Mine Health and Safety Council

MHSC

Review the Current Airborne Exposure Limits as Listed in Schedule 22.9(A)

Milestone Report:

Milestone 5: Draft Final Report (Summary Report)

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4 LIST OF ABBREVIATIONS

&	:	And
µg	:	Microgram
%	:	Percentage
ACGIH®	:	American Conference of Governmental Industrial Hygienists
Ag	:	Silver
As	:	Arsenic
Asb	:	Asbestosis
ASTDR	:	Agency for Toxic Substances and Disease Registry
Be	:	Beryllium
BEI	:	Biological Exposure Index
carc A1	:	Confirmed human carcinogens
carc A2	:	Suspected human carcinogens
carc A3	:	Carcinogenic in experimental animals, but with insufficient evidence of their carcinogenicity in humans
carc A4	:	Not classifiable as a human carcinogen
carc A5	:	Not suspected to be a human carcinogen
Cd	:	Cadmium
CDC	:	Centres for Disease Control, USA
CN	:	Cyanide
Co	:	Cobalt
CO	:	Carbon Monoxide
CO_2	:	Carbon Dioxide
COAD	:	Chronic Obstructive Airway Disease
COPD	:	Chronic Obstructive Pulmonary Disease
COVID-19	:	Coronavirus disease
Cr	:	Chromium
Cr II	:	Chromium Two or (II)
Cr (III)	:	Chromium Three or (III) or Trivalent chromium
Cr (V)	:	Chromium Five or (V)
Cr (VI)	:	Chromium Six or (VI) or Hexavalent chromium
CTPV	:	Coal Tar Pitch Volatiles
Cu	:	Copper
CWP	:	Coal Workers' Pneumoconiosis

DEE	:	Diesel Exhaust Emissions
DPM	:	Diesel Particulate Matter
DSEN	:	Dermal Sensitizer
e.g.	:	Latin phrase “exempli gratia” meaning “for example”
etc.	:	Latin phrase “et cetera” meaning “and so forth”
excl.	:	Excluding
F	:	Fluorine
Fe	:	Iron
FeCr	:	Ferrochrome
FeO_2	:	Iron Dioxide or Iron(II) oxide
Hg	:	Mercury
i.e.	:	Latin phrase “id est” meaning “that is”
ICSC	:	International Labour Organisation International Chemical Safety Cards
L	:	Litre
m^3	:	Cubic meter
MEK	:	Methyl Ethyl Ketone
mg	:	Milligram
MHSA	:	Mine Health and Safety Act
MHSC	:	Mine Health and Safety Council
MIBK	:	Methyl Isobutyl Ketone
Mo	:	Molybdenum
Mn	:	Manganese
NCO	:	Isocyanate Chemical Group
NH_3	:	Ammonia
NGT	:	Nominal Group Technique (modified)
Ni	:	Nickel
NIHL	:	Noise-Induced Hearing Loss
NIOH	:	National Institute for Occupational Health, South Africa
NIOSH	:	National Institute for Occupational Safety and Health, USA
NO_2	:	Nitrogen Dioxide
OAD	:	Obstructive Airway Disease
OEL(s)	:	Occupational Exposure Limit(s)
OMP	:	Occupational Medical Practitioner

Os	:	Osmium
OSD	:	Occupational Skin Disease
OSHA	:	Occupational Safety and Health Administration
Pb	:	Lead
PN	:	Pneumoconiosis
PNOC	:	Particle Not Otherwise Classified
ppm	:	Parts Per Million
Pt	:	Platinum
PVC	:	Polyvinyl Chloride
R	:	South African Rand
Rh	:	Rhodium
RMA	:	Rand Mutual Assurance
RSEN	:	Respiratory Sensitizer
SAMI	:	South African Mining Industry
Sb	:	Antimony
SCOEL	:	Scientific Committee on Occupational Exposure Limits
SEN	:	Sensitizer
Sil+TB	:	Silico-Tuberculosis
Sk	:	Skin
Sn	:	Tin
SO_2	:	Sulphur Dioxide
STEL	:	Short-term Exposure Limit
Ta	:	Tantalum
TB	:	Tuberculosis
Te	:	Tellurium
Ti	:	Titanium
TLV®	:	Threshold Limit Value® of the ACGIH®
TWA	:	Time-Weighted Average
U	:	Uranium
USA	:	United States of America
W	:	Tungsten
WHO	:	World Health Organization
Zr	:	Zircon

5 EXECUTIVE SUMMARY

This report is a summary of the detailed project report and only key outcomes from the project are reported. The comprehensive, integrated report can be requested from the MHSC.

The objectives of this research project were to:

1. Determine the impact of the current airborne pollutant exposure limits on employees' short- and long-term health.
2. Recommend appropriate OELs for the SAMI in line with Schedule 22.9(A) of the MHSA, including but not limited to, classification bands in terms of exposure risks.
3. Conduct a stakeholder workshop arranged and hosted by MHSC in Gauteng to present the outcomes of the project.

Ethical clearance was obtained from the Faculty of Health Sciences Ethics Committee. (Clearance: 51/2019)

Different sources were reviewed to determine which occupational disease have the highest prevalence. Fifteen of the occupational diseases with the highest number of reported cases were ranked, high to low: silicosis, emphysema, pulmonary tuberculosis, silico-tuberculosis, other respiratory conditions, primary lung cancer, asbestosis, coal workers' pneumoconiosis, chronic obstructive pulmonary disease, mesothelioma, allergic contact dermatitis, massive pulmonary fibrosis, mixed dust pneumoconiosis and occupational asthma.

The health effects that are associated with the occupational diseases with the highest prevalence involve primarily the respiratory tract and the skin. Of the 786 pollutants listed in Schedule 22.9(A), the respiratory system ~~is~~ targeted by 68.1% of the listed chemicals. Most noteworthy other target organs and systems that were identified include the eye, skin and the central nervous system. Fourteen of the fifteen occupational diseases that were identified are associated with the respiratory system and the other one was associated with the skin (allergic contact dermatitis). Diseases related to the respiratory system, eyes, skin, central nervous system and kidneys contribute to more than 80% of the occupational diseases with the highest prevalence. Of the airborne pollutants listed in Schedule 22.9(A), 78% of the pollutants have a combined health impact on more than five target organs.

A cost-benefit analysis framework was developed that can be applied by both government and industry to determine the financial impact, should an OEL be amended. In principle, the framework determines the net financial impact when the cost to comply with an OEL is subtracted from the benefits that will be derived now and in the future. The framework presents extensive coverage of the identification of various 'cost categories' which will be impacted as a result of any change in OEL. The model is only intended to provide a framework and, while a thorough model has been developed, further work needs to be performed to be able to determine detailed financial implications resulting from a change in OEL. The costing equations (and components thereof), in conjunction with some of the modelling already performed, will drive the value determination and the next steps in the research. At the stakeholder workshops most of the respondents agreed that a comprehensive cost-benefit analysis should form part of the implementation plan for revised OELs.

All 786 of the Schedule 22.9(A) OELs were selected to compare the current SAMI OELs with other national and international government agencies and standards generating organisations. Of all the current South African OELs, 85 airborne pollutants have OELs that are less stringent or potentially less protective when compared with international leading practice. When compared with international leading practice, Schedule 22.9(A) lacks important notations (which highlight toxicity endpoints of chemical substances) that convey important information regarding the route of exposure, toxicological and/or associated health effects. The most important differences were that skin notations, the influence on pregnancy and reproduction and classification in terms of carcinogenicity were lacking in Schedule 22.9(A).

Following the literature review and tabulated comparison of the OELs, inputs were obtained from experts, government, industry and labour on which airborne pollutants should be prioritised for OEL review. The purpose of the priority list is mainly to provide direction to the process to be followed to review OELs of airborne pollutants on completion of this project. Considering that there are 786 airborne pollutants in Schedule 22.9(A), some pollutants may require a comprehensive OEL review in the next five years while other pollutants can be reviewed over the next 10 to 15 years.

The objective of the expert target group engagement was to obtain an industry priority list from the Schedule 22.9(A) airborne pollutants, whose OELs should be reviewed following the recommendations from the participating industry and scientific experts. It is important to note that the participating experts did not have any knowledge of the OELs identified for revision by the research team. Pollutants could only be included on this industry priority list if 100% agreement or consensus was reached between all the participating experts.

A modified Nominal Group Technique (NGT) was used during the workshop to reach consensus on the pollutants that should be prioritised for review in the opinion of the experts. The priority list, as suggested by the experts, consisted of the following pollutants (in alphabetical order), namely, carbon monoxide (CO), chromium (metal and inorganic compounds), coal dust (respirable particulate), diesel particulate matter (DPM), nitrogen dioxide (NO_2), silica (crystalline, respirable particulate) and welding fumes.

The industry stakeholder engagement was held with a larger group of industry stakeholders, that included representatives from government and labour. The objective of this engagement was to allow various industry and governmental stakeholders to review and comment on the priority list of airborne pollutants that was developed during the expert target group engagement. The participants were asked questions on whether they agreed or disagreed with the OEL priority pollutant (six) list as identified by the experts for review. This include DPM as a new airborne pollutant in Schedule 22.9(A).

In summary, most of the participants agreed that the OELs for CO, chromium, coal dust, silica and welding fumes should be prioritised for review. However, most of the participants disagreed that the OEL for NO_2 should be prioritised for review. Further to these pollutants, the participants recommended that the following airborne pollutants should be prioritised for OEL review: All airborne pollutants with carcinogen, skin and sensitizer notations; ammonia, asbestos, benzene and associated compounds, coal tar pitch volatiles (CTPV), cyanide (hydrogen cyanide), fused silica, hydrogen sulphide, cyanide (hydrogen cyanide), particles not otherwise classified (PNOC), titanium dioxide, vanadium pentoxide, and wood dust.

The expert and industry stakeholder feedback that was received was taken into consideration to propose revised OELs for the prioritised airborne pollutants.

