is authorised to decide on fitness to perform risk work, and issues the certificate directly to the mine or employee.

**Exit medical** The exiting employee’s health status is required to be documented in detail and recorded on a certificate that is issued to the employee. The intention is that the employee will make this certificate available at his or her next place of work, thereby providing continuity from one place of work to another. This is particularly important where a lifetime cumulative hazard exposure record is necessary, as in occupations in which exposures are cumulative over time (silica dust, asbestos dust, carcinogens, noise, etc.). With the cumulative increase in exposure years to these agents, the likelihood of adverse health effects increases and the vigilance of the examining practitioner should increase accordingly.

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There is no statutory form for an exit certificate, but it should contain the following particulars.

- Particulars of the mine
- Particulars of the employee
- Exit medical summary, including:
  - Chest radiograph findings
  - Lung function findings
  - Audiometry findings
  - Other biological monitoring findings (where relevant)
- A list of the hazards to which the employee was exposed
- Any occupational diseases present
- Compensation received and outstanding

Some mine medical services have developed computerised exit medical certificates that are generated on completion of the examination.

The circumstances in which all of the above examinations are conducted will vary from mine to mine. Many mines will have their own infrastructure and employ medical staff. At these, the medical examinations will be conducted on site. At smaller mines and controlled works, off-site contracted medical practitioners will conduct some of these services. However this is conducted, the final common pathway is the issuing of a medical certificate of fitness. This is either handed directly to the employee or applicant who takes it to the Human Resources department for action (if any) or is passed directly to Human Resources by the medical practitioner.

Should the medical practitioner’s examination identify conditions that render the applicant (or current employee) unfit to work in the occupation, this needs to be handled in a fair and sensitive manner. This comprises a third stage of the process of certification — medical adjudication.

14.2.3 Stage 3: medical adjudication

Employees currently employed by a mine

Once the medical surveillance sequence is completed, the responsible practitioner is required to evaluate the findings and decide whether or not the person is fit for the occupation envisaged. Should the inherent requirements of the occupation be met, as defined by the code of practice, the certificate of fitness is signed accordingly. If the requirements are not met, a decision is to be taken as to how to deal with this.

Prior to the introduction of the new Labour Relations Act, in which new work applicants are to be treated for purposes of medical assessment in the same way as current employees, surveillance programmes often carried less stringent requirements for current employees than for new work applicants. Currently the practice is to apply the standards agreed in the code of practice to all participants in the medical surveillance programme in an equal fashion. However, some discretion is allowed to the responsible practitioner where some uncertainty exists as to the fitness of the candidate. A current employee has work history and work performances that are known to the company and practitioner, which is not the case for a new applicant.

Current employees who are found not to meet inherent health requirements which are not of a critical nature may be authorised to continue in their jobs, on the basis that they have a past record that indicates they are able to meet the performance requirements of the occupation.

Where no statutory exclusion is applicable, the decision as to whether or not to allow an employee to continue to work in an environment which has the potential to aggravate an already present medical condition, is a difficult one given the serious consequences to the employee of loss of job or earnings. In terms of the law, the primary onus is on the employer to reduce health and safety risks in the
environment so as to protect the health of all employees. This can be taken to include “vulnerable” employees. Whether this is reasonably practicable as defined in the Act remains a matter of legal interpretation.

One approach to this problem would be to allow the vulnerable employee to continue to work subject to closer medical surveillance. Evidence of significant worsening of the medical condition over a period involving at least three examinations (for example 6 months to a year, depending upon the severity of the problem), should be considered an absolute exclusion.

New applicants
The new Labour Relations Act requires the employer to regard a new applicant in the same light as an employee. Legally, the sequence described for the “unfit employee” (below) should apply to new applicants as well. It is legally contentious whether it is reasonable to keep a post open for a new applicant whilst he/she goes for treatment or rehabilitation for a medical condition that renders that applicant unable to meet the requirements of the job. Factors that would be taken into account in determining what was reasonable include whether there is an immediate operational need for the services of the applicant.

14.3 Managing the current employee found to be unfit

14.3.1 Stepwise approach
In this section, for the sake of brevity, “unfit”, “incapacitated” and “disabled” will be regarded as synonymous, notwithstanding the differences between them discussed earlier in this chapter.

Unfitness can be considered in the same way as disability, i.e. with respect to extent and duration.

Step 1: Decide whether temporary or permanent (duration)
The duration of the unfitness is the length of time that the employee is likely to remain unable to meet the requirements of the occupation.

- Temporarily unfit: the employee fails to meet the requirement of the job on the grounds of a medical condition that is temporary or treatable
- Permanently unfit: the employee fails to meet the requirement of the job on the grounds of a medical condition that is permanent or untreatable

Whilst the period of recovery is often difficult to predict in medicine, even very approximate estimates are useful for company management who are involved in human resources planning.

Note that the duration of unfitness is also dependent on whether or not the disorder is treatable under optimal conditions. Many factors influence this, including the reality that, whilst some conditions may be treatable in theory, the optimal medical treatment is not available for various reasons (financial, geographic or even cultural). If a remedial medical treatment is available, the condition should be regarded as temporary. Sometimes, a remedial medical treatment is not required, such as in cases when the disablement simply requires a prolonged period of recovery without specific intervention after which time normal function will be restored. This is usually the case in situations such as severe orthopaedic injuries at the end of their active rehabilitation phase. Normal physical capability might only be restored many months after active rehabilitation has been discontinued.

Step 2: Decide whether total or partial (extent)
The extent of the unfitness refers to the significance of the failure to meet the inherent requirements of the job, i.e. the likely consequences of the person continuing in that occupation. Many of the inherent job requirements, particularly the exclusions, are relative exclusions rather than absolute.
• **Relative exclusion:** This is a failure to meet the minimum standard of fitness, but the consequences of which do not automatically render the applicant unfit. A measure of decision latitude exists, according to circumstance.

• **Absolute exclusion:** This is a failure to meet the minimum standard of fitness, the consequences of which automatically renders the applicant unfit. No decision latitude exists.

For example, where hypertension is an exclusion for a particular occupation, it is reasonable to regard varying levels of raised blood pressure as relative levels of exclusion from that work. A blood pressure which is slightly over the normal limit requires a different reaction to a blood pressure which is life threatening. The employee with the slightly raised blood pressure could be allowed to return to work with the restriction that he return for regular monitoring, and that the blood pressure is seen to return to normal over time. By contrast, the employee with the critically raised blood pressure would be required to cease working in the relevant occupation immediately.

Where the disability is *partial*, the following issues should be addressed:

1. **Can the affected employee be deployed in an alternative occupation, even if this means a reduction in income?** Where available, the pension or provident fund should be approached for a top-up of the reduced income. This is a favourable option for insurance funds, as it constitutes a far lesser cost than a payout for total disability.

2. **If not, can the affected employee be retrained to meet the requirements of an alternative occupation?**

3. **If none of the above, can the employee’s occupation (or any other occupation) be reasonably adjusted to accommodate the disability?** This could include:

   - **Engineered adjustments**, such as redesigned work areas or workstations. An example is the installation of ramps and lowering of work surfaces for spinally injured employees, who may be redeployed to the workshops or other maintenance tasks. In general, the scope for engineered adjustments in the underground environment remains limited, unlike in surface operations and plants. The numbers of jobs available on surface are also far fewer than underground.

   - **Administrative adjustments**, such a reductions in hours of work (such as a “5/8th” post), or restricted duties. Restricted duties underground would include work in the haulages, at the bank, or in higher stopes. The restrictions would be determined by the employee’s specific limitations (removal from high heat, dust, dangerous machinery, heights, etc.).

An employer is not obliged to create a new post for the incapacitated employee, even for work-related illness. If any of the answers to the above questions are “yes”, then the logical sequence follows. If not, and the employer cannot leave the post unfilled for a longer period because of operational necessity, the employee is regarded as incapacitated and unsuitable for continued employment in the relevant occupation. Dismissal may then be considered.

### Step 3: Manage return to work, rehabilitation and reintegration

After steps 1 and 2, a more detailed look at the process of returning to work is required, whether this is to the employee’s original occupation, or an alternative.

All reasonable attempts should be made to enable the employee to recover, and return to some form of work. The first objective is to apply whatever medical treatment options are available to restore normal (or optimal) function. Should this not be possible, it is incumbent upon the employer to attempt to find other suitable work for the affected employee on the mine. This requirement applies to all affected employees — whether the underlying cause for the problem is work-related or not.

However, the Labour Relations Act makes special provision for those that have been injured on duty or have an occupational disease. In this case, there is a further requirement on the company to make every effort to find other suitable work for the affected employee. If no suitable alternative work is available, the employee is regarded as incapacitated and the procedure for incapacitated employees is initiated.
At this phase of the return to work sequence, the role of the physiotherapist, occupational therapist (or biokinetician, if available) may be essential for an optimal outcome. Rehabilitation must begin early and continue until such time as the residual function is optimised.

Rehabilitation generally begins while the affected person is under medical treatment (even as early as while the employee is still in hospital). Rehabilitation programmes vary, and may include complex psychomotor skills training, and restoration of fine motor control, gross motor strength and mechanical range of motion. An important element of rehabilitation, particularly of employees involved in major accidents, is aimed at minimising the psychological effects of the injury. Sometimes intervention measures may be psychological, such as for employees who are suffering from post-traumatic stress disorder. This is sometimes identified by unexplained slow return to physical readiness (See section 4.7.6.4).

The underground environment is demanding and the return to work process should not be too hasty. Some mining complexes have the advantage of simulated underground environments, where employees can be reintegrated to the underground environment in a safe and controlled manner. Structured incremental task requirements are given to the participants of the programme and their progress is monitored and scored. As their performance improves so does their confidence in their ability to return to work. Work readiness is generally a function of physical capability and emotional readiness. Protracted recovery times are identified readily and the appropriate intervention measures can be implemented without delay. Once this process is complete, the employee is required to pass through the heat stress acclimatisation programme, which is a further test of work readiness.

Given that hearing loss, lung impairment and tuberculosis, are such important issues in the mining industry, they deserve comment. Notwithstanding their prominence, they should be considered in exactly the same manner as outlined above, with the understanding that, where disability is consequent of an occupational disease, extra attempts are to be taken to avoid job loss. (Note, for example, that relatively few occupations underground will have minimum standards of hearing in the hearing frequencies affected by noise.)

Step 4: Determine whether there are benefits or entitlements available to the affected employee (compensation or disability award)

These entitlements come in various forms. For employees with occupational injuries or illnesses, there are statutory entitlements to compensation. These are covered later in this chapter.

Affected employees who are not covered by statutory compensation mechanisms have the following options to be considered:

- Permanent disability application under a policy taken out with a private insurance company
- Access to provident fund entitlements proportionate to the affected person’s contributions
- Ex gratia award made at the discretion of the company (employer)

These three options are dependent upon what benefits or entitlements are available. The most beneficial of these is a permanent disability award, which is subject to the provisions of the relevant insurance product. Whatever the entitlement, some important points need to be borne in mind.

- It should be emphasised to the affected employee that this is an application for a permanent disablement payment and is subject to the decision of the insurer (including statutory funds, such as that of the Compensation Commissioner). The medical practitioner completing the medical reports should not lead the employee to expect a specific outcome. This sometimes leads to unreasonable expectations and drastic disappointment.
- An understanding should be established between the employee, the employer and the responsible medical practitioner that the application is a combined effort in order to obtain the maximum possible benefit on behalf of the employee. The employee may be under the impression that it is the company that provides the payment and makes the decision regarding eligibility for the award. The role of the insurance company needs to be clarified

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Various insurance products exist in the market. These vary in complexity and in their provisions. The worst of these is the product that provides only for employees with permanent disabilities that render them totally unemployable (for any occupation) in the marketplace. This is a cheap group insurance product, previously widely purchased by companies, but which fortunately is seen less frequently today.

A preferred option is cover for disability to perform specific work, such as the work that the employee was involved when the disability occurred. This insurance product makes available a sum of money that the affected employee can use while he/she switches to alternative work. Some insurance companies also insist on a periodic review of the affected person in order to establish that they are indeed permanently disabled. This may take the form of a medical review every two years to determine whether rehabilitation might enable the affected employee to return to effective employment.

Provident fund payments follow a less complicated course. When the decision is reached that the employee is no longer employable, the provident fund is notified and the relevant entitlements are requested.

An ex gratia award may be made by the employer to disabled employees to reduce financial hardship.

14.3.2 Incapacity and “poor work performance”

14.3.2.1 Referral mechanisms and poor work performance

When the sequence described above is triggered during routine medical examinations, the referral procedure is usually unproblematic. However, when the employee is referred for a medical opinion for reasons of poor work performance, extensive periods of sickness absence, ill health, etc, the referral procedure needs to be clear to all involved. All too often medical professionals are confronted by an employee who is referred by company management for a medical opinion for an obscure reason. The real reason may be that management is suspicious of sick leave abuse or even misconduct, but because of inadequate policies or training, is using the referral to the medical practitioner as a form of arbitration between two conflicting points of view. This may have negative consequences for the relationship between the medical service and employees, and also for industrial relations. This kind of practice should be avoided. Instead, a structured approach should be followed.

The reasons for poor work performance are diverse. Besides a diagnosable medical problem, they may include social or financial problems at home, substance addiction, work conflict, and many others. The final common pathway is that the employee is either simply not at work, or when he/she is at work, performance is below the required standard. When this is the case the following approach is suggested.

