MHSC

Mine Health and Safety Council

CENTRE OF EXCELLENCE PROJECTS

Stakeholder Consultation Workshop on the Comprehensive Guidance Document for the Identification, Monitoring and Management of Hazardous Biological agents (HBAs) in the South African Mining Industry (SAMI)

Project Overview, Key Research Findings and Stakeholder Input to Refine the Guideline and Implementation Toolkit

Project number: CoE 220802

Stakeholder Consultation Workshop

Date: 27 November 2026
Venue: Glenburn Lodge, Muldersdrift
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Executive summary

The MHSC commissioned Project CoE 220802 because section 11 of the Mine Health and Safety Act requires mine employers to identify hazards, assess risks, record significant findings and consult mine health and safety committees on risk controls, yet the identification, monitoring and management of biological hazards needed mining-specific guidance. The project undertook a local and international desktop review, developed a four-stage continuous HBA health risk assessment framework and data-collection tools, examined workplace practices and available records at six champion mines, surveyed 36 respondents from different worker and management categories, and consulted regulators and organised labour. Its overarching deliverable was a comprehensive guideline and implementation strategy.

The strongest finding was not evidence of sector-wide pathogenic contamination, but an evidence-and-implementation deficit: mineworkers recognised possible sources such as dust (77.8%) and groundwater (36.1%), yet formal HBA identification was reported by only 25%; HBA-specific HIRA, SOPs and usable laboratory-to-corrective-action records were inconsistently available. Survey feedback and stakeholder consultations reinforced deficiencies in knowledge, investigation, coordinated occupational hygiene/medical/safety roles and capacity development.

The original MHSC TOR did not commission systematic environmental sampling and laboratory pathogen identification. The study therefore could not establish the actual prevalence of pathogens or occupational causation of reported illnesses. The guideline should be accompanied by a separately approved and resourced programme of site-specific sampling, competent laboratory testing and integrated health surveillance, while mines immediately strengthen risk-based HIRA and preventive controls.

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1.0 Original MHSC mandate: Problem, aim, scope and outputs

1.1 Problem statement from the MHSC call

The MHSC call (MHSC008/2025/26, pp. 2–4) stated that mine employees are exposed to several health hazards, including biological hazards, and that the study was commissioned to identify prevalent biological hazards and assess whether they were effectively managed. It placed this need in the context of the MHSA section 11 duties to identify hazards, assess risks, record significant findings and determine controls after consultation with mine health and safety committees. The underlying problem was therefore inadequate mining-specific evidence and practical guidance to translate existing general duties into comprehensive HBA identification, monitoring and control.

1.2 Aim and specific objectives

The study aimed to develop a comprehensive, practical guidance document that could be used or adopted by the SAMI to identify, monitor and manage biological hazards and incorporate HBA-specific hazard identification and risk assessment (HIRA), control measures and an implementation strategy. To achieve this, the project reviewed local and international evidence; identified legislative, guidance, standards and practice gaps; examined mining-relevant hazards and actual management arrangements; formulated feasible recommendations; developed draft guidance; and sought stakeholder input to refine and finalise the guidance (MHSC, 2025, §§2.3–2.4).

1.3 Expected deliverables and project timeframe

TOR expected output	Completed or planned project response
Literature review report identifying gaps	Milestone 2 structured evidence synthesis and legal/practice review
Report with actionable recommendations	Integrated evidence-to-action gap analysis
Draft guideline and implementation strategy	Milestone 4 draft guidance, assurance framework and operational toolkit
Hybrid stakeholder workshop outcomes	Regulator and labour engagements; stakeholder validation and outcomes documentation
Draft final guidance incorporating consultation input	Revised guidance and response-to-consultation log
Final report and publishable article	Final integrated reporting and scientific publication

The TOR specified 15 months: 12 months for project work and three months for initiation, contract administration and closeout. The successful proposal scheduled December 2025–February 2027; individual milestone dates are proposal-based and must be aligned to the signed agreement and approved amendments.

1.4 Intended and participating mine sites

The approved project proposal envisaged two gold mines (deep and shallow underground), two platinum-group-metal mines (underground and mechanised/open-pit), one surface coal mine and one underground base-metal mine. The later Milestone 3 evidence describes six champion mines comprising two gold, two platinum, one coal and one diamond operation. The substitution of a

diamond mine for the originally proposed base-metal mine needs documented MHSC approval or justification; the two configurations must not be represented as identical.