In the absence of a defined, national, approach it is proposed that a strategy is followed to adopt the Threshold Limit Values (TLVs®), notations and Biological Exposure Indices (BEIs®)

of the American Conference of Governmental Industrial Hygienists (ACGIH®). The reason for such an adoption is that the ACGIH TLVs® are health-based, comprehensively and systematically reviewed, and there is an established body of scientific knowledge available to the public at a reasonable cost. The adoption of the ACGIH notations will result in 225 carcinogenic pollutants that are assigned with a carcinogen notation (carc A1-A5), and 75 airborne pollutants with skin notations, and 66 sensitiser notations. Where the ACGIH does not have a notation, it is recommended not to adopt notations from another organisation to remain consistent with the ACGIH adoption strategy. It is also recommended that biological monitoring for specific airborne pollutants, as a form of medical surveillance, is included in the MHSA and that a BEI notation of the ACGIH is included as a note to those airborne pollutants listed in Schedule 22.9(A).

Online workshops were held to share the outcomes of the project with all stakeholders. Nearly 80% of the respondents agreed with the process that was followed to come to the recommended OELs. There was overwhelming support for the unchanged OELs, namely Chromium metal and Cr(II), PNOC, titanium dioxide, wood dust, and iron oxide (but change in fraction). Most of the respondents supported the recommended OELs for Silica (amorphous, fused and fume), lead, benzene and CO. The recommended OEL for hydrogen sulphide was opposed and there were mixed reactions on the proposed OELs for trivalent chromium (Cr(III)), hexavalent chromium (Cr(VI)) and vanadium pentoxide.

A few special recommendations are made. The recommendation to retract the welding fume OEL was supported by most of the participants. Furthermore, there was consensus that an OEL for diesel exhaust emissions (DEE) as total carbon (respirable fraction)), should be included in Schedule 22.9(A). However, there were concerns that the DEE OEL was too low considering the current engine technology, types of machines (tier) and quality of fuel. A recommendation to change the OEL of iron oxide, dust and fume [as Fe] from inhalable to respirable fraction was also supported.

The recommended OEL for coal dust was supported by 17% of the respondents while 28% of the respondents disagreed with this recommendation. Half of the respondents agreed with the recommend OEL but provided qualifying comments. Concerns were raised about non-compliance and the challenges associated with current control technologies. Respondents supported the health-based approach but prefer to focus on the 2024 Milestone for coal dust namely 1.5 mg/m^3, in this instance.

The recommended OEL for crystalline silica was supported by 38% of the respondents while 12% disagreed entirely. Some of the respondents (26%) commented that the focus should remain on the current 2024 Milestone, i.e. 0.05 mg/m^3. Other respondents (24%) noted factors such as challenges with current compliance, engineering compliance capabilities and the capabilities of current analytical laboratories to analyse samples within 95% confidence intervals.

There was a majority agreement among the respondents that the ACGIH TLVs® should be adopted as a standardized approach in the SAMI and no objections or health-based reasons were presented against this proposal. The respondents commented that a realistic phase-in period, will be between three to seven years, depending on the pollutant. Some of the key comments were that the OEL adoption of the recommended OELs should not deter the prevention strategy and that each pollutant should have its own phase-in period, based on the changes required and the controls available.

Based on the outcomes of this project, several recommendations are made for consideration.

- It is recommended that additional target organs / systems are included in the medical surveillance programmes following a comprehensive risk assessment of exposure to airborne pollutants.
- It is recommended that the comprehensive, tabulated comparison of all the Schedule 22.9(A) OELs with international leading practice is made available to industry as a standalone, reference document.
- It is recommended that the cost-benefit analysis framework is made available to government and industry for them to conduct a more comprehensive financial impact analysis when a revised OEL is implemented.
- It is recommended that policymakers approve the adoption of ACGIH TLVs, notations and BEIs® as a national process for OEL setting and review. Where the ACGIH does not have a notation, it is recommended not to adopt notations from another organisation to remain consistent with the ACGIH adoption strategy. It is also recommended that biological monitoring for specific airborne pollutants, as a form of medical surveillance, is included in the MHSA and that a BEI notation of the ACGIH is included as a note to those airborne pollutants listed in Schedule 22.9(A).

Considering the feedback and contributions from the respondents of the stakeholder workshop, further recommendations are made:

- Define a process of annual/biennial review of OELs to avoid long periods that may lapse without reviewing OELs, because the magnitude of change and/or reduction is too much for industry to comply with. Internationally, a defined process of review is followed and therefore, alignment with the ACGIH TLVs® can be considered as a best practice approach to review OELs.
- The proposed OEL changes for airborne pollutants with existing milestone OELs (e.g. coal dust and silica) beyond the existing 2024 Milestones, should only be considered after the milestone due date.
- A targeted workshop must be held with industry stakeholder, the Department of Mineral Resources and Energy (DMRE) and organised labour to discuss the implementation of revised OELs in industry. Each stakeholder should critically assess potential aspects within their control that may be a stumbling block on the road to compliance with the revised OELs such as conflicting business processes and/or restrictive legislation.
- Chemical laboratories that analyse for airborne pollutants should also be consulted when the implementation of revised OELs is discussed. The laboratories will have to align their testing to the reduced concentrations and need enough time for such an alignment.

6 INTRODUCTION

This report is a summary of the detailed project report and only key outcomes from the project are presented. The comprehensive, integrated report can be requested from the MHSC.

The number of compensation cases and reported deaths associated with airborne pollutant exposure in the mining industry serves as an indicator that mining employees in the South African Mining Industry (SAMI) may be exposed to airborne pollutant dose levels that may induce lung and other related pathologies. Review of occupational exposure limits (OELs) may contribute to the reduction of incidence of airborne pollutant pathologies, which was the focus of this project.

7 AIMS & OBJECTIVES

The objectives of this project were to:

1. Determine the impact of the current airborne pollutant exposure limits on employees' short- and long-term health.
2. Recommend appropriate OELs for the SAMI in line with Schedule 22.9(A) of the MHSA, including but not limited to, classification bands in terms of exposure risks.
3. Conduct a stakeholder workshop arranged and hosted by MHSC in Gauteng to present the outcomes of the project to date.

8 DEVIATIONS

There were two deviations on the project as a result of circumstances outside the project team's control such as COVID-19, however, corrective actions were taken. The following deviations are reported:

1. During Milestone 2 it was planned to conduct a systematic literature review to identify short- and long-term health effects and airborne pollutants associated with occupational diseases with the highest prevalence in the SAMI. It was clear that a systematic review approach was not appropriate to reach the objective of this phase in the project because most of the literature that reports on short and long-term health effects are not published in peer-reviewed journals (Munn et al., 2018). This was discussed at Programme Delivery Technical Committee (PDTC) meetings at the MHSC (8 Sept 2019 & 27 Feb 2020) where it was requested to change the systematic literature review to a scoping literature review. Approval for this change was given by the PDTC. This allowed the researchers to utilise reputable websites to obtain information on long- and short-term health effects.
2. Milestone 4 planned that a stakeholder workshop is arranged and hosted by the MHSC in Gauteng. At the time, COVID-19 regulations prohibited public gatherings and for this reason two online workshops were hosted on 15 and 22 October 2021. Two online workshops were held to accommodate members of the Department of Mineral Resources and Energy (DMRE) and other specialists who could not attend the first workshop. Real-time, interactive feedback were obtained and 137 individuals attended the two workshops.

9 METHODOLOGY

Figure 1 shows a high-level overview of the methodology that was followed to achieve the project aims and objectives.