Where managers are suspicious that sickness absence may be abusive rather than genuine, they should not involve the medical service in establishing misconduct. This remains a management responsibility. Management needs to determine, by evaluating all the information available, whether poor work performance (in this case, sickness absence) is justified.

- There are certain indicators of possible abuse of sick leave entitlement. These include excessive frequency of absence, medical certificates from a variety of doctors for a variety of ailments, medical certificates with inadequate information or frequent reference by the doctor on the certificate to “as I am informed” rather than “according to my examination”, frequent weekend related absence with or without a medical certificate, etc
- In cases of inadequate medical certificates, the company may request the employee to provide more information regarding the nature of the illness, should this be relevant. However, this option is rarely necessary. The employer may not insist on private or confidential information
- Where misconduct is established, the appropriate steps should be taken in accordance with the company’s disciplinary code
- The code of good practice, referred to in the Labour Relations Act, emphasises regular counselling of employees
14.3.2.2 Counselling the employee with poor performance due to sickness absence

Where no misconduct is established, the employee should be informed that the absence (or poor performance) is hampering his/her productivity, and that employer is entitled to dismiss unless there is an improvement in attendance. The counselling session should focus on:

- The negative operational consequences of the poor performance
- The fact that sickness does not provide an indemnity from performance appraisal
- The action to be taken to rectify the absence profile and poor performance, with an agreed schedule for improvement
- The consequences if the situation does not improve, including dismissal

Legal opinion indicates that the number of informal and formal discussions and verbal and written warnings required hinges upon “fairness”, which in turn is determined by a number of factors. The employer will be justified in having less tolerance for poor performance due to sickness absence if the employee is critical to the operation, and/or cannot be temporarily replaced.

The employee and employer should work together to establish an agreed pathway to recovery, meeting the needs of both the employee and the needs of the operation. This requires a stepwise approach, exactly as is described in section 14.3.1 above.

14.4 Role of the occupational medicine practitioner

Management of the issues of worker fitness and disability requires an understanding of labour law, risk management, occupational medicine and rehabilitation. Whilst the adjudication decisions may sometimes be complex, following the steps provided above should pose little problem in the majority of cases. The occupational medicine practitioner is best placed to integrate the variety of information including:

- the individual employee’s capabilities
- the demands of the specific occupation
- the company’s policies
- the requirements of the insurance agency (whether private or statutory)
- the opinions of specialists in various fields of medicine and rehabilitation

One of the most important failings of the medical adjudication examination is that it takes place in the confines of the medical station or surgery, and within the limited time available for a consultation. Important elements such as strength, endurance and physical capability can only be guessed at. An on-site assessment of the employee’s job and/or functioning, with an appropriate full-shift time frame, would be more informative. To this end, the services of an experienced occupational therapist are invaluable. Work capacity is ideally evaluated at the workplace. In the mining industry, this is not easily accommodated, and a simulated underground environment, such as a Training Centre, is the next best option.

14.5 Introduction to compensation for occupational disease

This section and the next deal with compensation of occupational diseases in the mining industry. The most common occupational diseases on the mines are respiratory disease (see also Chapters 5 and 6) and noise induced hearing loss (see Chapter 8).

Compensation of disease, rather than of injury from incidents or accidents, is emphasised in these sections because:

- Most of the conditions covered in previous chapters are classified as diseases and not injuries
- The operation of two distinct laws and administrations covering occupational diseases complicates the system of compensation of occupational disease in the mining industry
- Occupational diseases are underreported
- Delays in certifying and paying compensation for occupational diseases are on average longer than for injuries. Failure to follow the proper procedure adds to these delays
For historical reasons, there are two independent systems for compensating occupational disease that apply to miners.

The Occupational Diseases in Mines and Works Act, Act 78 of 1973 (as amended by Act 208 of 1993) (ODMWA) covers occupational lung disease in miners. These diseases are listed in Appendix 14.3. All occupational diseases not covered by ODMWA, and all injuries due to accidents or traumatic incidents, are covered by the Compensation for Occupational Injuries and Diseases Act (COIDA), Act 130 of 1993. The occupational diseases covered by COIDA are listed in Appendix 14.4.

While the above applies to most mines, certain smaller mining operations, as well as contractors employed in such operations, may report occupational lung disease in their employees under COIDA rather than ODMWA. Occupational health personnel serving such operations should seek clarification as to which Act applies to the employees under their care.

The government has expressed an intention to merge the two Acts and their administrations. However, this process is likely to take some years.

14.6 Occupational Diseases in Mines and Works Act

The first Act directed at compensation specifically for lung disease in miners was the Miners’ Phthisis Act of 1911. Since then there have been a number of successive such Acts which have extended the list of compensable conditions and expanded the responsibilities of employers in the treatment of occupational diseases, particularly tuberculosis. Racial discrimination was embodied in all of the legislation until the ODMWA was substantially amended in 1993. Compensation is currently based on earnings.

The Act currently makes provision for two types of compensation payments:

- Lump sum payments for first or second degree occupational disease, including chronic cardiorespiratory tuberculosis (TB) (i.e. cardiorespiratory TB that heals leaving permanent impairment)
- Payment of 75 percent of any wages lost, for up to six months, by in-service miners temporarily disabled from working because of tuberculosis. (After six months reassessment is required)

14.6.1 Treatment of occupational disease under ODMWA

The Act also places a responsibility on employers for payment for treatment of occupational disease in workers in their employ for a period of up to two years from diagnosis. Tuberculosis is the most common such treatable disease. Individual mines may either provide treatment in their own facilities at their own cost or reach arrangements with the Department of Health for subsidisation of such treatment.

The Act also provides for medical aid for treatment of occupational disease beyond two years, where such treatment will improve the clinical symptoms or “reduce the disease”. In such cases, the Compensation Commissioner for Occupational Diseases will either pay for such additional treatment or direct the employer or public facility to pay for it after considering which option is better. Cost of medication is covered at the generic price.

This section of the Act applies also to ex-miners. The Compensation Commissioner for Occupational Diseases may provide payment for treatment of occupational disease in ex-miners if the treatment will improve the compensated disease and the cost of medication is equivalent to the least costly that would yield the same results. An example is the payment for bronchodilator therapy for ex-miners with occupational COPD.

14.6.2 Administration of the Act under ODMWA

The Act and its administration fall under the national Department of Health (not the Department of Mineral and Energy Affairs). The Medical Bureau for Occupational Diseases (MBOD) and the Compensation of Occupational Diseases (CCOD), both in Johannesburg, administer the Act (see Appendix 14.5). The Director of the MBOD has broad responsibility for ensuring the adequate
performance and quality control of benefit medical examinations and removal of lungs for post-mortem examinations (discussed further below). The CCOD receives levies from operating mines on behalf of mineworkers and makes compensation or medical aid payments.

The Certification Committee of the MBOD is responsible for medically assessing claims for compensation. The committee is guided by standards set by the Minister of Health.

The Reviewing Authority of the MBOD will consider cases referred to it by the Certification Committee or after representation by outside parties or individuals not satisfied with a decision of the Certification Committee. Mineworkers can apply to appear before either of the above committees.

Payment of compensation for occupational lung disease under ODMWA is funded by levies on employers. (There are former asbestos mineworkers whose compensation is appropriated by parliament as their employing mines never contributed levies.) Previously levies were based on a risk rating determined by a Risk Committee and based on measurements of dust levels in mines. This arrangement under ODMWA has been superseded by the Mine Health and Safety Act, in terms of which employers pay a flat rate levy based on the commodity mined.

14.6.3 Definition of a compensable disease under ODMWA

A compensable disease is any permanent disease listed in the Act, plus any disease attributed by the Certification Committee to risk work (Appendix 14.3) and/or which has been recommended and approved by the Minister. Risk work is defined on the basis of exposure to harmful dust, gases, vapours or chemical substances.

14.6.4 Procedure for claims under the ODMWA

There are two stages in the process of assessment for compensation and payment of a claim under the ODMWA.

14.6.4.1 First stage: medical examination and certification

Benefit medical examinations

Miners have a lifelong right to medical examinations, called benefit medical examinations, to determine whether they have an occupational lung disease.

Miners may come to have a benefit examination in one of three ways (either in-service or after having left mine service):

- As a result of findings suggestive of an occupational disease during a routine medical examination such as medical surveillance or application for a certificate of fitness
- As a result of such findings during a clinical assessment of symptoms or illness causing the miner or ex-miner to seek medical attention
- By requesting an examination

Active mineworkers should be under regular medical surveillance in terms of the MHSA. If a mine employee wants a benefit medical examination over and above such surveillance, this request should be directed to the mine medical services. Mine owners are responsible for the cost of benefit medical examinations of employees.

Ex-miners may also be under “proactive surveillance”, whereby state provincial or other facilities have an agreement with the MBOD to provide two-yearly benefit medical examinations. This requires a prior assessment of the availability and quality of such facilities by the Director of the MBOD, and an agreement on tariffs to be paid.

If a medical practitioner without an agreement with the MBOD diagnoses occupational disease in an active miner, he/she must refer the worker to the mine. In the case of an ex-miner (during a consultation other for a benefit medical), the medical practitioner has a legal obligation to notify the Director of the MBOD, who will look at the records and can opt to pay at the recommended tariff for
“relevant necessary investigations” or request that the ex-miner be referred to an approved facility. Alternatively, the practitioner can refer the ex-miner to a medical practitioner or clinic authorised to do benefit medical examinations.

Finally, the ex-miner or anyone acting on his behalf can directly request a benefit medical examination from the Director of the MBOD (“inactive surveillance”).

**Timing of benefit examinations**

In 1998 a draft amendment of the ODMWA to increase the interval between benefit medical examinations from 6 to 12 months was but accepted but has not yet been gazetted. In the meantime the Director of MBOD has implemented a minimum interval of two years between routine benefit medical examinations for ex-miners.

The exception is in the case of a miner or ex-miner whose clinical condition at presentation to the medical services suggests an undiagnosed occupational lung disease or deterioration of an existing occupational lung disease. In such a case a benefit medical examination may be done immediately irrespective of when the previous examination was done.

**Case documentation in a benefit examination**

The minimum materials to be sent to the Director, MBOD, consist of:

- A medical history, occupational history and physical examination, including age, height and weight (forms obtainable from MBOD)
- Special investigations: recent postero-anterior chest x-ray; spirometry (minimum of forced expiratory volume in one second \([\text{FEV1]}\) and forced vital capacity \([\text{FVC}]\)); microbiology and/or histology, if relevant)

**Certification**

The practitioner conducting the benefit examination should submit the medical records (and invoice where relevant) irrespective of the clinical findings to the MBOD. Mines must submit all cases suspected of occupational lung disease picked up during their surveillance programme. In all cases, the Certification Committee makes the determination as to whether a compensable disease is present or absent.

In general terms, a scheduled disease is compensable if there is more than 10 percent impairment of cardiorespiratory function. If not, the case is categorised as “no compensable disease” (NCD). If the case is compensable, there are only two grades of award: first degree or second degree.

Proposed criteria to be used by the Certification Committee in determining whether compensation should be awarded and the grade were published in a draft regulation under ODMWA in 1998. (See RSA 1998 under Guide to Resources). This regulation has yet to be gazetted. In practice, the Certification Committee considers the following in make their determination:

- Evidence of the relevant exposure. In the case of a submission for occupational COPD alone, at least 10 years of high dust service or 20 years of low dust exposure are required
- Profusion of rounded (or in the case of asbestos, irregular) opacities on the chest x-ray
- Presence of progressive massive fibrosis on the chest x-ray
- Width and extent of pleural thickening along the chest wall on the chest x-ray, in the case of asbestos exposure
- Extent of lung function loss. (A judgement as to quality of the lung function test is made. If there is doubt as to quality, the Committee may require the test to be repeated. If no lung function test is submitted or a good quality test is unlikely to be obtained, the Committee may make a determination on severity based on other clinical criteria)
- Presence and extent of permanent cardiorespiratory tuberculosis following treatment
- Presence of lung cancer, mesothelioma or systemic sclerosis
- Extent of pathologic findings at autopsy
- Evidence of respiratory tract or skin sensitisation to platinum salts and associated disease.
Table 14.1 summarises the decision categories used by the Certification Committee, together with the compensation payable and the schedule of further benefit examinations.

**Table 14.1 Certification grades used by the MBOD Certification Committee and their implications**

<table>
<thead>
<tr>
<th>Certification</th>
<th>Percentage of disability</th>
<th>Compensation(^a, b)</th>
<th>Frequency of benefit examinations</th>
</tr>
</thead>
<tbody>
<tr>
<td>No compensable disease (NCD)</td>
<td>&lt; 10%</td>
<td>None</td>
<td>Every 2 years or when significant deterioration is found by medical attendant. Examinations are for life until death or second degree</td>
</tr>
<tr>
<td>First degree</td>
<td>10 — &lt; 40%</td>
<td>Minimum compensation of R12 922 and maximum R36 156. It is salary based(^b) and the maximum salary allowed in the calculations is R2 300 per month.</td>
<td>As above.</td>
</tr>
<tr>
<td>Second Degree</td>
<td>40 — 100%</td>
<td>Maximum R80 509.20, if not previously compensated. For upgrading from first degree (“reclassification”), R44 353.20 maximum.</td>
<td>No further benefit examinations.</td>
</tr>
</tbody>
</table>

\(^a\) Amounts at time of going to press. These and the maximum allowable salary for calculation purposes are increased from time to time.

\(^b\) The formulae for calculating the amount payable are listed in Appendix 14.6.