1.5 Critical boundary of commissioned work

The original MHSC TOR (MHSC008/2025/26, Sections 2.3–2.4) commissioned a local and international literature review, a gap assessment, actionable recommendations, draft guidance and an implementation strategy, followed by stakeholder validation and final reporting. Although the TOR sought an indication of hazards prevalent in South African mines, it did not specifically commission or resource systematic new environmental sampling, animal sampling, employee specimen collection or culture/molecular identification of pathogens across six operations. Consequently, the study evaluated plausible biological hazards and management gaps from published research, worker reports, inspected records and selected existing test results, not from a representative pathogen-surveillance programme. This is the principal interpretive boundary of all findings and motivates a separately approved, funded laboratory investigation (see Sections 6.2 and 7).

2.0 Methodology

2.1 Local and international literature review

The team undertook a structured desktop review of mining and comparable industrial evidence, national and international legislation, guidance and standards. The detailed Milestone 2 review documented a principal 1996–2024 publication window and identified PubMed, Scopus, Web of Science, Google Scholar, WHO, ILO and relevant South African sources. The associated Bani–Zungu framework paper used SPIDER (Sample, Phenomenon of Interest, Design, Evaluation, Research Type) to organise searches in Google Scholar and Scopus and reported 90 records considered at the search stage. Assistance from the university librarian facilitated identification and access to relevant subscription-based studies. The document does not supply a full independently reproducible librarian search log.

Documented search expressions included “hazardous biological agents”, “biological hazards”, “mining”, “occupational exposure”, “HIRA”, “risk assessment”, “biological risk management”, “occupational disease” and “infection control”; Boolean AND/OR was used. The review synthesised potential agents/sources, routes, health effects, laboratory methods, regulatory arrangements and operational gaps. References to publish mine microbiology reflect research conducted in those locations, not new sampling at the six South African sites.

2.2 Ethics, survey development and champion-mine situational analysis

The situational analysis received Category 1 (very-low-risk) ethics approval. The framework developed from the technical and literature reviews defined four sequential stages: (1) characterise mine work environments and potentially exposed activities; (2) identify HBAs and sources through a questionnaire, with laboratory work proposed as a subsequent component; (3) estimate potential health risks; and (4) identify preventive measures, communicate findings and verify controls. The framework’s original text and tables are reproduced unaltered in Appendix A.

The research team translated framework Tables 1 and 2 into an online questionnaire for employees, management and OHS management, and adapted the same domains into a records/practices

checklist for champion mines. Variables included commodity, mine type, work arrangement, sanitation, perceived symptoms, potential HBA sources, exposure-generating tasks, exposure routes, PPE, ventilation, procedures, medical service and laboratory decision-making. The paper reports Google Forms collection, unique respondent identifiers and descriptive Excel summaries. Six mines were assessed through survey responses, observations and available HIRA, SOP and testing records. The laboratory step set out in framework Table 3 remained proposed; it was not authorised as a comprehensive new field-testing programme under the original TOR.

Study qualification: The original framework proposed a minimum of 50 and maximum of 300 participants; 36 responses were analysed in the Bani–Zungu paper. This smaller descriptive sample limits representativeness, particularly for subgroup comparisons by job and commodity. Source Tables SI 5–7 contain variable question denominators; values must be checked against the underlying online export before final submission. The framework equation D = C × N is preserved in the original table but is a simplified index rather than a validated infectious dose or full quantitative microbial risk assessment (QMRA) model, which requires route-specific exposure and organism-specific dose–response inputs.

The four-stage framework operationalised: (1) mine environment and activities; (2) HBA identification and possible exposure; (3) assessment of health significance, contingent on pathogen measurements; and (4) controls and communication. As shown in original Framework Tables 1–2, the questionnaire covered employee, management and OHS management respondents, potential sources, symptoms, routes and preventive measures. Original Framework Tables 3–4 are future-facing technical tools and should not be mistaken for tests performed across the six champion mines.

2.3 Original four-stage HBA assessment framework and source tools (verbatim)

The original August 2026 framework narrative and its Tables 1–4 are reproduced below without altering their substantive source wording. Tables 1 and 2 informed the online questionnaire and mine records/practices checklist; Tables 3 and 4 specified a proposed pathogen-testing and health risk estimation stage that was not completed under the original TOR.