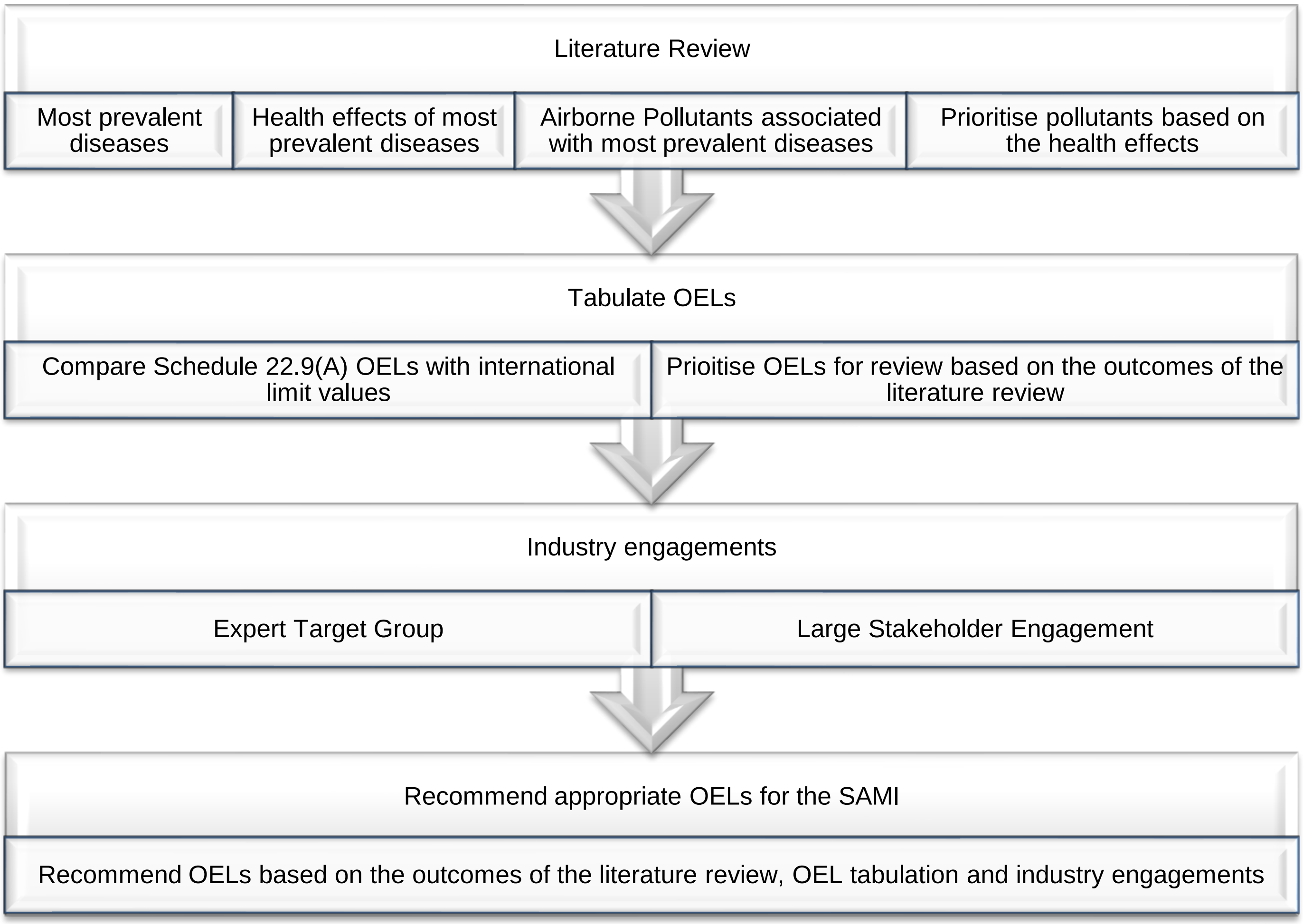

Figure 1: High-level overview of the project methodology

Ethical clearance was obtained from the Faculty of Health Sciences Ethics Committee. (Clearance: 51/2019)

9.1 LITERATURE REVIEW

A literature review was carried out to assess the impact of the current OELs on employees' short- and long-term health. The aim was to obtain the following information:

- Occupational diseases with the highest prevalence in the South African Mining Industry (SAMI);
- Conduct a systematic literature review to identify short- and long-term health effects of the occupational diseases with the highest prevalence in the SAMI;

- Conduct a systematic literature review to identify the airborne pollutant exposure/s that are associated with the occupational diseases with the highest prevalence in the SAMI; and
- Rank the occupational airborne pollutants according to the prevalence statistics of occupational diseases in the SAMI to prioritise the OELs of airborne pollutants to be addressed as a priority.

The following sources were reviewed to obtain occupational health statistics about the most prevalent occupational diseases:

- National Institute for Occupational Health (NIOH) pathology autopsy annual reports from 1975 – 2017;
- Disease rates per 1,000 autopsies for pulmonary tuberculosis, emphysema, silicosis, primary lung cancer, asbestosis, mesothelioma, massive pulmonary fibrosis, coal worker's pneumoconiosis and mixed dust pneumoconiosis;
- SAMI compensation claims: Rand Mutual Assurance (RMA) from 1995 – 2018;
- Mine Health and Safety Inspectorate from 2005 – 2017: occupational diseases reported per 1000 employees;

The Medical Bureau of Occupational Diseases (MBOD) and theHealthSource (Pty) Ltd were also contacted for data. Unfortunately, not data were received at the time the specific milestone was to be submitted.

The total numbers of diseases reported by the organisations were calculated to rank the respective occupational diseases. The Pareto principle, or also known as the 80/20 principle, was applied to determine which occupational disease/s contribute/s to more than 80% of the occupational cases reported per 1000 autopsies.

Literature was also reviewed to identify the short- and long-term health effects of the occupational diseases with the highest prevalence in the SAMI. The following literature sources were reviewed for information that are relevant to health effects namely, the Centres for Disease Control (CDC, USA), Mayo Clinics, John Hopkins Medicine, Agency for Toxic Substances and Disease Registry (ASTDR), Harvard Medical School (Harvard Health Publishing) platforms, American Lung Association, American Cancer Society and the Library databases of the University of Pretoria (UP). Appropriate search terms were used to obtain relevant literature and publications. Obtained literature and publications were then scrutinised to identify the most appropriate and relevant information regarding short- and long-term health effects. Conditions with poor prognosis were grouped under long-term health effects as these will usually develop after prolonged exposures.

To identify the airborne pollutant exposure/s associated with the occupational diseases, a scoping literature review was conducted to identify the airborne pollutant exposure/s associated with the occupational diseases with the highest prevalence in the SAMI. The aim was to link airborne pollutant exposures to the most prevalent occupational diseases.

Due to the complexity of the identified occupational diseases and the number of airborne pollutants that may contribute towards a number of the identified occupational diseases, a complete list of the current Schedule 22.9(A) airborne pollutants was compiled. The databases of the NIOSH Pocket Guide to Chemical Hazards and the ILO International

Chemical Safety Cards were used to extract information about target organs that are affected by the airborne pollutants.

In order to rank the occupational airborne pollutants that must be addressed as a priority, airborne pollutants that have an impact on 80% of the target organs were identified. This approach enabled the prioritisation of pollutants for OEL review.

9.2 COST-BENEFIT ANALYSIS FRAMEWORK

A cost-benefit analysis framework was developed to establish the financial impact if a specific OEL of an airborne pollutant is amended. The aim was to develop a high-level cost/benefit framework that incorporates SAMI related variables such as current cost categories and future financial benefits. The intent was to engage with industry to obtain input on the model and if possible, obtain data to test the framework.

At an industry stakeholder engagement (14 August 2020), a high-level overview of the model was presented. Attendees were given the opportunity to provide guesstimates on typical costs and benefits when an OEL is revised. The objective was to obtain a high-level perspective from the group. Attendees were asked the following questions:

- Estimated financial cost to comply with an amended OEL at a typical mining operation?
- Potential future financial benefit to the health system because of the reduced OEL?

9.3 TABULATE CURRENT OELS AGAINST INTERNATIONAL LIMIT VALUES

All 786 of the Schedule 22.9(A) OELs of the MHSA were compared with other national and international government agencies and standard generating organisations, namely:

- South African Department of Employment and Labour;
- National Institute for Occupational Safety and Health [NIOSH, United States of America (USA)];
- Occupational Safety and Health Administration (OSHA, USA);
- American Conference for Governmental Industrial Hygienists (ACGIH, USA);
- Health and Safety Executive (HSE, United Kingdom);
- European Union, particularly Germany; and
- Australia.

Notations (which highlight toxicity endpoints of chemical substances) were also listed for each pollutant as this conveys important information regarding route of exposure, toxicological and associated health effects.

Airborne pollutants identified to be associated with the most prevalent occupational diseases were grouped as priority airborne pollutants. Airborne pollutants linked with mining in the South African context were also added as priority airborne pollutants. Finally, airborne pollutants not included in the current Schedule 22.9(A) list, but which are associated with the most prevalent occupational diseases, were identified to be considered for inclusion.

9.4 ENGAGEMENT WITH STAKEHOLDERS

Figure 2 shows the two stakeholder engagements that followed the tabulation of OELs namely, an engagement with a small expert target group followed by a broader Industry stakeholder engagement.

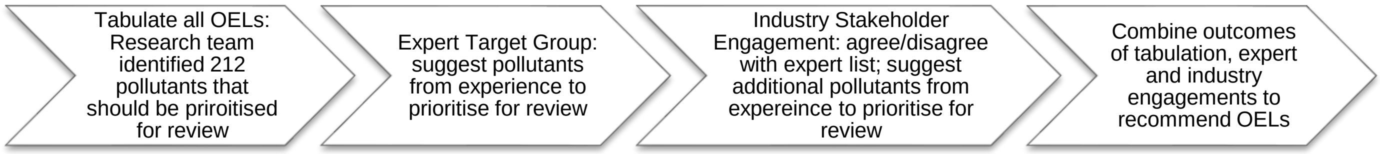

Figure 2: High-level overview of the industry engagements

Several experts (33) were identified by the research team based on their experience with occupational exposures, medical surveillance programmes and investigations that are associated with occupational diseases and were invited to participate in the engagement. The experts were not informed of the outcomes of the previous milestone exercises as the intent was to obtain blind inputs from the experts based on their expertise.

Prior to the workshop, the experts were each asked to propose five airborne pollutants that should be prioritised for review based on their expertise. Although all the airborne pollutants on Schedule 22.9(A) should be reviewed at some stage, it is not practical to revise 786 pollutants at once. For this reason, airborne pollutants that require immediate attention were prioritised for review. Experts were not asked to propose any OELs for any of the airborne pollutants.

The airborne pollutants that were proposed by the experts were used as the ‘Master List’ and a modified Nominal Group Technique was followed using an online platform. The objective of the modified NGT was to achieve a list of airborne pollutants that all the experts have 100% agreement on (i.e. consensus) and that the pollutants should be prioritised for review.