**Autopsies**

Occupational lung disease in miners detected at autopsy is also compensable. The ODMWA requires limited autopsies in deceased miners and places an obligation on medical practitioners attending the death of a miner or ex-miner to arrange such an examination (section 34.2 of the Act). Consent of the widow (if any) or an “adult near relative of the deceased” should be sought to conduct such an examination.

The practitioner must notify the MBOD or National Centre of Occupational Health (NCOH) who will arrange for the heart and lungs to be removed and transported to the Pathology Directorate, NCOH (see Appendix 14.5). The costs of removal and transportation are paid by the MBOD.

The same categories of NCD, first degree and second degree are used, based on a pathologic grading system, and the same amounts paid.

**Tuberculosis**

The coverage of tuberculosis under ODMWA is summarised below. See also Chapter 6.

In active miners:

- A miner treated for tuberculosis goes on sick leave initially for the length of time determined by the treating doctor. Initial submission to MBOD must be made at the date of diagnosis.
- If sick leave is used up, ODMWA makes provision for payment of 75 percent of his wage for up to six months. (Some companies offer additional benefits)
- If there is residual lung damage after treatment is completed, the miner is entitled to a benefit medical examination, i.e. a second submission to the MBOD.
- If the miner has both pneumoconiosis and TB, second degree compensation is payable. Depending on the extent of the pneumoconiosis, the number of previous episodes of TB, the miner’s lung function and immune status, and the type of work underground, the miner’s job may be changed. In all cases counselling must be offered and documented. Where a worker with pneumoconiosis
who recovers from the episode of active TB and is otherwise well, opts to remain underground he must be informed that compensation for occupational lung disease is at a maximum. Each case should be handled individually

In former miners:

- In general, the state is responsible for the diagnosis and treatment of TB cases that occur among former miners (as for the general population)
- Tuberculosis contracted within the first 12 months after leaving mine service is regarded as if it were contracted in service and must be submitted to the MBOD, as per the procedure above. Criteria for compensation apply as for active miners
- If there is pre-existing silicosis, or tuberculosis which was contracted while in mining service, any subsequent episode of tuberculosis which results in progression of the pre-existing disease is compensable
- Otherwise, tuberculosis contracted for the first time after 12 months after leaving mine service is not compensable as it is not regarded as attributable to mine work

14.6.4.2 Second stage: Confirmation of mining service and identity, and payment

In the event of a miner or ex-miner being certified by the Certification Committee as having a compensable occupational lung disease, the Director of the MBOD will refer the case documents to the Compensation Commissioner for Occupational Diseases in Johannesburg (see Appendix 14.5). The office of the CCOD falls under the Department of Health and should not be confused with that of the Compensation Commissioner under COIDA.

The functions of this office are to identity the claimant, validate the labour history and to make payments. The office writes to the mine if the miner is still in service, or to the claimant if not in service, requesting a number of items:

- Form GW 27/48 completed and certified: details of ID, current wage if in mine service and, labour history on the mines
- Certified copy of ID document
- Two sets of fingerprints, taken by a member of the South African Police Service or other qualified person (Form GW 24/17)
- Details of bank account for payment (form V 47) certified by bank manager
- Proof of mining service and other documentation, such as current pay slip if employed on a mine and/or letter from the mine (especially for any loss of earnings due to TB)
- In case of deceased miner, certified copy of marriage certificate, ID document of spouse and details of dependents

Failure to provide these documents will delay resolution of the claim.

Once awarded, payments are directly transferred to the claimant’s bank account.

In practice, there are a number of problems in this second phase of claiming under ODMWA that may prevent claimants from obtaining the compensation due to them. These obstacles are listed in Table 14.2. Such problems are more likely to occur if the claimant is no longer employed at the mine.

To overcome these obstacles, any person or institution performing benefit examinations has a responsibility to be conversant with the full procedure, i.e. both stages of a claim under ODMWA, and to inform (and assist) the claimant accordingly.

Post mortem payment to dependents

If the claimant who has been certified dies before receiving payment, or is certified post mortem, the surviving spouse or other dependent is entitled to the payment. Spouse identification is required or
completed when the organs are removed. In most mineworkers, the spouse or next of kin is known, as this information is completed at engagement. It is recognised that not all miners have a marriage certificate.

**Table 14.2 Problems arising in the second phase of claims submission under the ODMWA and possible solutions**

<table>
<thead>
<tr>
<th>Information requested</th>
<th>Problem</th>
<th>Solution</th>
</tr>
</thead>
</table>
| General               | • Forms GW 27/48 and V 47 never reach claimant  
  • Claimant doesn’t understand procedure/unaware that there is a second phase  
  • GW 27/48 sent long after miner re-trenched or has moved to unknown employment | • Use reliable address or that of medical practitioner/clinic  
  • Practitioner to assist  
  • Anyone performing benefit examination should be trained  
  • Education of miner at exit examination of the possibility of compensation, as well as obtaining forwarding address |
| ID, spouse’s ID ID | Sent uncertified | Certified by commissioner of oaths. Sending source i.e. mine or public facility to help. |
| Marriage certificate | Customary marriage — no certificate | May need affidavit. |
| Fingerprints | Poor quality | Use police service, or where possible self-presentation to CCOD. |
| Bank details | Not properly recorded and validated. | Bank details certified by bank official. |
| Current earnings on mine | Claimant no longer employed on mine. | Earnings will be estimated as if were employed. If initially submitted by mine, records of the mine must be sought. |
| Proof of employment | Claimant has no documents. | Company number if possible. Otherwise sworn affidavit. |
| Payment | Fraud by third parties to the process. | Claimant and practitioner to be aware. Only claimant’s bank account to be used. Claimant can lay complaint with police and culprit can be prosecuted. |

**Objections to decisions of the Certification Committee**

If the referring medical practitioner or the claimant objects to a decision of the Certification Committee, the claimant can by written request to the Director of the MBOD ask for the case to be referred to the Reviewing Authority for reassessment. The Reviewing Authority may endorse or reverse the Certification Committee’s decision, or request a joint sitting of the two committees to resolve the matter.

**14.7 Compensation for Occupational Injuries and Diseases Act (COIDA)**

COIDA covers both accidents and occupational diseases sustained at work.

**14.7.1 Definition of an accident and compensable disease under COIDA**

An accident is defined as an injury arising out of and in the course of a worker’s employment and resulting in a personal injury, illness or the death of the employee.

In practice, an occupational disease under COIDA is any disease listed in the Third Schedule of the Act. The worker must have been exposed to the causative agent listed in the Schedule (Appendix 14.4) for each disease. Occupational diseases in miners covered by ODMWA are not covered by COIDA.
Table 14.3 lists the top seven diagnostic groups reported from the mining industry to the Rand Mutual Assurance during 2001.

Table 14.3: Most common conditions reported to Rand Mutual Assurance under COIDA in 2001.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Percent of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper limb injuries</td>
<td>32%</td>
</tr>
<tr>
<td>Lower limb injuries</td>
<td>26%</td>
</tr>
<tr>
<td>Ear diseases including noise induced hearing loss</td>
<td>16%</td>
</tr>
<tr>
<td>Head injuries</td>
<td>9%</td>
</tr>
<tr>
<td>Eye injuries</td>
<td>7%</td>
</tr>
<tr>
<td>Back and abdominal injuries</td>
<td>6%</td>
</tr>
<tr>
<td>Toxic effects of noxious gases</td>
<td>4%</td>
</tr>
<tr>
<td></td>
<td>100%</td>
</tr>
</tbody>
</table>

The most common disease in miners reported under COIDA is thus noise induced hearing loss (see Chapter 7). The effects of toxic gases could be classified either as an accident or a disease depending on the circumstances.

Other diseases which may occur among miners but are clearly underreported are contact dermatitis (Chapter 12), work related musculoskeletal disorders due to repetitive movements (Chapter 11), hand-arm vibration syndrome (Chapter 7) and short term or long term toxic effects of various chemical and metallic substances including mercury, lead and manganese (Chapter 9).

Section 63 (b) of COIDA also provides for compensation of diseases that are not listed in the Third Schedule, provided that sufficient evidence is presented of causation. In theory, the burden of proof of causation is stronger than for listed diseases where a diagnosis and evidence of exposure are sufficient.

Occupationally acquired HIV infection in health workers is one non-scheduled disease that has been the focus of concern (see section 14.7.6.3).

In recent years, there has been an increase in number of claims submitted for post-traumatic stress disorder (PTSD). This is treated as an accident rather than a disease and is discussed in section 14.7.6.4 below.

14.7.2 Administration of COIDA

The office of the Compensation Commissioner administers the Act, and falls under the Department of Labour. The Act licences the Rand Mutual Assurance Company (Rand Mutual) to provide worker’s compensation to the mining industry, which it does for approximately 78% of all mines in South Africa.

The Rand Mutual Assurance Company was established at the turn of the century by the mining industry as a mutual assurance company, i.e. a non-profit organization. It currently insures approximately 350 000 mine workers and receives approximately 53 000 claims per annum. Of these claims approximately 85% are for occupational injury and 15% are for occupational disease.

Claims for occupational disease and injury are submitted in the first instance to Rand Mutual who adjudicates on the liability of the claim in terms of COIDA. The office of the Compensation Commissioner confirms acceptance or rejection of the claim, and if accepted, confirms the degree of disablement. The Commissioner thus exercises jurisdiction on all matters under COIDA. If the claim is accepted, Rand Mutual makes the necessary payments.
14.7.3 Benefits under COIDA

COIDA provides for four types of benefits:

- Payment of medical expenses incurred as a result of the injury or disease for a period of up to 24 months following diagnosis. Should treatment take longer the claimant must be assessed for a permanent disablement in the first instance. Motivation for further treatment that will reduce the disability will be considered
- Payment for total temporary disablement (TTD), for an initial period of up to 12 months which may be extended to 24 months at the discretion of the Compensation Commissioner
- Payment for permanent disablement. Compensation for permanent disablement is payable to an employee who has lost part of his body or has lost the use or function of a part of his body. There are two forms of compensation for permanent disablement. If the permanent disablement is rated at 30% or less the compensation takes the form of a lump sum. If the permanent disablement is rated at more than 30%, the compensation is in the form of a lifelong pension
- Death benefits to dependents if the death was due to the injury or occupational disease. (See Appendix 14.6)

Additional compensation may also be payable in cases of employer negligence. This is discussed in section 14.7.8.

Mining companies may, in addition to the above coverage, have taken out non-statutory insurance policies covering occupational injury and disease. A number of such policies are offered by the Rand Mutual Assurance Company, e.g. coverage of health care workers who are at risk of HIV infection in their work.

14.7.4 Procedures for submitting claims under COIDA

Detailed guides to submitting claims for injury and disease under COIDA can be found in Industrial Health Research Group (1995) and in Ross and Felix (1998) (see Guide to Resources). The responsibilities of the different parties in submitting claims for occupational disease are summarised below. Forms referred to can be obtained from Rand Mutual directly or through their website (www.randmutual.co.za). The equivalent forms for cases not falling under Rand Mutual can be obtained from the Compensation Commissioner in Pretoria (see also www.compensation.gov.za). It should be noted that the forms for occupational disease claims are different from those for occupational injury claims.

Medical practitioner

The procedure for submitting occupational disease is heavily dependent on appropriate diagnosis by the medical practitioner and recognition of the occupational nature of the disease. The medical practitioner completes the First Medical Report. This is sent to the employer and to Rand Mutual, and must be done within 14 days.

The date of commencement of an occupational disease is the date on which a medical practitioner diagnosed the disease for the first time.

If the practitioner continues to see the worker for treatment or other follow up, the practitioner completes Progress Medical Reports at regular intervals, but at a minimum at least once a month as necessary. Once the disease has cleared up or, if chronic, has stabilised, the practitioner completes the Final Medical Report. This should include an estimate of impairment or disability. These reports can be sent directly to Rand Mutual.

Failure of the medical practitioner to produce timeous, legible, well-motivated reports will hold up the claim to the detriment of the worker and to fee recovery. The reports should contain a clear concise history of the occupational injury or disease, stating the material signs and symptoms noted. They should include an X-ray report or comment on the X-ray as appropriate. If physiotherapy is prescribed, the doctor should give full details of the treatment requested. The treating doctor should state whether the patient is unfit for work and indicate when he/she is likely to return to work.
The fee for treating the worker is inclusive of the cost of completion of the medical report. In the final medical report the treating doctor should record the chance of residual disability of a permanent nature, after having allowed reasonable time and the necessary medical treatment for recovery.

The Act allows for the reopening of cases if the employee successfully motivates that further treatment will reduce his/her disablement or that his/her condition has deteriorated to the extent that further active treatment is essential. This includes significant progression of an occupational disease for which permanent disablement has previously been awarded. A report for the reopening of a claim must clearly state the patient’s present condition in relation to the original injury and the exact nature of the treatment proposed. No treatment should be given in a case being motivated for reopening until written approval has been received from Rand Mutual.

**Employer**

Having been informed by the medical practitioner (i.e. received the First Medical Report), the employer must complete the Employer’s Report of an Occupational Disease and submit this to Rand Mutual. The law requires this to be done within 14 days. If the employee has been put off work (temporary total disablement), the employer submits a Resumption Report when the employee returns to work.

In practice, failure of employers to submit Employer’s Reports is a common cause of delay in the processing of claims. Employers have no discretion over whether to submit an Employer’s Report, even if they wish to contest some aspect of the claim, once they have received a First Medical Report.

**Employee**

The Act specifies that the employee must inform the employer if he believes he/she is suffering from an occupational disease. In practice, this communication is most likely to come from the medical practitioner who makes the diagnosis. The employee can, however, complete a Notice of Occupational Disease and Claim for Compensation. This form is essential if the organisation in whose employ the worker contracted the occupational disease no longer exists, or if the employer refuses to complete an Employer’s Report.