2.3.1 Framework for continuous health risk assessment of HBAs in South African mines

This framework is produced from the Technical review (Milestone 1) and Literature review (i.e. currently being compiled). The framework is suggested to involve sequential stages. The **first stage** focuses on basic characteristics of the mining work environment, and outline of the activities that could lead to exposure to Hazardous Biological Agents (HBAs) (Table 1).

The **second stage** focuses on identification of HBAs in the mining workplace. The identification of HBAs will be conducted via two steps, including Questionnaire (Table 2) shared to the employees, management, and OHS management team of the mining workplace. Subsequently, sampling and laboratory analysis for identification of HBAs using culture (selective media) and molecular based methods (Metabarcoding for Phyla and Genera) (Metagenomics for Species). The workflow is shown in Table 3. Upon the identification of the species the components of Quantitative Microbial Risk Assessment (QMRA) will be used, depending on the observed exposure scenarios and species identities.

The estimation of health risks and diseases will be conducted in the **third stage.** Equation 1 followed by Table 4 will be used as a for health risk estimation and potential diseases.

$$D = C \times N \quad (1)$$

Where D is the dose of the pathogen (CFU or identified species), C is the concentration of the pathogen in a sample (CFU/ml, CFU/g, CFU/m^2/hour) or (% abundance when used metabarcoding or metagenomics), and N is the duration of exposure (number of days per month or year).

In the **fourth stage**, preventative measures are explored. The potential preventative measures to reduce exposure to HBAs in mining workplace will be reported according to the functioning of the mining institute. The reporting template for informing workers about the assessment results of HBAs in their workplace will be also developed. The template will allow workers to report on efficiency of the preventative measures, incidents of exposure to HBAs, and verification of the overall risk assessment. The template/tool for this stage is mainly depended on the data outcomes from the previous stages.

Table 1 Basic information of the mining work environment

This questionnaire will be distributed and completed by Employees, Management and OHS management team. The minimum of all participants is requested to 50 and maximum to be 300.

Mine (commodity and size):							
Total number of staff:							
Group/participants (Mark **"X")**		**Employee**		**Management**		**OHS Management**	
Basic demographic parameters (Mark "**X**")							
Female	**Male**	**Age**					
		18-21	22-35	36-45	46-55	56-65	65+

Basic sanitation services/Hygiene (Mark "**X**")	
Provision of hand sanitizer	
Hand sanitizing station	
Nearby bathrooms	
Change of work clothes/Personal protective equipment	
Potential occupational diseases	(Mark "**X**")
Fever	
Chest pains	
Joint pains	
Skin itching / rash	
COVID-19	
HIV/AIDS	
Pulmonary Tuberculosis/TB	
Silicosis	
No occupational disease	
Potential sources of HBAs in connection with the work process	(Mark "**X**", comment)
Soil debris from excavation of rocks containing micro and macroorganisms	

Mine dust	
Decaying and decomposing wood material	
Water from rocks (aquifers), water courses, and reservoirs	
Process water (mining, technology, fire-fighting, dewatering)	
Water-oil medium (power hydraulic cylinders)	
Insects (mosquitoes)	
Rodents (rats, mice)	
Microclimatic conditions (25 – 37 °C), (70 -90% Relative Humidity)	
Activities leading to exposure to HBAs	(Mark **"X**, comment)
Mechanical mining	
Manual mining	
Operation of electric, hydraulic, and diesel machinery and equipment	
Operation of drainage systems	
Installation of sidewalk lights	
Other (Please specify)	
Routes of exposure to HBAs	(Mark "**X**")
Respiratory/Inhaling	
Oral	
Dermal/ Skin contact	
Eyes	
Blood-borne	
Other information (Please specify)	

Table 2 Questionnaire for the mining workplace

This questionnaire will be distributed and completed by Employees, Management and OHS management team. The minimum of all participants is requested to 50 and maximum to be 300.

Mine				
Mining operation				
Total Number of staff				
Group/Participants (Mark **"X"**)	**Employee**	**Management**	**OHS Management team**	
Working hours				
Information about HBAs (Mark "**X**")	**Yes**	**No**	**Don't know**	**Comment**
Do you know about Bacteria, Fungi, and Viruses?				
Are you exposed to Bacteria, Fungi, or Viruses?				
Have Bacteria, Fungi, and Viruses ever been identified/measured?				