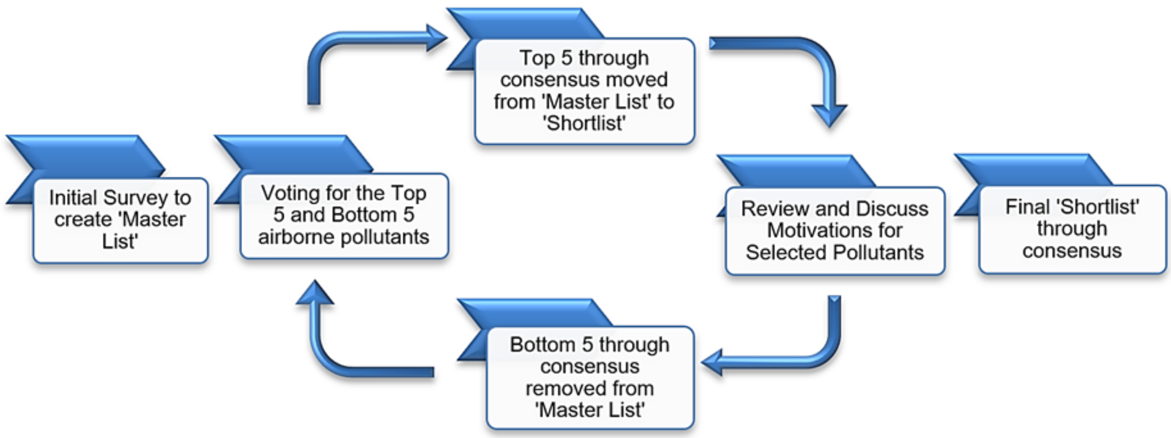

Figure 3: Modified Nominal Group Technique (NGT)

9.5 INDUSTRY STAKEHOLDER ENGAGEMENT

An engagement with a larger group of industry stakeholders was held on 14 August 2020 following the expert target group engagement. The intent was to share the outcomes of the expert target group engagement and obtain further inputs from industry about the airborne pollutants that are a concern. Again, the outcomes of the previous milestones were not shared with the group as the intent was to obtain blind input from stakeholders based on their expertise. Stakeholders were given the opportunity to review and comment on the priority list of airborne pollutants that was developed during the expert target group engagement. Participants in the workshop were asked two questions about the seven pollutants that were on the consensus list:

- Do they agree that the OELs of the airborne pollutants on the prioritised list must be recommended for review?
- Do they agree that an OEL must be included in Schedule 22.9(A) for one of the airborne pollutants on the prioritised list, namely DPM?

Participants were asked to provide reasons for their agreement or disagreements with the pollutants on the priority list. Participants were invited to propose additional pollutants that were not listed by the expert target group and to provide reasons for their choices.

9.6 RECOMMEND OELS FOR SAMI

There is no defined national strategy to establish or review OELs in South Africa (mining and non-mining). The impact of airborne pollutant exposures on the health of mine employees and the tabulated comparison of Schedule 22.9(A) with international leading practice were considered in order to recommend appropriate OELs for the SAMI.

The outcomes of the literature review, the tabulated comparison and the industry inputs were considered to formulate a national approach and the recommend OELs for the SAMI.

9.7 STAKEHOLDER WORKSHOPS

Two online, interactive stakeholder workshops were held to accommodate schedules of invitees to attend and participate by providing feedback and comments on the preliminary results of the project.

The purpose of the two stakeholder workshops were to:

- Explain the process that was followed to review the airborne pollutant OELs as listed in Schedule 22.9(A);
- Share the outcomes of the project to date;
- Obtain feedback on the outcomes of the completed milestones, integrity in the project approach, proposed national approach to OEL setting and review and the proposed OELs; and
- Answer questions that the participants may still have relating to the project.

Following the project overview presentation, the participants were invited to provide insights into the process that was followed to prioritise airborne pollutants for review and comment on whether they thought that there was integrity in the project approach.

In the second part of the workshop, the proposed OEL amendments were presented for the airborne pollutants. After every pollutant's discussion, participants were invited to comment on the information given and the proposals made by the research team. These comments and contributions were captured anonymously using the Poll Everywhere (PollEv) software programme.

The final part of the workshop was intended to obtain insights on some of the key decisions made through the course of the project – on which the proposed OEL amendments were based. Therefore, since a health-based approach and the adoption of the ACGIH TLVs® motivated the OEL revisions, comments, insights and affirmation on these decisions were considered as a final focus point to conclude the workshop.

10 RESULTS & DISCUSSION

10.1 LITERATURE REVIEW

After reviewing the different sources available, the following fifteen occupational diseases with the highest number of reported cases (ranked high to low), were found to be:

1. Silicosis;
2. Emphysema;
3. Pulmonary tuberculosis;
4. Silico-tuberculosis;
5. Other respiratory conditions;
6. Primary lung cancer;
7. Asbestosis;
8. Coal workers' pneumoconiosis;
9. Chronic occupational airway disease;
10. Mesothelioma;
11. Allergic contact dermatitis;
12. Massive pulmonary fibrosis;
13. Mixed dust pneumoconiosis;
14. Occupational asthma; and,
15. Obstructive airway disease.

There were differences in the numbers of cases reported for the same occupational disease because of the reporting criteria for the different agencies i.e.:

- RMA would report primarily on *processed* compensation claims;
- NIOH reports on *autopsy* cases; and
- MHSI reports on the number of *diseases* reported by OMPs in annual medical reports to the inspector of mines.

After multiple attempts to obtain information, no data were received from the MBOD and theHealthSource (Pty) Ltd.

However, the numbers reported in the annual medical reports can be used as an indication of the pollutants that need to be prioritised to address the burden of occupational diseases.

The outcomes of the literature review to identify health effects that are associated with the occupational disease with the highest prevalence, were:

- The short- and long-term health effects that are reported, involve primarily the respiratory tract and the skin.
- The short-term health effects are:
  - Respiratory system: shortness of breath, cough, chest pains, etc.
  - Skin: dry skin, irritation, rash, etc.
- The long-term health effects are:
  - Respiratory system: silicosis, emphysema, pulmonary tuberculosis, silico-tuberculosis, primary lung cancer, asbestosis, coal workers' pneumoconiosis, chronic obstructive pulmonary disease, mesothelioma, massive pulmonary fibrosis and mixed dust pneumoconiosis.
  - Skin: allergic contact dermatitis.

Table 1 shows the systems and organs that are targeted by the number of airborne pollutants that are listed in Schedule 22.9(A).

Table 1: Systems and organs that are targeted by airborne pollutants

Target system / organ	Rank	Number of times listed out of 786 airborne pollutants	%
Respiratory system	1	535	68.1
Eye	2	529	67.0
Skin	3	490	62.3
Central nervous system	4	343	43.6
Kidney	5	209	26.6
Liver	6	151	19.2
Blood	7	118	15.0
Cardiovascular system	8	105	13.4
Heart	9	12	1.5

Of the 786 pollutants listed in Schedule 22.9(A), the respiratory system is targeted by 68.1% of the listed pollutants. Other target organs identified were the eye (67.3%), skin (62.3%) and the central nervous system (43.6%). The high percentage for the respiratory system and skin as target organs / systems are aligned with the occupational diseases reported to have a high prevalence in the SAMI (Table 2). Fourteen of the 15 occupational diseases that were identified, are associated with the respiratory system and one of the 15 is associated with the skin (allergic contact dermatitis).

Table 2: The fifteen occupational diseases with the highest number of reported cases and associated target systems and organ/s

Occupational disease	Respiratory system	Skin
Silicosis	X	
Emphysema	X	
Pulmonary tuberculosis	X	
Silico-tuberculosis	X	
Other respiratory conditions	X	
Primary lung cancer	X	
Asbestosis	X	
Coal workers’ pneumoconiosis	X	
Chronic obstructive pulmonary disease	X	
Mesothelioma	X	
Allergic contact dermatitis		X
Massive pulmonary fibrosis	X	
Mixed dust pneumoconiosis	X	
Occupational asthma	X	
Obstructive Airway Disease	X	

Unfortunately, it was not feasible or possible to link specific airborne pollutants with the occupational diseases with the highest prevalence as one pollutant may be linked to multiple occupational diseases.

Different methodologies are used to report occupational diseases that are used by the various statutory and regulating bodies namely the National Institute for Occupational Health (NIOH), Rand Mutual Assurance (RMA), the South African Mining Industry (SAMI) and the Health and Safety Inspectorate (HSI). For this reason, a link could not be identified between specific airborne pollutants that may contribute to specific occupational diseases such as emphysema, other respiratory conditions, primary lung cancer, chronic occupational airway disease and allergic contact dermatitis.

However, airborne pollutants that have an impact on 80% of the target organs were identified as an approach to prioritise pollutants for OEL review. Based on this approach, a total number of 212 airborne pollutants were identified to be prioritised for review. Of the airborne pollutants listed in Schedule 22.9(A), 78% of the pollutants have a health impact on more than five target organs.

Diseases related to the respiratory system, eyes, skin, central nervous system and kidneys contribute to more than 80% of the occupational diseases with the highest prevalence.

In most cases, only one target organ / system is considered for medical surveillance when an employee is exposed to various airborne pollutants. Occupational diseases associated with specific organs or systems may therefore not be detected because no medical surveillance was completed on the other target organs / systems. In addition, the additive effect of various pollutants on an organ / system may also not be considered and this may lead to under-reporting of certain occupational diseases.

10.2 COST-BENEFIT ANALYSIS FRAMEWORK

The cost-benefit analysis framework presents extensive coverage on the identification of various "cost categories" which will be impacted as a result of any change in an OEL.

These 'cost categories' are used to derive the overall cost/benefit determination, as set out in the equations in Table 3 below:

Table 3: Cost Categories that form the basis of the cost-benefit analysis framework

Stakeholder Group	Cost, Benefit & Description	Cost/Benefit Determination (Equation)
Employer	Costs: Various measures required by the company to implement a revised OEL	C = Ce + Ca + Co + Ci + Cm + Cv+ Cp + [0.72 x (Cl + Cs +Cw)]
	Benefits: Reduction in insurance levies, reduction in costs associated with other replacement workers, fewer incident investigations, reduction in training costs, reduction in productivity loss.	B = Bi + Bt + 0.72 x Bp
	Net Financial Impact	Financial Impact = B - C

The driving factor of the financial model however, that will impact on the overall accuracy, is that of the availability of financial data and the OEL reduction measures implemented by mining companies.

Table 4 and 5 shows typical costs and benefits that may be considered when applying the model to a mining operation.