The COIDA system for occupational diseases suffers from a number of problems identified as arising in the office of the Compensation Commissioner. While attention has recently been paid to speeding up one component of the process, namely payment of costs of medical treatment, this is less important for occupational diseases than for accidents. Problems besetting occupational disease claims include long delays between submission and acceptance (or rejection) of the claim, lack of professional communication and further delays between acceptance and payment of disablement awards. Documents and chest x-rays are sometimes lost or mislaid, with frequent requests for documents already sent. It is thus essential that the company occupational health service maintain a good administrative system for recording and following up claims.

14.7.5 Calculation of benefits paid under COIDA

Medical aid is paid per a gazetted tariff, which is higher than scale of benefit rates. (In terms of Section 78 of the Act the employer or mutual assurance may motivate for a negotiated rate in return for early payment of accounts). This is paid directly to the health care provider.

For disablement (income replacement) payments, COIDA requires that impairment and disablement be calculated on a percentage basis from zero to 100 percent.

For temporary disablement (which in practice is usually total rather than partial), the Act allows for payment of 75 percent of the gross earnings of the worker. In the mining industry the employer generally continues to pay the disabled employee his/her normal salary for the duration of this period of total temporary disablement and recovers 75% of this amount from Rand Mutual. This recovery excludes the first three days of total temporary disablement.

Permanent disablement requires an assessment of percentage impairment, which is translated into percentage disablement. In the case of permanent impairment due to traumatic injury a guide to such percentages based on anatomical loss is provided in the Act in the form of Schedule 2, and in terms of various internal instructions of the Compensation Commissioner.
Detailed guides to the calculation of percentage impairment in a variety of injuries as well as disease states have also been published by the American Medical Association (See Guide to Resources and section 14.1.4 above).

Disablement under COIDA is defined as inability to work in the open labour market rather in the claimant’s usual occupation. In practice, if someone has to give up their occupation owing to an occupational disease, their chances of being re-employed in any other occupation in the South African labour market are drastically reduced. The older they are, the less likely they are to be able to retrain or find alternative work. Pro forma conversion formulae unfortunately do not take these circumstances into account.

A tripartite technical committee on occupational disease has recently been established by the Compensation Commissioner to review impairment and conversion into permanent disability ratings of occupational lung disease, in view of a possible merger of the ODMWA and COIDA at some stage in the future.

The formulae used to calculate compensation payments under COIDA are described in Appendix 14.6.

14.7.6 Specific diseases

14.7.6.1 Noise induced hearing loss

Noise is second only to airborne pollutants as a cause of disease among miners. Due to a change in the threshold for compensation of noise induced hearing loss in 1995 (Compensation Commissioner: Internal Instruction 168) the number and costs of claims from in the mining industry have risen substantially in recent years. (See Chapter 7, section 2.1).

A new procedure for identifying and evaluating cases of noise induced hearing loss for compensation was introduced in 2001 in a guideline issued by the Compensation Commissioner, Instruction 171 (RSA 2001). An important change over the previous procedure is the use of a working lifetime baseline audiogram to calculate whether compensation should be provided. When a baseline audiogram showing hearing loss is available, only the deterioration in hearing from the baseline is used for calculating disablement. Where employees transfer between employers, the recording of a new “baseline” at each new employer will enable the apportionment of liability from noise induced hearing loss between employers.

Baseline audiometry will be required in regulations (yet to be promulgated) by the Department of Minerals and Energy and by the Department of Labour. In addition the South African Bureau of Standards will be issuing an updated standard for the performance of audiometry.

Where there is no baseline, compensation will be based on the assumption that the employee’s hearing was entirely normal at the commencement of employment. Any loss of hearing due to noise in the latest audiogram will be attributed entirely to the latest employer.

In a Supplement to Instruction 171, a transitional arrangement between instruction 168 and 171 has been established. Employers are required to obtain baseline audiograms on all employees exposed above 85 dB(A) within two years of the supplement. New employees must have audiograms within 30 days. Where hearing loss is found at this baseline audiogram (during the transition period), this should be submitted for compensation in terms of Instruction 168.

Instruction 171 also introduced a measure of impairment termed percentage loss of hearing (PLH). This measure is calculated from a series of tables and based on a summation of hearing loss in each ear at each of the frequencies 0.5, 1, 2, 3, and 4 kHz. These tables can be found as Annexure A to Instruction 171. In this summation, the weighting of hearing loss varies from frequency to frequency. The weighting is highest for hearing loss at a frequency of 1 kHz and lowest for hearing loss at a frequency of 4 kHz.

The permanent disablement percentage is calculated by halving the PLH.
The threshold for submitting a claim for noise induced hearing loss is a PLH (or deterioration if a baseline is available) of 10 percent.

The requirements for submitting a claim for noise induced hearing loss are as follows:

- Claimant’s service record, in particular exposure to occupational noise at an intensity and duration likely to cause permanent hearing impairment. Such evidence may include documented noise level readings exceeding the occupational exposure limit of 85 dB(A).
- Diagnostic audiometry of appropriate quality performed by a diagnostic audiologist (see Chapter 7). (Conditions such as wax or infection must first be treated). Two diagnostic audiograms need to be submitted, taken at least 24 hours after the last exposure to excessive noise, not differing by more than 10 decibels (dB) at any frequency. If this condition is not met, a third audiogram is performed, and if this is not within the 10 dB limit, the assessment must be delayed for 6 months. All of these audiograms can be done on the same day but at “different sittings”. The better of the two audiograms within 10 dB (the one showing least hearing loss) is used for calculation of PLH.
- Copy of the baseline audiogram and calculated PLH.
- Medical opinion, stating that the loss is compatible with noise induced hearing loss, or if atypical, an explanation. An occupational medicine practitioner may provide this opinion, unless the PLH (or deterioration in PLH) is greater than 30 percent, or the case is complicated, in which case the opinion of an Ear Nose and Throat specialist is needed.

Instruction 171 covers also hearing loss due to mechanical or acoustic trauma, for which the procedure is similar.

14.7.6.2 Contact dermatitis

Irritant and allergic contact dermatitis are widely underdiagnosed and underreported conditions.
For submission of claims, in addition to the procedure described above, a dermatologist’s opinion is required on Form WCl.53. Patch tests are required in the case of allergic contact dermatitis. (See Chapter 12 for full list of forms).

14.7.6.3 HIV and AIDS in health care workers

The mining industry employs a large number of health care workers. Some of these are at risk of HIV infection from HIV infected blood and other fluids as a result of needle stick injuries and other exposures. While needle stick injuries are common, infection by this route is relatively rare, estimated at 3 per thousand infective exposures. (This risk is decreased by post-exposure prophylaxis with anti-retroviral medication.)

Although to date there have been no cases of seroconversion reported to Rand Mutual as a result of occupational exposure in the mining industry, the risk to healthcare workers increases as the prevalence of HIV infection rises among mineworkers.

The current position is that the Compensation Commissioner will not accept needle stick injuries as a compensable injury, nor pay for post-exposure prophylaxis with anti-retroviral drugs, nor for counselling until proven seroconversion has occurred. Needle stick injuries should thus not be reported to the Commissioner, although they need to be recorded (see below).

Only proven seroconversion after a documented exposure to HIV infected blood or other tissue will be accepted by the Commissioner as an occupational disease. In this case, the Commissioner will cover medical expenses and any temporary or permanent disability that arises.

Most mining medical centres have an additional policy with Rand Mutual providing benefits for health care workers who seroconvert as a result of a needle stick injury at work. The benefits vary in accordance with the cover purchased and generally take the form of a lump sum payment on seroconversion if all the conditions of the policy schedule are met.
The implication is that, for compensation purposes, every health care facility should have in place:

1. A written policy on needle stick and related injuries.
2. A system of procedures for recording such injuries.
3. If the source patient is identified and his/her HIV status is not known, a procedure for taking the patient’s blood for HIV testing, with consent and appropriate counselling.
4. A procedure for follow-up testing and counselling of workers who have been exposed in this way.
5. A procedure for submitting a claim for an occupational disease should the worker become HIV positive.

In addition, employers should make available, at their own expense, post-exposure prophylaxis to employees.

14.7.6.4 Post traumatic stress disorder (PTSD)

Under COIDA PTSD is regarded as an injury rather than a disease. For a diagnosis of PTSD to be considered both of the following should be present:

• The employee has experienced, witnessed, or was confronted by an event that threatened serious injury, physical harm, or death
• The person responds with intense fear, helplessness, or horror

According to Rand Mutual, the introduction of debriefing sessions for miners involved in seismic events has reduced the incidence of PTSD in the mining industry. The majority of cases seen are those of acute stress disorder that resolves following appropriate counselling and short-term treatment and does not become compensable.

A guideline for submitting claims for post-traumatic stress disorder is currently being prepared for the Compensation Commissioner and is in draft form.

14.7.7 Objections under COIDA

In terms of section 91 of the Act, a claimant can object to a decision of the Commissioner and is entitled to an administrative hearing at which evidence will be heard and the decision confirmed or reversed. This objection must be in writing (WG29) and submitted within 90 days of having been informed of the Commissioner’s decision.

14.7.8 Extra compensation and civil claims

COIDA provides for a system of no-fault insurance. In terms of section 35 of the Act, employees cannot sue their employers for negligence. This limitation on civil action is contained in the compensation systems of a number of countries, and reflects an “historical compromise” by which workers gave up their right to civil claims in return for an administrative system of no-fault insurance.

However, section 56 of the Act does provide for “increased compensation” to be payable if it can be shown that the employer was negligent. The hearing of a claim for increased compensation is by administrative process under the Act rather than as a civil claim in court. Substantial settlements may be paid if negligence on the part of an employer is found.

14.8 Guide to information resources

Fitness for work and disability: South African

Disability Assessment of Lower Backache — Consensus Document issued by the SA Orthopaedic Association, Society of Neurosurgeons of SA, and the Life Offices Association of SA.


Guidelines to the Management of Disability Claims on Psychiatric Grounds, issued by the Life Offices Association of SA and the Society of Psychiatrists of SA.
Guidelines on Assessing Disability due to Cardiac Disease, issued by the Life Offices Association of SA, the Cardiac Society of SA, and the SA Society of Cardiac Practitioners.

SASOM Guidelines for Minimum standards of Fitness to Drive. South African Society of Occupational Medicine, P.O. Box 16179, Lyttleton, Tel (012) 667-5160 /1.

**Fitness for work and disability: international**


**Compensation: COIDA**


**Compensation: ODMWA**


**Acknowledgements**

The authors are grateful to Dr Arthur Begley of the Rand Mutual Assurance Company and Dr Audrey Banyini, former director of the Medical Bureau for Occupational Diseases, for providing invaluable insight into the workings of the respective compensation systems.
Appendix 14.1: Minimum standards of fitness to perform work at a mine on initial examination.

This document is taken from the guideline for occupational medical practitioners, provided by the Department of Minerals and Energy. The practitioner may apply more or less stringent standards depending on circumstances or risk assessment, at a specific mine.

**Infectious Diseases**

Significant infectious diseases may preclude work in certain occupations.

Gastro-Intestinal Infectious Diseases: Special care should be taken to ensure that persons suffering from Gastro-intestinal Infectious Diseases should not be involved in the handling of food.

Active, Infectious Pulmonary Tuberculosis: An employee suffering from active infection should be referred for appropriate treatment. The employee is not fit to work where there is continuing infectivity or serious permanent impairment. Employees, where either one or both lungs have been seriously affected by previous tuberculosis, should not be exposed to dust environments.

**Endocrine and Metabolic Diseases**

Diabetes Mellitus: Diabetics may be employed in such occupations as the medical practitioner may consider safe having regard to their condition. Insulin dependent diabetics should not work underground except under exceptional circumstances where the OMP is satisfied that all required health or safety concerns have been met. Well-controlled, mild non-insulin dependent diabetics may be certified fit to work in a particular category of work underground. Diabetics should not work as drivers of passenger or dangerous goods conveyance. Well-controlled, mild non-insulin dependent diabetics may be certified fit to work as drivers for non-passenger or ordinary goods conveyance.

Obesity: A degree of obesity adversely affecting heat tolerance or the ability to exercise, mobility, general health or possible medical evacuation may render a person unfit for a particular category of work.

**Diseases of the Blood and Blood Forming Organs**

Any significant disease of the haemopoietic system may preclude employment in certain categories of work.

**Mental Disorders**

Acute or Chronic Psychosis: A person with a psychosis may not be fit for a particular category of work.

Alcohol or Substance Abuse[Dependence: Persistent alcohol or substance abuse affecting health by causing physical or behavioural disorder may render a person unfit for a particular category of work. Such persons will not be certified fit for employment as drivers of passenger or dangerous goods conveyances. Any person being considered for employment as a driver of passenger or dangerous goods conveyance should be screened for alcohol or substance abuse. It is advised that an alcohol and substance abuse policy, which has been agreed by the Health and Safety Committee, be in place on mines.

**Diseases of the Nervous System and Sensory Organs**

Epilepsy and Other Conditions of Altered or Impaired Consciousness: Any medical condition which may result in an altered or impaired level of consciousness, including epilepsy renders a person unsuitable for employment in certain areas or occupations on a mine, such as underground, or operation of moving machinery or in dangerous situations such as working at heights, near water, high voltage electricity or any other potentially dangerous situations.
Notwithstanding the above, an epileptic under medical treatment and without any events within a preceding period of two years may be considered for certain categories of work underground or on the surface.