For OHS Management team (Have there been any illness among employees involving exposure to Bacteria, Fungi, and Viruses?)				
Have encountered illness?				
Have you been hospitalized?				
Are you receiving any treatment?				
Do you maintain personal hygiene (e.g. wash hands regularly)?				
Do you have access to the clean eating space?				
Basic Information about Protective measures (Mark "**X**")	**Yes**	**No**	**Don't know**	**Comment**
Provided PEE (Mark **"X")**	**Yes**	**No**	**Don't know**	**Comment**
Hard helmet, Safety boots, and Visibility vests				
Gloves, Eye/Hearing protection, and Dust mask				
Fall protection				
Self-contained self-resecure				
Information about Technical measures (Mark **"X"**)	**Yes**	**No**	**Don't know**	**Comment**
Are working environment ventilated?				
Are there any installed air/gas filters?				
Are there any installed toxic gas detectors?				
Are there any installed fire detectors?				
Information about Organizational measures (Mark "**X**")	**Yes**	**No**	**Don't know**	**Comment**
Is there a reporting procedure in case of injury or accident?				

Is there medical service facility (e.g. clinic or specialised doctor)?				
Other information (Please share)				

Table 3 Sampling and lab analysis procedures

The outlined procedures are still open for development and validation. Extensive microbial techniques (i.e. biochemical, antimicrobial resistance tests, Microscopy) and bioinformatics will be applied for identification of different species associated with potential occupational diseases.

Sample (n=3)	Sampling	Lab analysis
Water (Aquifers, Process water)	Aseptically, using sterile schott bottles (1 L). Cooler box (≤ 4 °C), delivery to the lab within 24 hours.	**Culture based**: • Serial dilution and spread plate on Agar (Tryptic soy, Nutrient and mf-C) for bacteria. • Spread plate on Sabouraud and Potato Dextrose agar for fungi. • Plaque assay for viruses (host cells will be explored) **Molecular based**: DNA extraction (e.g. Zymo Research/ QIAGEN kits). PCR (specific primers). Sequencing. Bioinformatics (Metabarcoding and Metagenomics). • 16 rRNA primers for bacteria • ITS1/ITS4 primers for fungi • Multiplexing for viruses
Sediment/Dust and swab samples	Aseptically, using sterile falcon tubes. Sterile swabs. Cooler box (≤ 4 °C), delivery to the lab within 24 hours.	**Culture based**: • Culture in sterile nutrient broth • Serial dilution and spread plate on Agar (Tryptic soy, Nutrient, m-FC, McCartney) for bacteria • Spread plate on Agar (Middlebrook 7H10/7h11 and Lowenstein-Jensen Medium) for *Mycobacterium* • Spread plate on Sabouraud and Potato Dextrose agar for Fungi • Plaque assay for viruses **Molecular based**: Resuspending the samples in saline solution (IX Phosphate buffer solution) then conduct as described above for water samples.

Sample (n=3)	Sampling	Lab analysis
Social/Clean (eating space) Bathroom	Aseptically, using Sterile swabs. Cooler box (≤ 4°C), delivery to the lab within 24 hours.	**Culture based**: Use of specialised solid media as described above. **Molecular based**: Eesuspended swabs in IXPBS, then conduct as described above for water samples.
Air	Impactor (Andersen) with multi-hole discs, allows to classify the number of colonies according to particle size (e.g. 1-5 µm, >5 µm). Exposure of solid media (agar plates) in the air for specific duration	**Culture based**: Use of specialised solid media as described above for sediment/dust samples. Incubation and colony counting of the exposed agar plates
Rodents	Live traps and delivery to the lab within 24 hours.	**Initial assessment**: Physical condition of rodents, collection of biological samples (blood, oral and anal swabs). **Culture based**: Use of specialised media as described above. **Serological approaches**: Evaluate presence of antibodies against different zoonotic pathogens. **Molecular based**: DNA extraction, PCR, Sequencing, and Bioinformatics
Insects (e.g. Mosquitoes)	Live traps using nets (Mosquito trapper)	Mosquito gut microbiome analysis (**Molecular based**)

Table 4 Health risk estimation and potential diseases

Some/most of the outlined HBA genus/species will be revealed via culture-based techniques (**selective media and control strains**) and molecular techniques (Metabarcoding and Metagenomics). Other revealed genus/species that are not presented in this Table will be also investigated for their potential diseases.