Table 4: Variables in "cost" determination

Category	Code	Occurrence	Cost
DIRECT	Ce	Continuous / once-off	Costs associated with various engineering controls (HoC 3), such as: 1) Insulating 2) Isolating 3) Ventilation etc.
	Ca	Continuous / once-off	Costs associated with various administrative controls (HoC 4), such as: 1) Demarcation 2) Occupational Health Program 3) Medical surveillance (health worker/specialist, medical tests, medical supplies etc.) 4) Training and information (on change in process / new ways of working etc.)
	Ci	Continuous	Cost associated with more frequent incidence investigations associated with a more stringent OEL
	Co	Once-off	Costs associated with once-off expenditure associated with adopting a new OEL, such as: 1) New Equipment 2) New method 3) New technology 4) New medical equipment/expenses
	Cm	Continuous / once-off	Costs associated with changes in Mandatory and other Codes of Practice
	Cv	Continuous	Costs associated with any potential increase in compensation levies as a result of more "approved" compensation payments as a result of the lower OEL level.
	Cp	Continuous	Cost for **new** personal protective equipment (HoC 5)
INDIRECT	Cl	Continuous	Cost associated with productivity loss due to process elimination techniques (HoC 1)
	Cs	Continuous	Cost associated with process substitution techniques (HoC 2)
	Cw	Once-off	Cost associated with productivity loss as a result of a complete mine work stoppage

Table 5: Variables in "benefit" determination

CATEGORY	CODE	APPLICABILITY	BENEFIT
DIRECT	Bh	Government	Benefits associated with a lower cost of: 1) Medical treatment, including hospitalisation, surgery, consultations, radiation therapy, chemotherapy/immunotherapy 2) Medical tests (associated with greater biological monitoring)
	Bi	Employer	Reduced total cost stemming from fewer incidences, illnesses & fatalities, including: 1) Reduced insurance payments/levies associated with disability/death pay-outs to the compensation commissioner or otherwise. 2) Reduced replacement/overtime costs associated with getting replacement mineworker when the ill employee is on sick leave. 3) Fewer incidence investigations (specialists and laboratory work) resulting in a cost reduction.
	Bt	Employer	Reduced training costs* associated with lower mine worker fatalities and reduced number of re-accommodations.
INDIRECT	Bp	Both	Productivity 'incremental gain' due to lower mortality: The economic 'loss' to society due to premature death is reduced with fewer fatalities.
	Bl	Both	Reduced 'Lost earnings' associated with lost working days: Loss of earnings and output due to absence from work due to illness or treatment is reduced with fewer fatalities/incidences.

After developing the cost-benefit analysis framework, it was tested with a group of individuals from industry who confirmed that the major cost categories have been identified. The research team requested data from a few mines in order to test the model, however, the information was not forthcoming.

When attendees of the Industry Stakeholder Engagement (14 August 2020) were asked to provide their high-level perception of typical costs and benefits when an OEL would be revised, the estimates on initial cost ranged from R450 000 to R80 million for a pollutant. There was limited understanding of the future cost-benefit implications associated with an amendment to the relevant OEL. However, there was general agreement that the cost implications were not just for the individual employee but also for his/her community because occupational disease has an impact on the broader community and the economic activity surrounding the mines. A comment was made about the cost of future litigation vs. cost of controlling the problem right now. Smaller mining operations may also find it difficult to implement control measures in line with the revised OELs.

10.3 TABULATED COMPARISON OF ALL OELS WITH INTERNATIONAL LIMIT VALUES

The comprehensive, tabulated comparison of all the Schedule 22.9(A) national OELs with international leading practice is available from MHSC on request and is considered a good reference document for future use.

During the literature review a total number of 212 airborne pollutants were identified to be prioritised for review because these airborne pollutants have an impact on 80% of the target organs / systems (refer to Tables 6 & 7). Of these 212 pollutants, 85 (40%) airborne pollutants have OELs that are less stringent or protective when compared with current international leading practice.

When compared with international leading practice, Schedule 22.9(A) lacks important notations (which highlight toxicity endpoints of chemical substances) as this conveys important information regarding the route of exposure, toxicological and associated health effects. The most important differences were that skin notations, the influence on pregnancy and classification in terms of carcinogenicity were lacking in Schedule 22.9(A).

Table 6: Priority hazardous chemical substances with a skin notation as per Schedule 22.9(A) of the MHS Act aligned with most prevalent occupational diseases.

Methyl bromide	Hydrogen—cyanide and cyanide salts [as CN] Calcium cyanide	Platinum salts, soluble [as Pt]
Methyl ethyl ketone [MEK]	Hydrogen—cyanide and cyanide salts [as CN] Potassium cyanide	*n*-Propanol
*Carbon disulphide	Hydrogen—cyanide and cyanide salts [as CN] Sodium cyanide	Rosin core solder pyrolysis products [as formaldehyde]
Carbon tetrachloride	*Lead tetra- ethyl [as Pb]	Thallium, soluble compounds [as Tl]
Chloroform	Lead tetra- methyl [as Pb]	Tin compounds, organic except cyhexatin [as Sn]
*4,4'- Methylenebis (2-chloroaniline) [MBOCA]	Mercury alkyls [as Hg]	Toluene
Methyl isobutyl ketone [MIBK]	Methanol	Wood dust: Hardwood
Hydrogen—cyanide and cyanide salts [as CN] *Hydrogen cyanide	Nitrobenzene	Xylene, *o*-, *m*-, *p*- or mixed isomers

Note: Cells highlighted in grey are aligned with the most prevalent occupational diseases listed in Table 2. Pollutants marked with an asterisk (*) must be kept as far below the OEL as is reasonably practicable (refer to Note [b] of Schedule 22.9(A)).

Table 7: Priority hazardous chemical substances without a skin notation as per Schedule 22.9(A) of the MHS Act aligned with most prevalent occupational diseases.

Acetic acid	Cyclohexane	Mica respirable particulate	* Silica, crystalline [respirable particulate] Tridymite
Acetone	Diatomaceous earth, natural [respirable particulate]	Molybdenum compounds [as Mo] soluble compounds	Tridymite
Acetonitrile	Fluorodichloromethane	Molybdenum compounds [as Mo] insoluble compounds	* Silica, crystalline [respirable particulate] Tripoli
Aluminium alkyl compounds	*Dichloromethane	Nickel, organic compounds [as Ni]	Tripoli
Aluminium metal inhalable particulate	*Methylene chloride	*Nickel, inorganic compounds [as Ni] soluble compounds	Silica, fused [respirable particulate]
Aluminium metal respirable particulate	Fluorides [as F]	*Nickel, inorganic compounds [as Ni] insoluble compounds	Silicon inhalable particulate
Aluminium oxides inhalable particulate respirable particulate	Fluorine	Nitric acid	Silicon respirable particulate
Aluminium oxides inhalable particulate respirable particulate	*Formaldehyde	Nitric oxide	Silicon carbide inhalable particulate
Aluminium salts, soluble	Gasoline	Nitrogen	Silicon carbide respirable particulate
Ammonia	Graphite, natural and synthetic inhalable particulate	Nitrogen dioxide	Silver
Ammonium chloride, fume	Graphite, natural and synthetic respirable particulate	Nitrous oxide	Silver compounds [as Ag]
Antimony and compounds [as Sb] except antimony trisulphide and antimony trioxide	Gypsum inhalable particulate	*Nickel	Sodium hydroxide
*Arsenic and compounds, except arsine [as As]	Gypsum respirable particulate	Nickel carbonyl [as Ni]	Sulphur dioxide
Arsine	n-Heptane	Tetracarbonyl nickel	Sulphur hexafluoride
*Asbestos, all forms	Hexane, all isomers except n-Hexane	n-Octane	Sulphuric acid
Asphalt, petroleum fumes	n-Hexane	Oil mist, mineral	Talc respirable particulate
*Benzene	Hydrogen bromide	Osmium tetroxide [as Os]	Tantalum metal and oxide dust [as Ta]
Benzyl chloride	Hydrogen chloride	Ozone	Tellurium and compounds, except hydrogen telluride [as Te]
*Beryllium and beryllium compounds [as Be]	Calcium cyanide	Paraffin wax, fume	Tin compounds, inorganic except SnH4 [as Sn]
n-Butane	Potassium cyanide	Particles not otherwise classified [PNOC] inhalable particulate	Titanium dioxide inhalable particulate
Butan-2-one (Methyl ethyl ketone, ACGIH)	Sodium cyanide	Particles not otherwise classified [PNOC] respirable particulate	Titanium dioxide respirable particulate
*Cadmium and cadmium compounds, except cadmium oxide fume, cadmium sulphide and cadmium sulphide pigments [as Cd]	Hydrogen fluoride [as F]	Pentane, all isomers	Tungsten and compounds [as W] soluble
*Cadmium oxide fume [as Cd]	Hydrogen sulphide	*Phenylethylene	Tungsten and compounds [as W] insoluble
*Cadmium sulphide and cadmium sulphide pigments respirable particulate [as Cd]	Indium and compounds [as In]	*Styrene, monomer	Turpentine
Calcium silicate inhalable particulate respirable particulate	Iron oxide, dust and fume [as Fe]	*Vinyl benzene	Uranium (natural). Soluble and insoluble compounds [as U]
	Iron salts [as Fe] (Soluble, as Fe)	Phosgene	Vanadium pentoxide inhalable particulate
Calcium silicate inhalable particulate respirable particulate	Isocyanates, all [as—NCO]	Platinum metal	Vanadium pentoxide fume and respirable paniculate
Carbon black	Kaolin, respirable particulate	Platinum mine dust respirable particulate	Vinyl acetate
Carbon dioxide	*Lead, elemental, and inorganic compounds [as Pb]	Polyvinyl chloride [PVC] inhalable particulate	Welding fumes
Carbon monoxide	Liquified petroleum gas [LPG]	Polyvinyl chloride [PVC] respirable particulate	White spirit [Stoddard Solvent]
Cement inhalable particulate respirable particulate	Magnesium oxide [as Mg] inhalable particulate	Portland cement inhalable particulate	Wood dust: Soft wood
Cement inhalable particulate respirable particulate	Magnesium oxide fume (correct term)	Portland cement respirable particulate	Yttrium
Chlorine	Magnesium oxide [as Mg] fume and respirable particulate	Potassium hydroxide	Zinc chloride, fume
Chlorobenzene	Manganese, elemental, and inorganic compounds [as Mn]	Propane	Zinc oxide, fume
Trichloromethane (Chloroform, ACGIH)	Manganese, fume [as Mn]	Rhodium (as Rh] metal fume and dust	Zirconium compounds [as Zr]
Chloromethane	Manganese cyclopentadienyl tricarbonyl [as Mn]		Oxygen
Methyl chloride	Tricarbonyl(eta-cyclopentadienyl) manganese	Rhodium (as Rh] soluble salts	Aluminium welding fumes
Chromium, metal and inorganic compounds [as Cr] Cr [II] compounds	Manganese tetroxide	Rubber fume	Cyanides, except hydrogen cyanide, cyanogen and cyanogen chloride
Chromium, metal and inorganic compounds [as Cr] Metal and Cr [III] compounds	Manganese tetroxide	*Rubber process dust	Nickel, subsulfide
Chromium, metal and inorganic compounds [as Cr] Cr [VI] compounds	Man-made mineral fibres [Glass, slag and rock wool fibres]	Silica, amorphous inhalable particulate	Talc inhalable particulate
Coal dust [respirable particulate]	Methane	Silica, amorphous respirable particulate	
Coal tar pitch volatiles [as cyclohexane soluble]	Methyl alcohol	* Silica, crystalline [respirable particulate] Cristobalite	Limestone
*Cobalt and cobalt compounds [as Co]	*1,1,1-Trichloroethane	Cristobalite	Marble
Copper Fume [as Cu]	Methyl chloroform	* Silica, crystalline [respirable particulate] Quartz	Silica fume [respirable particulate]
Copper Dust and mists [as Cu]	Mica inhalable particulate	Quartz, crystalline	