No persons with a history of epilepsy may ever be certified fit as a driver for passenger or dangerous goods conveyance.

**Ear, Nose and Throat.**

An ear, nose and throat examination is required (which includes intact tympanic membranes and functioning Eustachian tubes) and the minimum standards set below must be met for occupations involving changes in barometric pressure and/or exposure to noise.

**Audiometric standards.**

Pure tone audiometric screening at 0.5 kHz, 1 kHz, 2 kHz and 3 kHz must meet the following criteria:

- **AGE 16-39:** pure tone average of 15 dB or less;
- **AGE 40 AND ABOVE:** Pure tone average of 25 dB or less;
- **IRRESPECTIVE OF AGE:** a threshold of 45 dB or less at 3 kHz.

**Hearing Aids.**

The use of a hearing aid by those working in a designated noise zone should not be permitted.

**Vision.**

Binocular vision is necessary for all categories of underground employees.

Visual acuity, corrected, should be:

- **Underground:** 6/9 binocular
- **Surface:** 6/18 binocular
- **Passengers or dangerous goods:** 6/9 binocular conveyance
- **Weaker eye:** 6/12 binocular, 6/24 weaker eye

**Colour vision and normal visual fields are required for passenger, dangerous and non-dangerous goods conveyances and certain other occupations, such as electricians. A normal visual field refers to at least 50 degrees nasal and 70 degrees temporal vision.**

**Cardiovascular system**

The cardiovascular system should be free from acute or chronic disease, which may impair ability to undertake the required physical exertion for a particular category of work. Employees with cardiovascular disease, particularly ischaemic heart disease or uncontrolled hypertension are not suitable for employment as drivers of passenger or dangerous goods conveyances.

**Respiratory system**

The respiratory system should be free from acute or chronic disease, which may impair the ability to meet the required physical performance of a particular category of work.

For screening purposes a lung function test is normal if FEV1, is greater than 80% of predicted or the (FEV1/FVC) ratio is equal to or greater than 70%.

In individuals where there are mild abnormalities of lung function this test should not be the sole criterion on which an individual is precluded from mine work. If the individual otherwise appears to have a normal cardiorespiratory system and is able to meet the physical performance requirements of the specified occupation then he may be found fit for a particular category of work. Refer to the MOHAC Guidance Note for OMPs on lung function testing.
Any respiratory impairment, whether occupational or non-occupational in origin, equal to or greater than that which may be required for a certification of second degree occupational lung disease, would disqualify for work in an environment considered a respiratory risk.

**Disease of the digestive system**

There should not be any significant disease of the digestive system, which may impair ability to perform a particular category of work.

**Diseases of the genito-urinary system**

There should not be any cases of unexplained proteinuria, glycosuria, haematuria or other urinary abnormalities, which may render a person unfit for a particular category of work.

**Skin**

A history of or presence of skin conditions liable to be aggravated by working conditions may preclude employment in a particular category of work.

**Musculo-skeletal system**

There should be sufficient musculo-skeletal integrity to undertake the required physical exertion for a particular category of work.

**Heat Tolerance**

For employees working in conditions where the wet bulb temperature is equal to or exceeds 27.5 degrees centigrade, or the dry bulb temperature is equal to or exceeds 37.0 degrees centigrade, the COP drawn up in accordance with the Guideline for the Mandatory COP on Heat Stress Management of the DME, once issued, should be applied. Employees who need to work in such environments, must meet all the physical requirements and pass the necessary screening tests prescribed in this guideline and COP referred to above before declared fit to work.

Until this guideline contemplated in paragraph above is issued, the COP drawn up under the Minerals Act Regulation 10.12 must be applied.

**Note:** The Occupational Medical Practitioner should take into account local variation in job requirements as well as a worker’s experience and individual circumstances.
Appendix 14.1 (cont) Schematic guideline for job placement evaluation

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No hazard</th>
<th>Mine/works: surface</th>
<th>Mines: underground</th>
<th>Surface or underground</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>At initial placement</td>
<td>At initial placement and then 3 yearly</td>
<td>At initial placement and then 2 yearly</td>
</tr>
<tr>
<td>Frequency of examination</td>
<td>At initial placement</td>
<td>At initial placement and 3 yearly</td>
<td>At initial placement and then 3 yearly</td>
<td>At initial placement and then annually</td>
</tr>
<tr>
<td>Minimum age at employment</td>
<td>16 years</td>
<td>18 years</td>
<td>18 years</td>
<td>21 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vision (corrected)</td>
<td>—</td>
<td>6/18 Binocular</td>
<td>6/9 Binocular</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6/24 Worst</td>
<td>6/12 Worst</td>
<td></td>
</tr>
<tr>
<td>Colour Blindness</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Exclude</td>
</tr>
<tr>
<td>Visual field at least: 50/70</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Exclude</td>
</tr>
<tr>
<td>Hearing (Pure tone average of 0.5, 1, 2 and 3 KHz)</td>
<td>Age: 16 — 39 years &lt; 15 dB loss; Age 40 + &lt;25 dB loss. Also: &lt; 45 dB loss at 3 kHz all ages</td>
<td>Exclude for 2 years</td>
<td>Exclude for 2 years</td>
<td>Permanent exclusion</td>
</tr>
<tr>
<td>Epilepsy/Neurological state affecting level of consciousness</td>
<td>—</td>
<td>Exclude for 2 years</td>
<td>Exclude for 2 years</td>
<td>Permanent exclusion</td>
</tr>
<tr>
<td>Diabetes</td>
<td>—</td>
<td>Well controlled diabetes</td>
<td>NIDDM: well controlled IDDM: exclude except in special circumstances</td>
<td>Only well controlled NIDDM allowed</td>
</tr>
<tr>
<td>Cardiovascular (e.g. ischaemic heart disease)</td>
<td>Must have sufficient cardiorespiratory function to cope with job and environment</td>
<td>Exclude</td>
<td>Exclude</td>
<td></td>
</tr>
<tr>
<td>Alcohol/drug abuse screen</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Consider testing: exclude if positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Compulsory testing: exclude if positive</td>
</tr>
</tbody>
</table>

A Non-passenger and ordinary goods conveyance and work involving heavy or potentially dangerous machinery: e.g., drivers or operators of non-passenger locomotives, dump trucks, delivery vehicles, loaders, cranes, forklifts, tractors, pumps, riggers, shaft timbermen, ventilation fan attendants, fridge plant staff, electricians, instrument technicians and other occupations thought to fall in this category.

B Passenger and dangerous goods conveyance: e.g. winding engine drivers, drivers of buses, taxis locomotives, onsetters, banksmen, and other occupations thought to fall within this category.

Note: The Occupational Medical Practitioner should take into account local variation in job requirements as well as a worker’s experience and individual circumstances.
## Appendix 14.2: Sample occupational risk and exposure profile

<table>
<thead>
<tr>
<th>COMPANY:</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>OCCUPATION (and brief description):</td>
<td>Driver — LOCO</td>
<td></td>
</tr>
<tr>
<td>SECTION:</td>
<td>DEPARTMENT:</td>
<td>DIVISION:</td>
</tr>
<tr>
<td><strong>JOB CHARACTERISTICS:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rate all aspects on a scale of +/++. (± = None; + = Low; ++ = Medium, +++ = High;)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>PHYSICAL REQUIREMENTS:</strong></td>
<td><strong>HAZARD EXPOSURE:</strong></td>
<td></td>
</tr>
<tr>
<td>Hearing</td>
<td>+</td>
<td><strong>PHYSICAL:</strong></td>
</tr>
<tr>
<td>Vision: Acuity</td>
<td>++</td>
<td>Noise</td>
</tr>
<tr>
<td>Colour</td>
<td>+</td>
<td>Heat</td>
</tr>
<tr>
<td>Vis fields</td>
<td>+++</td>
<td>Cold</td>
</tr>
<tr>
<td>Depth</td>
<td>++</td>
<td>Glare</td>
</tr>
<tr>
<td>Night vision</td>
<td>++</td>
<td>Vibration (Segmental)</td>
</tr>
<tr>
<td>Balance</td>
<td>Vibration</td>
<td>Chemical 4</td>
</tr>
<tr>
<td>Gender specific: M/F</td>
<td>Radiation (Ionising)</td>
<td>Chemical 5</td>
</tr>
<tr>
<td>Smell</td>
<td>Radiation (Non-Ionising)</td>
<td></td>
</tr>
<tr>
<td>Hand-eye co-ord</td>
<td>+++</td>
<td>Other</td>
</tr>
<tr>
<td>Hand-eye-foot co-ord</td>
<td>+++</td>
<td>Other</td>
</tr>
<tr>
<td><strong>ERGONOMIC:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use of both hands required</td>
<td>+++</td>
<td>Heights</td>
</tr>
<tr>
<td>Use of both feet required</td>
<td>++</td>
<td>Confined spaces</td>
</tr>
<tr>
<td>Climbing ladders/stairs</td>
<td>+</td>
<td>Abnormal posture</td>
</tr>
<tr>
<td>Heavy manual work</td>
<td>+</td>
<td>Repetitive movements</td>
</tr>
<tr>
<td>Fine delicate work</td>
<td></td>
<td>Prolonged sitting</td>
</tr>
<tr>
<td>Clarity of speech</td>
<td>+</td>
<td>Prolonged bending</td>
</tr>
<tr>
<td>Ability to read/write</td>
<td>++</td>
<td>Prolonged standing</td>
</tr>
<tr>
<td>Height: Tall/Med/Short</td>
<td>Shift work</td>
<td>++</td>
</tr>
<tr>
<td>Poor lighting</td>
<td>++</td>
<td>Parasites</td>
</tr>
<tr>
<td>Uneven terrain</td>
<td>++</td>
<td>Bacteria</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td>Other</td>
</tr>
<tr>
<td><strong>BIOLOGICAL:</strong></td>
<td><strong>DUST:</strong></td>
<td></td>
</tr>
<tr>
<td>Hard Hat</td>
<td>Y</td>
<td>Mask</td>
</tr>
<tr>
<td>Eye Protection</td>
<td>Respirator</td>
<td>Fleece-lined jacket</td>
</tr>
<tr>
<td>Face Shield</td>
<td>Hearing Protection</td>
<td>Y</td>
</tr>
<tr>
<td>Gloves</td>
<td>Safety Boots</td>
<td>Y</td>
</tr>
<tr>
<td><strong>PPE REQUIRED:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>For exclusions, see the mine Code of Practice. Particular exclusions are: Poor vision, uncontrolled epilepsy, diabetes or hypertension.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Approved by:</td>
<td>Position:</td>
<td>Date:</td>
</tr>
</tbody>
</table>
Appendix 14.3: Occupational diseases compensable under the Occupational Diseases in Mines and Works Act (ODMWA)

- Silicosis in miners and surface workers exposed to silica dust
- Silicotuberculosis in miners and surface workers
- Coal workers' pneumoconiosis in coal miners
- Obstructive airways disease in miners
- Tuberculosis, compensable only if cardio-pulmonary organs involved, in miners or those exposed to dust on surface
- Progressive systemic sclerosis or scleroderma, in miners exposed to silica dust

Section (e) of the Act includes any other permanent disease of the cardio-respiratory organs which experts consider attributable to risk work. In practice, this sections covers:

- Occupational asthma in platinum salt workers ("platinosis")
- Asbestosis (interstitial lung disease) in asbestos miners
- Malignant mesothelioma in asbestos miners
- Pleural plaques in asbestos miners
- Asbestos-related lung cancer in asbestos miners
- Bronchiolitis obliterans due to nitrous fumes in mine workers
- Stannosis in tin miners
- Hard metal pneumoconiosis, usually in drill shop workers
### Appendix 14.4: Occupational diseases compensable under COIDA