HBA	Genus/species	Antibiotic resistant		Duration of exposure		Potential diseases/symptoms
		Yes	No	Days/ Month	Days/ Year	
Bacteria	• Clostridium perfringens • Clostridium tetani • Clostridium spp • Fluoribacter bozemanae • Legionella pneumophila • Leptospira interrogans • Mycobacterium kansasii • Burkholderia psuedomallei • Rickettsia typhi • Mycobacterium tuberculosis • Salmonella typhi					• Gas gangrene • Tetanus • Wound malignant edema, enteritis • Pneumonia • Legionellosis • Leptospirosis, Weil's disease • Pulmonary mycobacteriosis • Meliodosis: acute lymphadenitis • Endemic rat typhoid fever • Pulmonary tuberculosis • Typhoid
Viruses	• Hepatitis A virus enterovirus type 72 • Dobrava-Belgrade hantavirus • Seoul hantavirus • Hepatitis B virus (HEPATITIS B, HBV)					• Hepatitis A, gastroenteritis • Hemorrhagic fever with renal syndrome (HFRS) • HFRS • Hepatitis B, liver cancer
Fungi	• Aspergillus flavus • Candida albicans • Candida tropicalis • Epidermophyton floccosum • Trichophyton rubrum • Mycotoxins (mold) • Ancylostoma duodenale • Balamuthia mandrillaris • Necator americanus • Strongyloides stercoralis					• Pulmonary mycosis, bronchial asthma • Candidiasis of the skin, nails, oral cavity • Candidiasis of the skin, nails, urinary track infection. • Dermatophytosis, allergies. • Dermatophytosis, allergies. • Mycotoxicosis. • Ankylostomatosis, diarrhea, pneumonia. • Pneumonia, encephalitis, dermatitis, keratitis. • Antilostomosis. • Echinococcus, meningitis.

3.0 Literature review: biological agents, sources, occupational pathways and effects

The literature review established that mining biological hazards may arise from contaminated mine and process water, aerosols generated by dust suppression, sediments, damp timber, ventilation systems and biologically contaminated dust; communal food/water/sanitation facilities; contaminated clothing; human respiratory transmission; rodents, bats and other wildlife; and health-service work. The risk depends on the agent, source, task, route and duration of contact, worker vulnerability and controls. Crystalline silica and coal dust are not themselves biological agents, although dust may also convey microbial material.

Source/Environment	Possible organisms or relevant agents	Potential health effects/Route	Evidence
Underground mine water, sprays, process/dust-suppression water	Legionella pneumophila; environmental non-tuberculous mycobacteria (NTM/MOTT)	Inhaled aerosols: Legionnaires' disease; NTM lung infection in susceptible people	Madera-García et al., 2019; Corbett et al., 1999; Kwenda et al., 2015
Water, mud, stagnant sumps, wet rock and rodent-contaminated sediment	Leptospira spp.; other environment-dependent organisms	Contact with skin breaks or mucosa: leptospirosis, fever, myalgia, possible kidney/liver injury	CDC, 2024; project literature review
Air, drilling aerosols, ventilation, damp wood, mine dust	Aspergillus, Penicillium, Staphylococcus aureus, bacterial fragments/endotoxin	Allergy, airway symptoms, opportunistic infection; antimicrobial resistance where demonstrated	Wei et al., 2015; Cheluszka et al., 2023; Paśmionka et al., 2025
Crowded vehicles, waiting areas and clinics	Mycobacterium tuberculosis and respiratory viruses	Airborne infection, including pulmonary TB	Corbett et al., 1999; WHO TB guidance
Food, drinking water, canteens, sewage, waste	Salmonella, pathogenic E. coli, norovirus, Giardia; contamination-dependent	Gastroenteritis, diarrhoea, vomiting, hepatitis A where relevant	WHO drinking water and food safety guidance
Showers, change houses, wet floors and boots	Dermatophytes (Trichophyton); waterborne Legionella if present	Tinea pedis; aerosol-related pneumonia when water system contaminated	WHO ringworm; CDC Legionella
Rodent droppings, nests, underground food and stored supplies	Leptospira; selected rodent-associated hantaviruses and other pathogens	Leptospirosis; pathogen-specific fever, renal/pulmonary disease; potential aerosol exposure	CDC rodent control; WHO hantavirus
Baboons, monkeys and shared food/water/waste interfaces	Potential faecal bacteria and parasites; viruses with evidence varying by species	Bites, scratches, faecal contact; possible gastrointestinal or wound illness	Drewe et al., 2012; species-specific One Health evidence
Mine clinic, first aid and healthcare waste	HBV, HCV, HIV and other healthcare pathogens	Sharps, blood/body-fluid contact; hepatitis and HIV	WHO occupational hazards in health sector