Note: Highlighted cells are aligned with the most prevalent occupational diseases listed in Table 2. Pollutants marked with an asterisk (*) must be kept as far below the OEL as is reasonably practicable (refer to Note [b] of Schedule 22.9(A)).

10.4 EXPERT TARGET GROUP ENGAGEMENT

Ten (10) of the 33 experts that were invited were available for the workshop on 23 July 2020. The modified NGT was used to survey expert opinion and ten experts were enough to survey expert opinion. Figure 4 shows an overview of the background of the Expert Target Group participants.

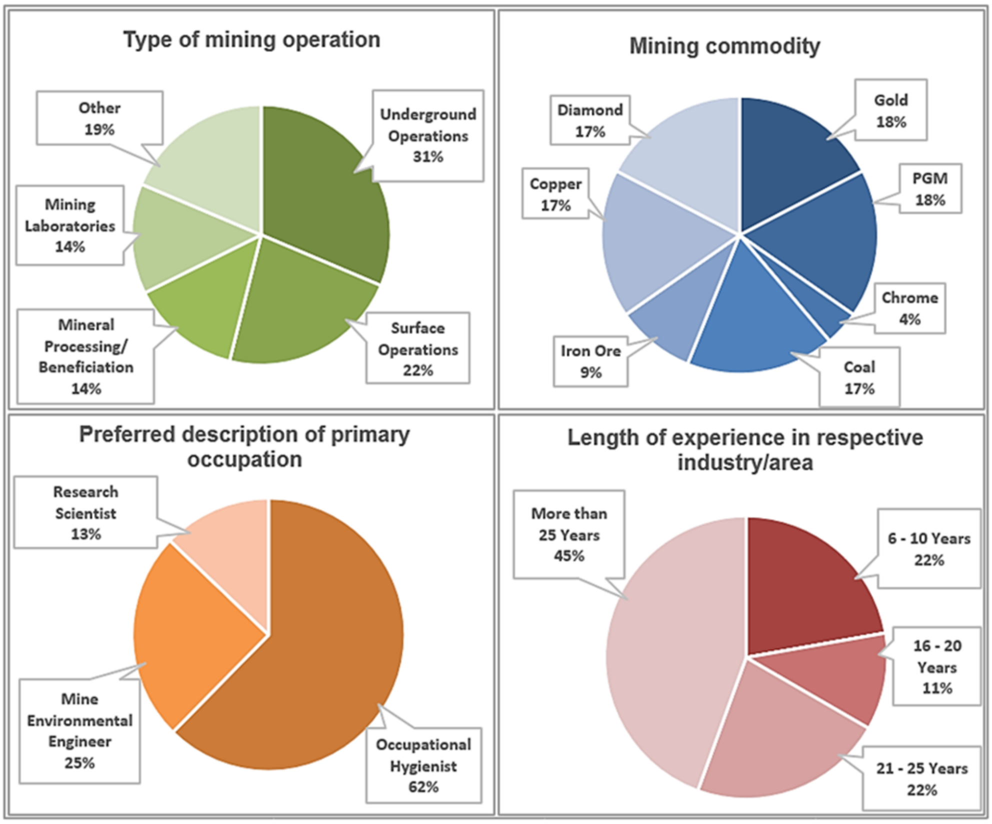

Figure 4: Background of the expert target group

None of the occupational medical practitioners (OMPs) that were invited could attend as they were involved in COVID-19 projects. However, a research scientist with an epidemiology/toxicology background was one of the experts. Six of the ten experts had more than 20 years' experience in the mining industry in relation to occupational exposure to airborne pollutants.

After four rounds of the modified NGT process, consensus was reached by the expert target group. The consensus list of airborne pollutants that must be prioritized for the review or inclusion of the OEL in Schedule 22.9(A) of the MHSA, are listed in alphabetical order: carbon monoxide (CO), chromium, coal dust, diesel particulate matter (DPM; new), nitrogen dioxide (NO_2); silica, and welding fumes.

Six of the airborne pollutants that were suggested by the experts were on the list of 212 airborne pollutants that were prioritised for review by the research team. Some of the pollutants that were proposed by the experts were associated with the occupational diseases with the highest prevalence in the SAMI. One of the pollutants, namely DPM, was also suggested by the research team to be included in Schedule 22.9(A) as a new pollutant.

10.5 INDUSTRY STAKEHOLDER ENGAGEMENT

Figure 5 shows the outcomes of the industry stakeholder engagement. More than 60% of the respondents to the questionnaire agreed that the OELs for CO, chromium, coal dust, silica and welding fumes should be reviewed. More than 95% of the respondents agreed that DPM should be included in Schedule 22.9(A) as a new airborne pollutant. However, more than 66% of the respondents disagreed that the OEL for nitrogen dioxide should be reviewed.

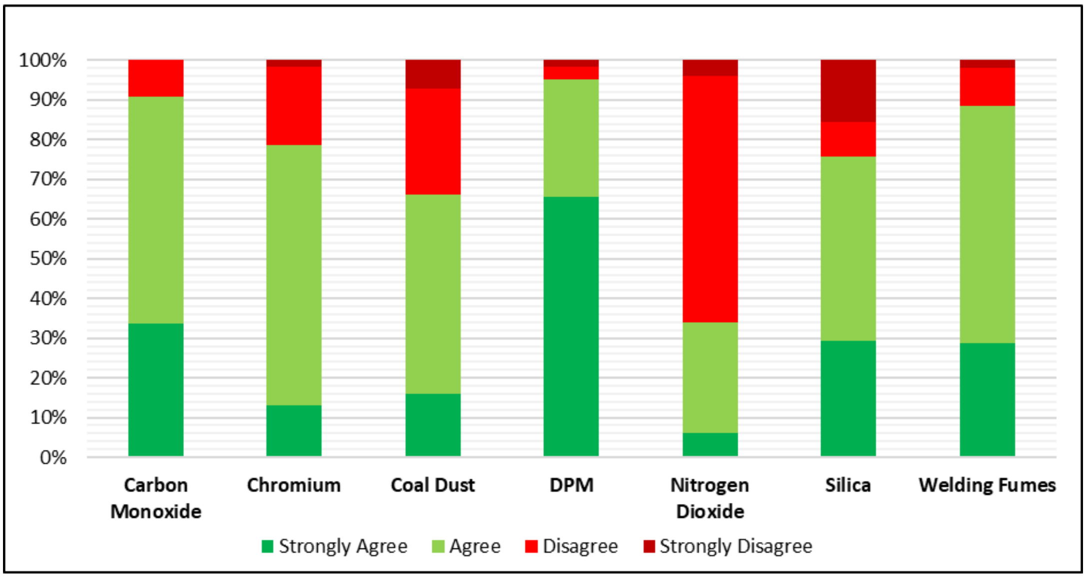

Figure 5: Results of the industry stakeholder engagement

In addition to the seven pollutants, the respondents in the workshop recommended that the following airborne pollutants should be prioritised for OEL review:

- All carcinogens, skin and sensitizer chemicals need to be reviewed;
- Ammonia;
- Asbestos;
- Benzene and associated compounds;
- Coal tar pitch volatiles (CTPV);
- Cyanide (hydrogen cyanide);
- Fused silica;
- Hydrogen sulphide;
- Particles not otherwise classified (PNOC);
- Respirable dust;
- Titanium dioxide;
- Vanadium pentoxide; and
- Wood dust.

In addition to DPM, some participants suggested that a new airborne pollutant is included in Schedule 22.9(A) namely, “respirable dust”, to account for complex mixtures of dust.

The total number of airborne pollutants that were suggested for OEL review and inclusion, was approximately 21. The suggestion to review the OELs for airborne pollutants with carcinogenic, skin and sensitiser notations, will increase the number and align with the priority list that was prioritised by the research team, namely 212 pollutants.

10.6 Recommend OELs for the SAMI

Based on the outcomes of the impact of airborne pollutant exposures on the health of mine employees and the tabulated comparison of Schedule 22.9(A) with international leading practice, appropriate OELs for the SAMI were recommended.