<table>
<thead>
<tr>
<th>Disease or condition</th>
<th>Required exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Conditions related to physical exposures</strong></td>
<td></td>
</tr>
<tr>
<td>Hearing impairment</td>
<td>Excessive noise</td>
</tr>
<tr>
<td>Hand-arm vibration syndrome (Raynaud’s phenomenon)</td>
<td>Vibrating equipment</td>
</tr>
<tr>
<td>Any disease due to overstraining of muscular tendinous insertions</td>
<td>Repetitive movement</td>
</tr>
<tr>
<td>Dysbarism, including decompression sickness, baro-trauma or osteonecrosis</td>
<td>Abnormal atmospheric or water pressure</td>
</tr>
<tr>
<td>Any (radiation induced) disease</td>
<td>Ionising radiation</td>
</tr>
<tr>
<td><strong>Lung disease</strong></td>
<td></td>
</tr>
<tr>
<td>Tuberculosis or nontuberculous mycobacterial disease of the lung</td>
<td>Crystalline silica Exposure of health care worker to patient with open disease.</td>
</tr>
<tr>
<td>Pneumoconiosis (fibrosis of the parenchyma of the lung)</td>
<td>Organic or inorganic fibrogenic dust</td>
</tr>
<tr>
<td>Pleural thickening causing significant impairment of function</td>
<td>Asbestos or asbestos dust</td>
</tr>
<tr>
<td>Mesothelioma of the pleura or peritoneum or other lung malignancy</td>
<td>Asbestos</td>
</tr>
<tr>
<td>Occupational asthma</td>
<td>Metals: platinum, nickel, cobalt, vanadium, chrome salts</td>
</tr>
<tr>
<td></td>
<td>Welding or soldering fumes</td>
</tr>
<tr>
<td></td>
<td>Resins, plastic forming or hardening agents: isocyanates, epoxy resins, acrylic</td>
</tr>
<tr>
<td></td>
<td>acids or acrylates.</td>
</tr>
<tr>
<td></td>
<td>Chemicals: formaldehyde, amines, diamines, anhydrides, Organic dust (e.g. grain,</td>
</tr>
<tr>
<td></td>
<td>flour)</td>
</tr>
<tr>
<td></td>
<td>Animal or insect matter, moulds, fungi, spores.</td>
</tr>
<tr>
<td></td>
<td>Proteolytic enzymes</td>
</tr>
<tr>
<td>Byssinosis</td>
<td>Flax, cotton or sisal</td>
</tr>
<tr>
<td>Extrinsic allergic alveolitis</td>
<td>Moulds, spores, other allergenic proteins, toluene di-isocyanate</td>
</tr>
<tr>
<td>Bronchopulmonary disease</td>
<td>Metal carbides (hard metal)</td>
</tr>
<tr>
<td><strong>Other cancers</strong></td>
<td></td>
</tr>
<tr>
<td>Malignancy of the lung, skin, larynx, mouth cavity or bladder</td>
<td>Coal-tar, pitch, asphalt, bitumen or volatiles thereof</td>
</tr>
<tr>
<td>Angiosarcoma of the liver</td>
<td>Vinyl chloride monomer</td>
</tr>
<tr>
<td>Malignancy of the bladder</td>
<td>4-amino-diphenyl, benzidine, beta naphthylamine, 4-nitro-diphenyl</td>
</tr>
<tr>
<td>Leukaemia</td>
<td>Benzene</td>
</tr>
<tr>
<td>Melanoma of the skin</td>
<td>Polychlorinated biphenyls</td>
</tr>
<tr>
<td><strong>Skin disease</strong></td>
<td></td>
</tr>
<tr>
<td>Allergic or irritant contact dermatitis</td>
<td>Dust, liquids or external agents or factors</td>
</tr>
<tr>
<td><strong>Conditions caused by metals or chemical compounds</strong></td>
<td></td>
</tr>
<tr>
<td>Erosion of the tissues of the oral cavity or nasal cavity</td>
<td>Irritants, alkalis, acids or fumes thereof.</td>
</tr>
<tr>
<td>Any disease or pathological manifestation</td>
<td>Beryllium, cadmium, phosphorus, chromium, manganese, arsenic, mercury, lead, Fluorine.</td>
</tr>
<tr>
<td><strong>Infectious diseases</strong></td>
<td></td>
</tr>
<tr>
<td>Brucellosis, anthrax, Q-fever, bovine tuberculosis, Rift Valley Fever</td>
<td>Various infective agents (see COID Act).</td>
</tr>
</tbody>
</table>
## Appendix 14.5: Organisations involved in the administration of ODMWA and COIDA

<table>
<thead>
<tr>
<th>Institution</th>
<th>Contact details</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical Bureau for Occupational Diseases</td>
<td>The Director, Box 4584, Johannesburg 2000. Ph: 011 403 6322 Fax: 011 403 6322</td>
<td>Certifies compensable disease. Oversees issuance of certificates of fitness.</td>
</tr>
<tr>
<td>Rand Mutual Assurance Company Limited.</td>
<td>Box 61413, Marshalltown 2107 Ph: 011 497 6600 Fax: 011 492 1253 <a href="http://www.randmutual.co.za">www.randmutual.co.za</a></td>
<td>Insurer for the mining industry but operates under COIDA. Makes payments for claimant’s injury and occupational diseases not covered by ODMWA.</td>
</tr>
</tbody>
</table>
Appendix 14.6: Method of calculating compensation payment under ODMWA and COIDA

**Occupational Diseases in Mines and Works Act**

\((A \times 12) \times B\): (subject to minimum and maximum amounts — see Table 14.1)

Where:

- **A** is the monthly person’s earnings up to an amount of R2,300 (If the person is no longer in mine service, an estimate is made of what he would have been earning had he been in mine service at the time of certification).
- **B** = 1.31 for first-degree certification.
- **B** = 2.917 for second-degree certification where the person had previously received a first-degree award other than for tuberculosis. (B takes on a higher value if the previous certification was for tuberculosis alone, the exact value depending on when the award for TB was made.)

**Compensation for Occupational Injuries and Diseases Act**

**Permanent disablement percentage 30% or less → Lump sum.**

*Formula:* Monthly earnings × 15 × disablement percentage/30.

*Example:* Earnings: R2,000, 20% disablement → Payment: R2,000 × 15 × 20/30 = R20,000 lump sum.

**Permanent disablement percentage 31% — 100%: → Monthly pension for life.**

*Formula:* Monthly earnings × 75% × disablement percentage.

*Example:* Earnings R2,000, 40% disablement. → Payment: R2,000 × 75% × 40% = R600 per month for life.

**Death benefits**

*Contribution to funeral costs* up to a maximum of R6,490.

*Widow’s lump sum:* an amount equal to twice the monthly pension that would have been payable to the deceased for 100% permanent disablement, up to a maximum payment of R16,360.50. (In customary unions, two or more widows will share the lump sum equally).

*Standard widow’s pension:* payable to a widow (40% of the pension) and up to three dependent children (20% each). The pension is calculated at 75% of monthly earnings of the deceased up to R10,907 i.e. a maximum pension of R8,180.25 per month.

COIDA provides for a minimum standard pension of 75% of minimum earnings of R1,166 per month, i.e. R874.50 per month. The widow’s pension is paid for her lifetime, whether or not she remarries.

The children’s component of the pension ceases when the child attains 18 years of age or dies or marries before that age. Where dependent is completing secondary education or undergoing tertiary education, Rand Mutual will continue the child’s pension beyond the age of 18 years.

Dependents are permitted to commute up to R400 per month of their pensions into a lump sum if approved by the Compensation Commissioner as in their interests.

Notes:

- All compensation in terms of COIDA is exempt from income tax.
- Pensions may be increased from time to time.
- The maximum lump sum for 30% permanent disablement is based on a maximum allowable monthly earnings of R6,110, and amounts to 15 × R6,110 × 30/30 = R91,650.
- The standard pension paid for 100% permanent disablement is 75% of maximum allowable monthly earnings up to R10,905, i.e. the maximum pension of R8,180.25 per month.
CHAPTER 15

Personal Protective Equipment

There is a bewildering array of personal protective equipment. The basic principles of equipment selection are provided in this introductory overview. They include identifying hazards, measuring their concentration, understanding the use and limitations of specific devices, ensuring adequate personal fit, undertaking the necessary maintenance and making sure that employees are adequately trained in the use of equipment under both normal and emergency conditions.

Dr R Guild
Occupational Health & Safety Consultant

Haggis Guild is a medical practitioner with an MBA and 20 years experience in the South African mining industry. He has practised at all levels within occupational health services including delivery of medical care; development health and safety protocols; development of medical surveillance programmes, institution of quality assurance programmes and corporate management. He now consults to local and international clients, offering expertise in health risk assessment and management, information systems and corporate governance.
Glossary

APF: assigned protection factor
HPD: hearing protection device
NRR: noise reduction rating
PPE: personal protective equipment
15.1 Introduction

If any occupational health risk cannot be eliminated, controlled at source or during transmission, or if extra safeguards are required, workers must be protected in one of 3 ways:

- by enveloping the worker in a stream of uncontaminated air, thus displacing any airborne pollutants;
- by segregation or separation, using a shield or conditioned enclosure;
- by providing personal protective equipment (PPE).

15.1.1 Displacement

This depends upon the creation of a clean airflow over the worker and towards the work, carrying away the work by-products, preferably towards some form of extraction system. The provision of localised supply ventilation has corresponding economies in the volume of air required, in comparison with a system of blanket ventilation. This technique is most suited to well-defined workstations (e.g. control rooms within smelter or refinery complexes, cabs in moving equipment) but may also be used in the underground mining environment. Care must be taken to ensure that local turbulence is minimised, so that effectiveness of the control is maintained e.g. high velocity air movement and turbulence from an underground fan can increase airborne dust concentrations within the vicinity due to disturbance of dust that has settled on the footwall.

Thermal comfort of workers should also be considered so that the combination of air temperature and velocity is such that cold draughts are not experienced at the workstation. Accordingly, supply diffusers must be carefully chosen and the air temperature accurately controlled, to optimise the air velocity directed at the worker. This is particularly important where air is discharged from above and behind, as the back, neck and head are the parts of the body most sensitive to draughts.

15.1.2 Enclosing or shielding the worker

Isolating the worker from an unconvivial or toxic environment is a technique that is often adopted within smelters, refineries and workshops, where the working process is too large or expensive to control hazards at source or in the transmission stage. Isolation cubicles can be used to protect from noise, ionising radiation, heat and cold, as well as from airborne toxins. In most cases, the enclosure will require ventilation and, possibly, air-conditioning and the amounts of air required must be calculated. As a general rule, each person enclosed will require 10 l of fresh air per second but this amount can be varied, depending upon the size of enclosure and whether or not smoking is permitted (legislation relating to smoking should be considered in this regard). For example, a small enclosure containing one person who smokes would require a fresh air rate of 25 l s⁻¹, whereas a spacious enclosure in which no smoking takes place could be ventilated with as little as 5 l s⁻¹ per person.

15.1.3 Personal protection

The Mine Health and Safety Act (MHSA) places responsibilities on both the employer and employee. The employer (section 6, MHSA) must ensure an adequate supply of health and safety equipment that entails:

- supplying all necessary health and safety equipment and facilities to each employee;
- maintaining the equipment and facilities in a serviceable and hygienic condition;
- ensuring sufficient quantities of PPE are available to each employee as required;
- ensuring instruction in the proper use, the limitations and the appropriate maintenance of the equipment.

The employee (section 22(c), MHSA) should use and take proper care of protective clothing and other health and safety equipment provided by the employer.

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The organs of the human body that are vulnerable to attack from external sources are the eyes, the ears, the skin and the respiratory system. In the case of the first three, a barrier or attenuation device should be worn over the organ being protected. With regard to airborne pollutants, respiratory protection involves the wearing of a device that either cleans the polluted air to a safe level or provides a stream of uncontaminated air from a separate source.

In most cases, these devices appear to provide a cheap alternative solution to engineering control methods. On closer scrutiny, however, the management problems that are created by their introduction make this alternative less attractive. In order to make the decision to use personal protective devices routinely, it is necessary to hold discussions involving trade union’s or workers’ representatives and, once the decision to go ahead has been made, arrangements must be put in hand for the education and training of the users. A complete back-up system of purchasing, storage, cleaning, repair, inspection, testing and replacement has also to be established. Moreover, the reaction of the worker to being asked to wear the devices may involve financial inducements and changes of contract conditions before adoption. It is highly likely that management supervision will have to be strengthened.

15.2 Respiratory protection

The preferred method of reducing worker exposure to respiratory hazards is to minimise the quantity of contaminants in the air through elimination, substitution or engineering controls. Sometimes machinery can even be adjusted to reduce the level of emissions. Engineering controls, however, do not always solve the problem. These controls can be too costly, impractical, and time-consuming or they may not work in some operations. When engineering controls or work practices cannot reduce exposure to an acceptable level, the practical method and (ideally) effective way to protect workers is to implement personal respiratory protection.

Even if there is an opportunity to use engineering controls in the future, respirators can help provide immediate and effective protection for workers until hazards are otherwise eliminated. Most workers accept at face value the importance of wearing eye protection, hard hats, safety boots and gloves, because the unfortunate consequences of inadequate protection are immediate and dramatic. However, they may not recognise the importance of wearing respiratory protection, because many potentially harmful airborne contaminants in the workplace often cannot be seen or tasted, and their damaging effects may not be felt until years later.

Worksite-specific procedures for a respiratory protection programme must include the following:

1. Procedures for selecting respirators for use in the workplace;
2. Medical evaluations of employees required to use respirators;
3. Fit testing procedures for respirators;
4. Procedures for proper use of respirators in routine and any reasonably foreseeable emergency situations;
5. Procedures and schedules for cleaning, disinfecting, storing, inspecting, repairing, discarding, and otherwise maintaining respirators;
6. Procedures to ensure adequate air quality, quantity, and flow of breathing air for atmosphere- supplying respirators;
7. Training of employees in the respiratory hazards to which they are potentially exposed during routine and emergency situations;
8. Training of employees in the proper use of respirators, including putting on and removing them, any limitations on their use, and their maintenance; and

Establishing a basic respiratory protection programme can be broken down into four steps:

1. Identifying the respiratory hazards and concentrations (see chapters 4, 9)
2. Understanding health effects (see chapters 5, 9)
3. Selecting appropriate respiratory protection
4. Training in the proper use and maintenance of respiratory protection
15.2.1 Identifying respiratory hazards and concentrations

This is summarised below and more fully covered in chapters 4 and 9.

- Identify contaminants by type and their sources
- Identify which workers may be exposed
- Measure the concentrations of contaminants to which workers may be exposed
- Assess the risk associated with contaminant exposure
- Establish ongoing monitoring programmes for contaminants

15.2.2 Understand health effects

This is summarised below and more fully covered in chapters 5 and 9.

- Understand how workplace contaminants affect health
- Establish medical screening procedures
- Avoid conditions that are Immediately Dangerous to Life or Health

15.2.3 Selecting appropriate respiratory protection

The following issues need to be addressed when selecting appropriate respiratory protection:

15.2.3.1 Select the appropriate filter cartridge for the contaminant(s)

The contaminant(s) in the work environment will determine the appropriate type of filters and/or charcoal cartridges. For dust and fibres, the medium is a filter, which must be replaced when dirty. For gases and vapours, the medium is a chemical absorbent specifically designed for the gas or vapour to be removed. The absorbing medium is housed in a canister or a cartridge for ease of handling and renewal. Extreme caution must be observed to ensure that the correct medium is used for the pollutant in question and, where dust and fibres are concerned, it is critical to consider the size range of the particles to be removed, in order to select the appropriate filter medium. Filters are also available for combinations of dust, gases and vapours.

Respirators do not provide any protection from an atmosphere deficient in oxygen.

15.2.3.2 Select the respirator type appropriate for the given hazard level

Respirators come in many designs but there are two general types of respirators: air-purifying respirators that filter contaminants from workplace air, and atmosphere-supplying respirators that provide fresh air from an uncontaminated source. The concentration levels will determine the type of respirator required: half-face/full-face, or negative/positive pressure, for example.

The respirator selected must have an assigned protection factor (APF) adequate for the particular workplace exposure. Calculate the so-called hazard ratio and then select a respirator with an APF greater than or equal to that hazard ratio. Note that APFs should be used as guidelines as many aspects e.g. fit are influencing factors.

\[
\text{Hazard ratio} = \frac{\text{airborne contaminant concentration}}{\text{occupational exposure limit}}
\]
Air-purifying respirators

Disposable respirators are manufactured from the filtering material; some are suitable for respirable-sized dusts. The facepiece is at a negative pressure as the lung provides the motive power.
APF: 5

Half-mask respirators, manufactured from rubber or plastic and designed to cover the nose and mouth, have a replaceable filter cartridge. With the appropriate cartridge fitted, they are suitable for either dust, gas or vapour. The facepiece is at a negative pressure, as the lung provides the motive power.
APF: 10

The full-facepiece respirator, manufactured from rubber or plastic, is designed to cover the mouth, nose and eyes. The filter medium is contained in a canister directly coupled or connected via a flexible tube. With the appropriate canister fitted, it is suitable for either dust, gas or vapour. The facepiece is at negative pressure as the lung provides the motive power.
APF: 50

Powered air-purifying respirators

The powered respirator, with a half mask or full facepiece, is made of rubber or plastic maintained at a positive pressure as the air is drawn through the filter, by means of a battery-powered fan. The fan, filter and battery are normally carried on the belt, with a flexible tube to supply the cleaned air to the facepiece.

Half-mask — APF: 50
Full facepiece, helmet — APF: 1000

Powered visor respirators have a fan and filters carried in a helmet, with the cleaned air blown down over the wearer’s face inside a hinged visor. The visor can be fitted with side shields, which can be sized to suit the wearer’s face. The battery pack is normally carried on the belt. A range of filters and adsorbents is available as is a welder’s type.
Loose fitting — APF: 25

There are many variations in the above types of devices and manufacturers’ catalogues should be consulted before choosing. Professional assistance is often required.
**Supplied-air respirators (airline)**

These provide a supply of uncontaminated air, from a source that is either drawn from fresh air or compressed air or is supplied from a high-pressure cylinder carried with the wearer.

With a fresh air hose apparatus, a supply of fresh air is fed to a facepiece, hood or blouse, via a large-diameter flexible tube. The motive power is provided either by a manually or electrically powered blower, giving a positive pressure in the facepiece. It is important to establish a suitable fresh air base for the blower and, if manually operated, 2 operators should be present.

Continuous flow, loose fitting — APF: 25
Half-mask — APF: 50
Full facepiece — APF: 1000

A compressed air-line apparatus supplies air via a reducing valve to a facepiece, hood or blouse. If a normal compressed air supply is used, it is necessary to filter out contaminants such as oxides of nitrogen, carbon monoxide and oil mists from the air before introducing it to the wearer. Specially designed air compressors for breathing apparatus are preferred, as these use special lubricating oils to minimise air contamination.

Pressure demand with full facepiece — APF: 1000

**Pressure demand airline with escape self-contained breathing apparatus**

Self-contained breathing apparatus uses cylinders of air or oxygen, feeding a mouthpiece or facepiece via a pressure-reducing valve. Open-circuit sets contain sufficient air or oxygen for a duration of use of between 10 and 30 min. Closed-circuit sets, which recirculate and purify exhaled breath, can last up to 3 hours.

APF: 2000

If a chemical can be absorbed through the skin, skin protection may be required in addition to respiratory protection; eye protection may also be necessary if not provided by the respirator. Failure to provide adequate skin or eye protection can invalidate established exposure limits (which are generally set for inhalation of airborne contaminants only unless “skin” notation is specified) and make respirator use ineffective for protection against certain workplace contaminants.
15.2.3.3 Match the respirator to the worker

Employees using tight-fitting facepiece respirators must be:

- tested prior to initial use of the respirator with the same make, model, style, and size of respirator that will be used to ensure adequate sealing,
- whenever a different respirator facepiece (size, style, model or make) is used, and
- at least annually thereafter.

Facial hair, missing dentures and certain skin conditions can affect the seal and result in leakage of contaminated air into the mask.

15.2.3.4 Select respirators that are comfortable to wear

If strenuous work is to be performed, or if the respirator is to be worn for an extended period of time, it may be desirable to select a lightweight respirator with low breathing resistance. If a respirator does not have good worker acceptance and does not stay on the worker’s face, it will not provide the protection needed.

15.2.3.5 Match the respirator to the job conditions

Consider the entire package of safety equipment required for the job. The respirator selected must be compatible with hard hats, goggles, glasses, welding hoods, face shields, etc. In addition, the worker must be able to communicate and perform required job duties without removing the respirator.

Also consider the distance the worker must travel to get to an uncontaminated work area, as well as obstacles or equipment present in the area. If ladders or scaffolds must be climbed, an air-purifying respirator or a combination air-purifying/airline respirator may be appropriate.

15.2.3.6 Select approved respirators and replacement parts

A respirator may not be able to help protect against all contaminants present in a particular work environment. Specific limitations are stated on the approval labels and are included with user instructions and limitations. These must be carefully reviewed for each respirator before use.

15.2.3.7 Select respirators that can be easily maintained and repaired

Each user should be provided with a respirator that is clean, sanitary, and in good working order and cleaned and disinfected after each use. The manufacturer should advise on the life of the canister or cartridge, taking into account the environment in which it is being used and the device must be replaced at the interval recommended. Central maintenance procedures are preferable to allowing the wearers to service their own respirators as nominated responsible persons will build up expertise on care and maintenance, apply routine tests and keep records on the respirators.

15.2.4 Training in the proper use and maintenance of respirators

The following issues should be addressed:
Develop a written plan and document it

Evaluate workers for their ability to use respirators and to be physically able to perform the work. Respirator use may place a physiological burden on an employee that varies with the type of respirator worn, the job and workplace conditions in which the respirator is used, and his/her medical status. Accordingly, a medical evaluation must be implemented to determine the employee’s ability to use a respirator, especially the more sophisticated types. Annual medical evaluations are not required but should be repeated under the following situations:

- an employee reports medical signs or symptoms that are related to his/her ability to use a respirator;
- information from the respiratory protection programme, including observations made during seal testing and programme evaluation, indicates a need for employee re-evaluation; or
- a change occurs in workplace conditions (e.g., physical work effort, protective clothing, and temperature) that may result in a substantial increase in the physiological burden placed on an employee.

Develop and implement training procedures

Conduct on-going training for management, supervisors and workers

Explain how to wear respirators, their uses and limitations

Develop and follow respirator maintenance procedures, including cleaning, inspection and repair

Perform respirator fit testing on at least an annual basis

Respiratory protection is generally uncomfortable to wear, particularly those types using the lungs to provide the motive power and those with negative-pressure facepieces. As the resistance of a filter has to be overcome by the wearer’s lungs, the higher the resistance, the less comfortable the apparatus becomes and the greater the temptation to remove it for some temporary respite. It has been shown that the removal of the respirator, even for a short period of time, can seriously reduce the degree of protection given.

Because there is no “all-purpose” respirator to help protect against all contaminants and concentrations, employers must match expected respiratory protection needs with various respirator models. The choice of equipment is vast and much confusion can arise as to which device to use for a particular hazard. As the wrong choice may seriously affect the health of the wearer and could lead to illness or death, competent advice is required. For example, 3M publishes a respirator selection guide and a computer software package to match specific contaminants and concentrations with an appropriate 3M respirator (http://www.3m.com/intl/CA/english/market/traffic/ohes/index.html).

15.3 Hearing protection

Because noise is produced in a range of frequencies, the choice of hearing (not ear) protection must be based upon the measured spectrum of the noise to be attenuated. Hearing protectors are either ear-muffs, which cover the ears, or ear plugs that are inserted into the ear canals. Within these 2 groups, however, there are several subdivisions. Ear-muffs can have several degrees of attenuation, and ear-plugs can be of a variety of materials both disposable and reusable. Fig. 15.9 shows attenuation data for 4 types of hearing protection and shows the importance of frequency.

![Figure 15.9 Comparison of attenuation data for 4 hearing protectors](image-url)

It is recommended that hearing protection should be used if the workplace noise levels cannot be reduced to below 82 dB(A). The degree of protection provided should be such that the level at the worker’s ears is below 82 dB(A).

15.3.1 Theoretical protection

To calculate the degree of protection given by hearing protectors it is necessary to measure the sound spectrum of the noise emitted at the workplace, using octave band analysis, and compare it against the attenuation capacity of the hearing protection devices. This is best illustrated using an example (Table 15.1).

Table 15.1 Example of calculation to find the degree of attenuation provided by a particular ear-muff against a typical mining industry noise

<table>
<thead>
<tr>
<th>Octave band mid-frequency</th>
<th>Hz</th>
<th>63</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1k</th>
<th>2k</th>
<th>4k</th>
<th>8k</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured sound pressure level of typical noise (dB)</td>
<td>92</td>
<td>96</td>
<td>102</td>
<td>101</td>
<td>98</td>
<td>97</td>
<td>94</td>
<td>93</td>
<td></td>
</tr>
<tr>
<td>A-weighting correction</td>
<td>-26</td>
<td>-16</td>
<td>-9</td>
<td>-3</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>-1</td>
<td></td>
</tr>
<tr>
<td>Corrected level (measured SPL plus correction)</td>
<td>66</td>
<td>80</td>
<td>93</td>
<td>98</td>
<td>98</td>
<td>98</td>
<td>96</td>
<td>92</td>
<td></td>
</tr>
<tr>
<td>Approximate summation of levels</td>
<td>83</td>
<td>99</td>
<td>101</td>
<td>102</td>
<td>97</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estimated level of noise unprotected (104 dB(A))</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ear muff attenuation, mean of measurements (dB)</td>
<td>--</td>
<td>13</td>
<td>20</td>
<td>33</td>
<td>35</td>
<td>38</td>
<td>47</td>
<td>41</td>
<td></td>
</tr>
<tr>
<td>Standard deviation</td>
<td>--</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Assumed protection of ear-muff (mean minus SD) (dB)</td>
<td>--</td>
<td>7</td>
<td>14</td>
<td>27</td>
<td>29</td>
<td>31</td>
<td>38</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>Corrected level (from above)</td>
<td>66</td>
<td>80</td>
<td>93</td>
<td>98</td>
<td>98</td>
<td>98</td>
<td>95</td>
<td>92</td>
<td></td>
</tr>
<tr>
<td>Levels at ear (corrected level plus protection)</td>
<td>66</td>
<td>73</td>
<td>79</td>
<td>71</td>
<td>69</td>
<td>67</td>
<td>56</td>
<td>59</td>
<td></td>
</tr>
<tr>
<td>Approximate summation of levels</td>
<td>74</td>
<td>80</td>
<td>71</td>
<td>61</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estimated level of noise at ear with protection (81 dB(A))</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Noise is a combination of sounds at various frequencies and intensities and can be expressed as a combination of all frequencies summed together in one value. As the human ear is more sensitive to certain frequencies than others, instrument measurements have to be weighted. The most commonly used is the A weighting correction where there are standard dB corrections related to specific frequencies as shown in Table 15.1.

Each “corrected” mid-octave level can be added together but their total combined intensity is not the simple numerical sum of the decibel level of each separate intensity.

Because the logarithmic nature of the decibel scale, they must be added according to the chart in Figure 15.10.

The assumed protection of the hearing protector, also expressed in mid-octave values, should then be subtracted from the corrected level and the result added as before to produce the estimated dB(A) at the wearer’s ear.

15.3.2 Use of noise reduction rating

The noise reduction rating (NRR) describes the average sound level reduction (attenuation) provided by a hearing protection device (HPD) when worn by 10 different people during a laboratory test.
However, under actual working conditions, HPDs only provide 30% – 50% as much attenuation as the NRR.

As in the respiratory case, hearing protection can be uncomfortable, particularly if worn for long periods, as the wearer may feel enclosed and isolated and, with ear-muffs, perspiration can build up around the seals. Wearers are, thus, tempted to remove them to ease discomfort. It has been shown that removal of hearing protection, even for short periods, will reduce the overall protection substantially, the effect being increasingly more pronounced as noise levels increase.

This effect is illustrated in Fig. 15.11 from which it can be seen that protection giving 20 dB(A) attenuation, when worn 100% of the time, will only give an effective 10 dB(A) protection, when worn 90% of the time.

For most wearers, the NRR displayed on manufacturers’ goods significantly overestimates the HPD protection in the workplace.