In the absence of a defined, national approach it is proposed that a strategy is followed to adopt the Threshold Limit Values (TLVs®), notations and Biological Exposure Indices (BEIs) of the American Conference of Governmental Industrial Hygienists (ACGIH). The reason for such an adoption is that the ACGIH TLVs® are health based, comprehensively and systematically reviewed and there is an established body of scientific knowledge available to the public at a reasonable cost.

A more pragmatic approach to the setting of OELs is not recommended. A pragmatic approach that takes other factors into account such as the financial implications and socio-economic factors (to name a few), may result in a subjective and biased approach. There is a risk that the OEL may be influenced by the political and economic agenda of the day. When the ACGIH TLVs® are adopted, the focus remains on the health of employees.

It is further proposed that a phased-in approach to the strategy is taken to enable the SAMI to implement effective controls in complying with a new or reduced OEL. If a policy decision is made to adopt the ACGIH TLVs®, a consistent approach in the reviewing and setting (adoption) of OELs is implemented. Such a policy decision affords the SAMI the opportunity to adapt their controls for other pollutants (not only those listed as a priority) with a view to align with the ACGIH TLVs®.

Cognisance should be taken of the impact that the ACGIH adoption will have on the reporting of over-exposures and the annual sampling schedules according to the classification bands of the homogenous exposure groups (HEGs). If a TLV® is adopted for a pollutant, initially there may be a significant increase in the reporting of over-exposures to the Mine Health and Safety Inspectorate (MHSI). It is proposed to keep the classification bands unchanged but that a phased-in approach to the transition to the ACGIH TLVs® and the knock-on effect on associated processes should be taken into consideration.

If the ACGIH does not state a TLV® for an airborne pollutant, adoption of an OEL from another reputable OEL setting country or organisation, with preference for those setting health based OELs, may be considered. However, this must be documented clearly for future reference and use. A proposed alternative is to adopt OELs from the European Union. If no other OEL can be adopted, due to an airborne pollutant not listed by another OEL setting country or organisation, then the OEL as currently listed in Schedule 22.9(A) will remain effective until further notice or review.

Table 8 shows a summary of the proposed OELs for the airborne pollutants that were identified by stakeholders to be prioritised for OEL review, and OEL inclusion in the case of DPM.

The adoption of the ACGIH TLVs® are recommended for the following airborne pollutants on Schedule 22.9(A): CO, chromium (metal and inorganic compounds): Cr(III) water-soluble compounds and Cr(VI) water soluble compounds, coal dust (respirable particulate), silica (crystalline and fused (respirable particulate)), benzene, hydrogen sulphide, lead (elemental, and inorganic compounds [as Pb]), and vanadium pentoxide inhalable particulate.

It is recommended that the OELs for the following airborne pollutants on Schedule 22.9(A) remain unchanged: ammonia, arsenic and compounds (except Arsine (as As)), particles not otherwise classified [PNOC] (inhalable and respirable particulate), titanium dioxide (inhalable and respirable particulate), vanadium pentoxide (fume and respirable particulate), and wood dust (hard wood and soft wood).

Special recommendations are made for the following airborne pollutants:

- Include a new airborne pollutant on Schedule 22.9(A) namely "diesel exhaust emissions (DEE) as total carbon (respirable fraction)");
- Iron oxide, dust and fume [as Fe]: change from inhalable to respirable fraction; and
- Welding fumes: retract or remove from Schedule 22.9(A). Most of the OELs for the individual constituents and associated oxides remain unchanged for now.

Table 8: Amended OELs proposed for some airborne pollutants

Airborne Pollutant	Current MHSA Schedule 22.9(A) OEL	Proposed amendment to OEL	Change	Proposed Notation
Carbon monoxide (CO)	35 mg/m³ / 30 ppm C 115 mg/m³ / 100 ppm	25 ppm C 100 ppm	▼ 1.2x =	None
Chromium (metal and inorganic compounds)	Metal and Cr(III) compounds - 0.5 mg/m³	Cr(0) - 0.5 mg/m³ (I)	=	None
		Cr(III) water-soluble compounds - 0.003 mg/m³ (I)	▼ 166x	Cr(III): carc A4 Skin DSEN RSEN
	Cr(II) compounds - 0.5 mg/m³	None	=	None
	*Cr(VI) compounds - 0.05 mg/m³	Cr(VI) water soluble compounds - 0.0002 mg/m³(I) STEL 0.0005 mg/m³(I)	▼ 250x	Cr(VI): carc A1 Skin DSEN RSEN
Coal dust (respirable particulate)	2 mg/m³	Coal dust, Anthracite - 0.4 mg/m³	▼5x	carc A4
		Coal dust, Bituminous or Lignite - 0.9 mg/m³	▼ 2.2x	carc A4
Diesel particulate matter (DPM)	None	Diesel Exhaust Emissions (DEE): Total Carbon, Respirable fraction – 0.16 mg/m³	New	carc A1
	Quartz – 0.1 mg/m³	0.025 mg/m³	▼ 4x	carc A2

Airborne Pollutant	Current MHSA Schedule 22.9(A) OEL	Proposed amendment to OEL	Change	Proposed Notation
*Silica, crystalline (respirable particulate)	Cristobalite – 0.1 mg/m^3	0.025 mg/m^3	▼ 4x	carc A2
	Tridymite – 0.1 mg/m^3	0.025 mg/m^3	▼ 4x	None
	Tripoli – 0.1 mg/m^3	0.025 mg/m^3	▼ 4x	None
Silica, amorphous	Inhalable particulate – 6 mg/m^3	None	=	None
	Respirable particulate – 3 mg/m^3	None	=	None
Silica, fume (respirable particulate)	2 mg/m^3	None	=	None
Silica, fused (respirable particulate	0.1 mg/m^3	0.025 mg/m^3	▼ 4x	None
Welding fumes	5 mg/m^3	Retract	Retract	None
Ammonia	25 ppm	25 ppm STEL 35 ppm	=	None
*Arsenic and compounds, except Arsine (as As)	0.01 mg/m^3	0.01 mg/m^3	=	carc A1
*Benzene	1 ppm	0.5 ppm STEL 2.5 ppm	▼ 2x	Skin carc A1
Hydrogen sulphide	10 ppm STEL 15 ppm	1 ppm STEL 5 ppm	▼ 10x ▼ 3x	None
Iron oxide, dust and fume [as Fe]	5 mg/m^3	5 mg/m^3 (respirable)	Change from inhalable to respirable fraction	carc A4
*Lead, elemental, and inorganic compounds [as Pb]	0.1 mg/m^3	0.05 mg/m^3	▼ 2x	carc A3
Particles not otherwise classified [PNOC]	Inhalable particulate - 10 mg/m^3	None	=	None
	Respirable particulate - 3 mg/m^3	None	=	None
Titanium dioxide	Inhalable particulate - 10 mg/m^3	None	=	carc A4
	Respirable particulate - 5 mg/m^3	None	=	None
Vanadium pentoxide	Inhalable particulate - 0.5 mg/m^3	Inhalable particulate - 0.05 mg/m^3	▼ 10x	carc A3
	Fume and Respirable particulate - 0.05 mg/m^3	None	=	None
Wood dust	*Hard wood - 1 mg/m^3	None	=	Sen
	Soft wood - 5 mg/m^3	None	=	None

* indicate airborne pollutants for which exposure must be kept as far below the OEL as is reasonably practicable as listed at present in Schedule 22.9(A) of MHSA.

The adoption of the ACGIH notations on Schedule 22.9(A) will result in 225 carcinogenic pollutants that are assigned with a carcinogen notation (carc A1-A5), 75 airborne pollutants with skin notations, and 66 sensitiser notations. Therefore, 19 airborne pollutants are confirmed human carcinogens (carc A1) and 22 are suspected human carcinogens (carc A2). From the list, 90 airborne pollutants are assigned a carc A3 notation, with evidence of them being carcinogenic in experimental animals, but with insufficient evidence of their carcinogenicity in humans. In total, 166 airborne pollutants are assigned with a carc A4 notation (not classifiable as a human carcinogen) and three with a carc A5 notation (not suspected to be a human carcinogen).

Where ACGIH does not have a notation, it is recommended not to adopt notations from another organisation to remain consistent with the ACGIH adoption strategy.

At present Schedule 22.9(A) does not make provision for biological monitoring as a form of medical surveillance. Biological Exposure Indices (BEIs) are frequently indicated as a notation along with carcinogen, skin and sensitiser notations (where applicable), to indicate to occupational health and hygiene professionals that biological monitoring needs to be performed for a particular pollutant. It is recommended that biological monitoring for specific airborne pollutants, as a form of medical surveillance, is included in the MHSA and that a BEI notation is included as a note to those airborne pollutants listed in Schedule 22.9(A). For this, the BEIs of the ACGIH can be adopted.

10.7 Stakeholder workshop

Two online industry stakeholder workshops were held on 15 October 2020 and 22 October 2020, using Google Meet platform supplemented with Poll Everywhere (PollEv), a dynamic online polling platform that allows participants of virtual workshops to vote on custom generated polls to attain and record feedback and/or contributions from the workshop participants.

Although the workshops were attended by approximately 137 individuals over the two days, not all the workshop participants responded with comments to the questions that were asked. It is assumed that the individuals that responded to the proposed OEL for a specific pollutant, have enough knowledge about that pollutant in order to provide comments.

Nearly 80% of the respondents agreed with the process that was followed to come to the recommended OELs.

A high-level overview of the respondent feedback is provided below when participants were asked to comment on the proposed OELs for the prioritized pollutants:

- There was overwhelming support for the unchanged OELs, namely chromium metal and Cr(II) (100% support), PNOC (88% support), titanium dioxide (100% support), wood dust (79% support). The OEL for iron oxide remains unchanged but the recommendation to specify the respirable fraction was supported by 86% of the respondents.
- Most of the respondents supported the recommended OELs for lead (95% support) and benzene (94% support). While 79% of the respondents agreed with the recommended OEL for CO, 10% of the respondents disagreed and argued that the current OEL should be maintained.
- The recommended OEL for hydrogen sulphide was opposed by 79% of the respondents.

- The recommendation to retract the welding fume OEL and that exposure should be controlled for the individual metal constituents, was supported by 73% of the respondents.
- Mixed reactions were received from the respondents in terms of agreement and disagreement, for the recommended OELs for trivalent chromium (Cr(III)), hexavalent chromium (Cr(VI)) and vanadium pentoxide.
- There was consensus among the respondents that an OEL for DPM should be included in Schedule 22.9(A)) as diesel exhaust emissions (DEE): total carbon (respirable fraction), however, there was concern that the OEL was too low considering the current engine technology, types of machines (tier) and quality of fuel.
- The recommended OEL for Coal Dust was supported by 17% of the respondents while 28% of the respondents disagreed. Half of the respondents agreed with the recommend OEL but provided qualifying comments. Concerns were raised about non-compliance and the challenges associated with current control technologies. Respondents supported the health-based approach but prefer to focus on the 2024 Milestone for Coal Dust namely 1.5 mg/m^3.
- The recommended OEL for crystalline silica was supported by 38% of the respondents while 12% disagreed entirely. The disagreement is surprising as a note in the current Schedule 22.9(A) requires that exposure must be kept as far below the OEL as is reasonably practicable. Some of the respondents (26%) commented that the focus should remain on the current 2024 Milestone, i.e. 0.05 mg/m^3. Other respondents (24%) noted factors such as challenges with current compliance, engineering control capabilities and the capabilities of current analytical laboratories to analyse samples within 95% confidence intervals.
- In terms of the other forms of silica (amorphous, fused and fume), 52% of the respondents supported the OEL recommendations. However, 19% disagreed with the proposed change for fused silica, noting that this change is not achievable in industry.

There was majority agreement (86%) among the respondents that the ACGIH TLVs® should be adopted as a standardized approach in the SAMI and no objections or health-based reasons were presented against this proposal.

Most of the respondents (80%) agreed that a comprehensive cost-benefit analysis should form part of the implementation plan for revised OELs.

When asked to comment on a realistic phase-in period, 60% of the responses were 3-5 years followed by 5-7 years (23%). Some of the key comments that were made were that the OEL adoption of the recommended OELs should not deter the prevention strategy and that each pollutant should have its own phase-in period, based on the changes required and the controls available.

11 CONCLUSIONS

The reported short and long-term health effects primarily involve the respiratory tract and the skin. Knowledge of the symptoms associated with the short and long-term health effects, of the most prevalent occupational diseases in the SAMI, will guide occupational medicine and health practitioners in terms of the required equipment to diagnose the identified respiratory tract and skin diseases.

Early detection of the identified occupational diseases by occupational medical practitioners and support medical staff is critical to ensure that appropriate control and management actions are taken to lower exposure in the section/s where the employee(s) work. To achieve this, regular engagement with management is critical to ensure that action plans are put in place to budget for required control and management actions to lower exposure.

The identification of an airborne pollutant with health effects on more than one organ / system as well as the health impact of various chemicals on a single organ system, highlight the importance and need of proper risk assessment, occupational hygiene monitoring and medical surveillance programs in the SAMI. Furthermore, if signs and/or symptoms are observed by occupational medical practitioners or support medical staff during annual medical surveillance, it needs to be reported to management and occupational hygienists without delay to ensure that appropriate control and management actions are taken to lower exposure in the section(s) where the employee(s) work. Occupational hygienists must also communicate outcomes of surveys in such a manner to assist occupational medical practitioners to make informed decisions in terms of medical surveillance programs to be implemented.

Airborne pollutants identified to be associated with the most prevalent occupational diseases were grouped as priority airborne pollutants. In addition, airborne pollutants linked with mining in the South African context were also added as priority airborne pollutants. Finally, airborne pollutants not included in the current Schedule 22.9(A) list, but which are associated with the most prevalent occupational diseases, were identified to be considered for inclusion.

A total number of 212 airborne pollutants were identified to be prioritised for review. Of the 212 substances, 85 (40%) airborne pollutant's occupational exposure limits are less stringent or protective when compared with one or more of the occupational exposure limit values published by NIOSH, OSHA, ACGIH, HSE, European Union, Germany, Australia and the DoEL. Differences in terms of notations were also evident. The most important differences are skin notations, influence on pregnancy and classification in terms of carcinogenicity.

A cost-benefit analysis framework was developed that can be applied by both government and industry to determine the financial impact, should an OEL be amended. In principle, the framework determines the net financial impact when the cost to comply with an OEL is subtracted from the benefits that will be derived now and in the future. The framework presents extensive coverage on the identification of various 'cost categories' which will be impacted as a result of any change in OEL.

However, as this is a high-level framework, more information may be required when an OEL is changed, specifically when information associated with a specific company or individual mine. While more information may be required to conduct the financial analysis, the framework does nevertheless, provide a starting basis for further development by the end-user. Consequently, to determine the full impact of a change to an OEL, a comprehensive assessment should be conducted by both government and the employer, respectively.

The expert target group and industry stakeholder engagements provided different perspectives and interesting insights into the concerns related to the OELs for some airborne pollutants that are listed on Schedule 22.9(A). Some stakeholders would like to include DPM and respirable dust in Schedule 22.9(A) as two new pollutants.

A strategy was proposed to adopt the health based ACGIH TLV®s when revision of current OELs in Schedule 22.9(A). The reason for such an adoption is that the ACGIH TLV®s are health based, comprehensively and systematically reviewed and there is an established body of scientific knowledge available to the public at a reasonable cost.

A policy revision decision by government, industry and organised labour to adopt the ACGIH TLV®s will afford the SAMI the opportunity to adapt their controls for other pollutants (not only those listed as a priority) with a view to align with the ACGIH TLV®s is recommended.

Cognisance should be taken of the impact that the ACGIH adoption will have on the reporting of over-exposures and the annual sampling schedules according to the classification bands of the HEGs. If a TLV® is adopted for a pollutant that is lower than the current one, initially there may be a significant increase in the sampling requirements and the reporting of over-exposures to the MHSI. It is proposed to keep the classification bands unchanged but that a phased-in pragmatic approach to the transition of the ACGIH TLV® and the knock-on effect on associated processes should be taken into consideration.

The workshops were well attended by the different industry stakeholders and respondents in general gave comprehensive feedback. Most of the respondents agreed with the process that was followed to come to the recommended OELs and most respondents agreed that the ACGIH TLVs® should be adopted as a standardized approach in the SAMI. None of the respondents objected or presented health-based reasons against the proposal to adopt ACGIH TLVs®.

When participants were asked to comment on the proposed OELs for the prioritized pollutants, there was general agreement with the recommended OELs. Most of the respondents recognised the health-benefit associated with OELs that are more stringent. However, many challenges were raised with the implementation of the recommended OELs. There was general concern about non-compliance to lower OELs, challenges to implement engineering controls and the financial impact this will have on the mines. The overwhelming support that a comprehensive cost-benefit analysis should form part of the implementation plan for revised OELs, further support the concerns about the financial viability of the OELs.

Most of the respondents commented that a realistic phase-in period should be between three and seven years, however, that each pollutant should have their own phase-in period. In terms of coal dust and crystalline silica, respondents commented that the focus should remain on the 2024 Milestones instead.

The stakeholder feedback illustrated how challenging it will be to implement the recommended OELs that are aligned with the ACGIH TLVs®. The outcomes of this project provide a starting point when all stakeholders are engaged to discuss the implementation strategy going forward.

12 RECOMMENDATIONS

Based on the outcomes of this project, several recommendations are made for consideration.

- It is recommended that additional target organs / systems are included in the medical surveillance programmes following a comprehensive risk assessment of exposure to airborne pollutants.
- It is recommended that the comprehensive, tabulated comparison of all the Schedule 22.9(A) OELs with international leading practice is made available to industry as a standalone, reference document.
- It is recommended that the cost-benefit analysis framework is made available to government and industry for them to conduct a more comprehensive financial impact analysis when a revised OEL is implemented.
- It is recommended that policymakers approve the adoption of ACGIH TLVs, notations and BEIs® as a national process for OEL setting and review. Where the ACGIH does not have a notation, it is recommended not to adopt notations from another organisation to remain consistent with the ACGIH adoption strategy. It is also recommended that biological monitoring for specific airborne pollutants, as a form of medical surveillance, is included in the MHSA and that a BEI notation of the ACGIH is included as a note to those airborne pollutants listed in Schedule 22.9(A).

Considering the feedback and contributions from the respondents of the stakeholder workshop, further recommendations are made:

- Define a process of annual/biennial review of OELs to avoid long periods that may lapse without reviewing OELs, because the magnitude of change and/or reduction is too much for industry to comply with. Internationally, a defined process of review is followed and therefore, alignment with the ACGIH TLVs® can be considered as a best practice approach to review OELs.
- The proposed OEL changes for airborne pollutants with existing milestone OELs (e.g. coal dust and silica) beyond the existing 2024 Milestones, should only be considered after the milestone due date.
- A targeted workshop must be held with industry stakeholder, the Department of Mineral Resources and Energy (DMRE) and organised labour to discuss the implementation of revised OELs in industry. Each stakeholder should critically assess potential aspects within their control that may be a stumbling block on the road to compliance with the revised OELs such as conflicting business processes and/or restrictive legislation.
- Chemical laboratories that analyse for airborne pollutants should also be consulted when the implementation of revised OELs are discussed. The laboratories will have to align their testing to the reduced concentrations and need enough time for such an alignment.

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14 REFERENCES

A comprehensive list of references is included in the integrated report that can be requested from the MHSC.

American Conference of Governmental Industrial Hygienists (2019). TLVs and BEIs. Based on the Documentation of the Threshold Limit Values for Chemical Substances and Physical Agents & Biological Exposure Indices. ISBN: 978-1-607261-05-6.

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