Figure 15.10 Chart for adding two unequal noise levels

Figure 15.11 The effects of removing hearing protectors for a period of time (after Else, D (1974))
If noise levels are much in excess of 90 dB(A), protection must be worn continuously to maintain levels below 82 dB(A) at the ear, averaged over the whole shift. It can thus be seen that better overall protection may be provided by using a lower degree of attenuation from an ear plug, which may be more comfortable and acceptable and thus not removed during the shift, than from the higher attenuated but less comfortable ear-muffs.

Therefore, the NRR should be reduced to provide a practical estimation of attenuation from HPDs and a useful reduction method is provided in Figure 15.12.

**Figure 15.12 An example of reducing the NRR**

8-hour TWA noise exposure: 93 dB(A)
NRR of hearing protectors: 29 dB(A)
Subtract 7 dB from NRR: 29 – 7 = 22 dB(A)
Divide by 2: 22 ÷ 2 = 11 dB(A)
Subtract 11 dB from 8-hour TWA exposure: 93 – 11 = 82 dB(A)

Decide if 82 dB(A) (“protected exposure”) is below the permissible exposure limit for noise.

### 15.3.3 Reasons for attenuation leaks

1. **Improper sizing**: Ear plugs come in several sizes. It is important to offer all sizes and to pick the correct one. Wearers tend to fit plugs too loosely, causing gaps between the plug and the ear canal, or too tightly, causing a comfort problem, which can result in plugs that are worn in the pocket rather than in the ear! In some cases, the same individual will have two differently sized ear canals, so each ear should be sized separately.

2. **Faulty insertion**: This is probably the most common reason for attenuation leaks in ear plugs. Most users have had little or no training in inserting ear plugs, so they may not know how to do it properly. Also, unlike the laboratory situation, users tend to insert the plugs loosely if they know that they must wear them for long periods of time.

3. **Compatibility problems**: Hearing protection often needs to be worn with other types of protective gear, such as helmets and safety glasses. Ear-muffs are incompatible with helmets unless they are specially mounted on the helmet. Temple bars of safety glasses can break the seal of ear-muff cushions, allowing noise to leak into the ear. The small pads through which certain temple bars may be inserted will certainly improve the worker’s comfort, but the muff’s attenuation will still be somewhat reduced. In addition to safety equipment, long hair, beards, and large earrings can interfere with the seal of ear-muff cushions.

4. **Communication**: Workers will often remove their hearing protectors or loosen them so that they can communicate with each other, hear warning signals or the sounds of their machines. HPDs will attenuate both the desired signal and the unwanted noise but they also change the nature of sounds (by changing the frequency spectrum) because they attenuate the high frequencies more than the low ones. In addition, workers who already have a noise-induced hearing loss will have a more difficult time hearing the desired sounds when they wear protectors, giving them another reason to loosen their protectors and let them leak. Because of this, a hearing protector with the highest NRR may not give the best overall protection.

5. **Wear and tear**: Nothing lasts forever, and that applies to ear-muffs as well as ear plugs. Although foam plugs are reusable on a few occasions, they will become less flexible, no longer moulding to the ear canal, and will develop attenuation leaks. Pre-moulded and custom-moulded plugs will shrink with age, and some will crack, becoming brittle and less malleable. Ear-muff headbands may lose their tension, ear cups may no longer fit securely, and the cushions may deteriorate with age, becoming brittle and no longer conforming to the head. Some pre-moulded ear plugs may need to be replaced in a few weeks if the wearer develops a considerable amount of ear wax or perspiration. In any case, protectors should be checked at least every SIX months.

Chewing gum, talking, and moving around could also influence normal wear and tear. These activities
can loosen the fit of hearing protectors and lead to the development of attenuation leaks. It is a good idea for the wearer to be aware of these possibilities and to check a protector’s fit periodically. Plugs need not be removed and reinserted, but rather pushed somewhat deeper into the canal as necessary.

6. User modification: Sometimes workers will become creative in their treatment of hearing protectors, to the detriment of the protector’s attenuation. To improve comfort without changing the protector’s appearance at a distance, workers may cut the flanges of a pre-moulded plug or cut a foam plug across its diameter. In this way the plug may hardly be inserted at all and yet will still appear to be in the ear canal. Muffs may be modified by springing the headband or they can be “personalised” by drilling holes in the form of one’s initials into ear cups. In both instances, considerable attenuation will be lost.

Despite this list of problems, HPDs can be worn comfortably and effectively on the job. This occurs when employers as well as employees are well trained in all aspects of these devices and use them conscientiously.

15.3.4 Selecting appropriate HPDs

A wide variety of HPDs is available and selection should take cognisance of the attenuation level required and the human factors described in section 15.3.2. Therefore a range of hearing protection should be made available, so that wearers can choose the type that is most comfortable for them.

Ear-muffs

These consist of a cup-shaped cover over each ear, held in place by a spring-loaded headband. To ensure a good seal around the ear, the cups are edged with a cushion filled with liquid or foam. The degree of attenuation is affected by the material of the cup and its lining and the success of the device depends upon the quality of the seal around the ear.

Servicing and replacement facilities must be provided for ear-muffs because they will deteriorate with time, in particular at the seals, which become distorted and harden with age.

Figure 15.13 Ear-muffs

Ear plugs

These can be of a variety of materials.

Disposable plugs

glass down
plastic-coated glass down
wax-impregnated cotton wool
polyurethane foam

Reusable plugs

paste-filled rubber
paste-filled plastic
permanent moulded plastic e.g. variphones

Figure 15.14 Ear plugs
All reusable plugs require washing after use and a sterile place for storage. Disposable plugs are available commercially in wall-mounted dispensers or in cartons containing several days supply for 1 person.

As with all forms of personal protective devices, adequate training must be provided so that the wearers can understand the reasons for providing them. In-house training programmes should be implemented and can be aided by films and/or slide presentations. Hearing protection manufacturers can assist with audio-visual aids and explanatory leaflets. Routine audiometric measurements on workers provide an opportunity to encourage them to wear hearing protection.

15.4 Eye and face protection

Protection should be provided to guard against:

- impact of small particles projected at a low/high velocity
- the impact of heavy particles at a low/high velocity
- the splashing of hot or corrosive liquids
- the contact of the eyes with irritating gases or vapours
- abeam of electromagnetic radiation at various wavelengths, including laser beams

15.4.1 Selecting appropriate eye and face protection

Eye protection takes the form of spectacles, goggles or face shields, all of which are available from numerous manufacturers and suppliers, in a wide range of sizes. Suitability for the hazard and comfort must be the over-riding factors in choosing the particular device, as the users must have complete confidence in the protection it provides and must not be forced to remove it to relieve discomfort during the operation for which protection is required. A preoccupation with discomfort may also distract from the task in hand and lead to errors and accidents.

Each harmful agent may require a particular form of eye protection that may be unsuitable for another agent. In some cases, the protection may have to be extended to the whole face. An appropriate range of suitable forms of protection should, therefore, be made available for the user to choose the one to suit the shape of his/her face. This may mean having products from more than one manufacturer available.

Safety spectacles are only suitable for low energy hazards but are available in a wide range of sizes to suit the face.

Types: clear, clip on, prescription, tinted (anti-flash).

Goggles are suitable for a wide range of hazards but limited in fittings from any one manufacturer.

Types: chemical, dust, gas, gas welding, general purpose, molten metal.

Shields are suitable to protect the eyes or the whole face, can be attached to a helmet or a head band but may be hand-held.

Types: eye, face, furnace viewing, welding.

Figure 15.16 Safety goggles
15.4.2 Problems associated with use of protection

Some of the problems involved in the use of eye protectors are given below. Several can be overcome by suitable selection but certain problems are inherent in the use of such devices.

1. They may not guard against the hazard.
2. They may not fit properly.
3. They may be uncomfortable due to uneven pressure on the face.
4. They may restrict the field of view.
5. Spectacles worn for correction of vision may interfere with the wearing of eye protectors and vice versa. Whilst safety spectacles with corrective lenses are available, their suitability is limited to minor eye hazards.
6. Optical services and follow-up may be necessary to deal with problems of refraction of light.
7. Eye protectors may interfere with the wearing of respiratory and/or hearing protection. Where more than one organ is to be protected, an integrated combined protective device may, therefore, be more suitable.
8. Due to discomfort, the wearer may be tempted to remove the protector from time to time, with a consequent loss of protection for that period.
9. Fitting, cleaning, inspection and replacement procedures are necessary.
10. Training may be required for users and for maintenance staff.

15.5 Skin protection

Skin protection (see chapter 14) includes guarding hands, feet and body against:

- damage from dermatitic or corrosive agents
- absorption into the body via the skin
- radiant heat
- cold
- ionising and non-ionising radiation
- physical damage

15.5.1 Selecting appropriate skin protection

The material used for gloves, aprons or garments must be suited to the purpose and must be chosen carefully. Note should be taken of the following points:

1. Protective clothing, particularly a whole-body garment, sets up a microclimate, which may limit the loss of body heat, causing discomfort and leading to possible stress. Some such garments can be ventilated.
2. Some garments restrict the movement of limbs, which slows the worker and increases fatigue.
3. Provision must be made for changing, cleaning and storage of protective clothing.
4. Impervious gloves must be sufficiently long to tuck under a sleeve to prevent materials spilling inside.
5. Low temperatures may make certain plastic materials too stiff to be usable.
**Hand protection**

<table>
<thead>
<tr>
<th>Materials</th>
<th>Protection</th>
<th>Gloves</th>
</tr>
</thead>
<tbody>
<tr>
<td>asbestos</td>
<td>abrasion</td>
<td>armoured</td>
</tr>
<tr>
<td>cotton</td>
<td>chemical</td>
<td>chainmail</td>
</tr>
<tr>
<td>leather</td>
<td>electrical</td>
<td>disposable</td>
</tr>
<tr>
<td>moleskin</td>
<td>fire/flame/heat resistant</td>
<td>electricians</td>
</tr>
<tr>
<td>neoprene</td>
<td>general purpose engineering</td>
<td>gauntlets</td>
</tr>
<tr>
<td>nitrile</td>
<td>hygiene</td>
<td>hand pads</td>
</tr>
<tr>
<td>nylon</td>
<td>low temperature</td>
<td>mitts</td>
</tr>
<tr>
<td>polythene</td>
<td>radiation</td>
<td>reversible</td>
</tr>
<tr>
<td>PVC impregnated</td>
<td></td>
<td>surgical</td>
</tr>
<tr>
<td>PVC rubber</td>
<td></td>
<td>X-ray</td>
</tr>
<tr>
<td>terry cloth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>terylene</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Body protection**

<table>
<thead>
<tr>
<th>Materials</th>
<th>Protection</th>
<th>Garments</th>
</tr>
</thead>
<tbody>
<tr>
<td>asbestos</td>
<td>buoyant</td>
<td>aprons</td>
</tr>
<tr>
<td>chainmail</td>
<td>chemical</td>
<td>armlets and sleeves</td>
</tr>
<tr>
<td>cotton (denim etc)</td>
<td>exposure</td>
<td>capes</td>
</tr>
<tr>
<td>glass fibre</td>
<td>fire/flame/heat resistant</td>
<td>disposable</td>
</tr>
<tr>
<td>leather</td>
<td>high-visibility fluorescent</td>
<td>gloves</td>
</tr>
<tr>
<td>melton</td>
<td>ionising radiation</td>
<td>hoods</td>
</tr>
<tr>
<td>moleskin</td>
<td>proofed</td>
<td>overalls</td>
</tr>
<tr>
<td>neoprene</td>
<td>quilted</td>
<td>suits — hot entry</td>
</tr>
<tr>
<td>nylon, terylene</td>
<td>ventilated</td>
<td>trousers</td>
</tr>
<tr>
<td>paper and disposable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>plastic coated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>polyurethane</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PVC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>wool</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**15.6 Foot and leg protection**

An multitude of different gear is available

**Foot and leg protection**

<table>
<thead>
<tr>
<th>anti-static footwear</th>
<th>knee pads</th>
</tr>
</thead>
<tbody>
<tr>
<td>boots and shoes</td>
<td></td>
</tr>
<tr>
<td>chemical footwear</td>
<td></td>
</tr>
<tr>
<td>clogs</td>
<td></td>
</tr>
<tr>
<td>cold-storage footwear</td>
<td></td>
</tr>
<tr>
<td>conductive footwear</td>
<td></td>
</tr>
<tr>
<td>foundry boots</td>
<td></td>
</tr>
<tr>
<td>gaiters/spats</td>
<td></td>
</tr>
<tr>
<td>knee boots</td>
<td></td>
</tr>
<tr>
<td>moulded footwear</td>
<td></td>
</tr>
<tr>
<td>non-slip footwear</td>
<td></td>
</tr>
<tr>
<td>over boots and over shoes</td>
<td></td>
</tr>
<tr>
<td>rubber ankle boots</td>
<td></td>
</tr>
<tr>
<td>soles and heels</td>
<td></td>
</tr>
<tr>
<td>thigh boots</td>
<td></td>
</tr>
</tbody>
</table>
15.7 Guide to information resources


Lex Patra’s Clan-Series (2) 2001/2 Check Lists, Addresses and Numbers. Occupational Health Association of South Africa


Information sources for personal protective equipment

http://www.cdc.gov/niosh/respinfo.html: Topics relating to the decision logic required to select respirators, listing of approved respirators and maintenance procedures for respirators

http://www.cdc.gov/niosh/noise/noisepg.html: Topics relating to noise and hearing loss, hearing conservation programmes and hearing protection devices

Reference material


Acknowledgements

The author is grateful to the members of the South African Protective Equipment Manufacturers’ Association (SAPEMA) for providing invaluable assistance in understanding the specifications and limitations of personal protective equipment.
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