Table SI 2 Published mining-related HBA studies (original Bani–Zungu table)

Study aim/Purpose	Approach	Findings and suggestions	References
Investigation of the presence of *Mycobacterium* related strains in SA mining environments.	Conducted sampling of sputum, water, mud, and cigarette butts. Air sampling was also conducted using MRE type 113A gravimetric dust sampler, airborne biological sampler (DMEM, Corporation), and SA-Super 90. Microbial analysis was conducted using culture-based techniques (Middlebrook 7H10 media) and molecular techniques (Polymerase chain reaction).	Across the samples 16.5% was observed to have NTM, while 57.2% contained nonspecific bacteria. The NTM strains were reported to be *M.gordonae* (21.3%) and *M.scrofulaceum* (14.9%). Continuous analysis of *Mycobacterium* and NTM was recommended for early detection of diseases.	Lowe, 1999
Explanation of the significance of occupational biohazards. Detailing the potential diseases related to exposure to HBAs.	Compiled as Handbook section on Mine Occupational Hygiene measurements for MHSC. Sampling and analysis methods (culture based) are explained.	The Surface air Sampler is recommended and its SOP is provided withing the Handbook.	Mine Health and Safety Council, 2007 The HBA paper's numbered entry points to a different publication, while the table describes the handbook's biohazards chapter
Investigation of the occurrence and diversity of airborne fungi and potential health risks.	Air sampling (50 L) was conducted using the Air Ideal 3P Sampler onto Potato Dextrose Agar (i.e. culture media for fungi).	Diverse fungal species were observed and the most dominant were noted to be *Penicillium notatum*, *P.urticae*, and *Aspergillus flavus*. Across the different mines fungal diversity was observed to be significantly different due to the varying microclimate. The observe airborne fungi was reported to not have health risks, however there are possible health risks overtime.	Pusz et al., 2014

Study aim/Purpose	Approach	Findings and suggestions	References
Investigation on microbial diversity and abundance in bioaerosols of a coal mine.	Collection of bioaerosols was conducted after drilling using a bioaerosol sampler (Quick Take 30, SKC, USA) embedded with a sterile filter of 0.22 µm pore size at air flow rate of 20L/min for 1.5 hours. The filters were processed for DNA extraction and quantification, followed by Polymerase chain reaction and pyrosequencing. Bioinformatics was conducted using Mothur pipeline.	Microbial concentrations were obtained and diverse phyla and genera were observed. Potential pathogens such *as Acinetobacter schindleri, Aeromonas cavernicola, Alternaria alternata, Aspergillus penicillioides, Cladosporium cladosporioides*, and *Penicillium brevicompactum* were identified. Continuous microbial profiling is suggested regarding health of the coal miners.	Wei et al., 2015
Quantification of *Legionella pneumophila* in non-potable water that is used for dust controlling during mining operations.	Aseptic water sampling was conducted at different points of usage, including storage tank. Culture based analysis was conducted using Leogiolert test kit (IDEXX) to quantify the concentration of *Legionella pneumophila* across different water samples. Physicochemical analysis was also conducted to observe correlation.	The water samples (93%) were observed to have *Legionella pneumophila* and high concentration of $8.35x10^4$ MPN/L was obtained in the sprinkler system. The estimated Disability Adjusted Life Years (DALYs) from the Quantitative Microbial Risk Assessment (QMRA) model indicated low health risk if the ventilation system is operating. Ventilation system is suggested to reduce the risk of infection with *Legionella pneumophila*.	Madera-García et al., 2019

Study aim/Purpose	Approach	Findings and suggestions	References
Investigation on isolation of *S. Areus* from coal mine bioaerosol, followed by evaluation of its sensitivity/resistance towards different antibiotics.	Measured the microclimate parameters such as Temperature, Relative humidity, air velocity, and respirable dust. Air sampling was conducted via aspiration using MAS-100 ECO air sampler (Merck, Germany), embedded with Mannitol agar plates. Further identification, biochemical tests, and antibiotic resistance of *S. Areus* strains were conducted using selective media.	Different strains of *S. Areus* were observed to be sensitive to oxacillin, while 30% of the identified strains indicated multi-antibiotic resistance. The analysis of microbial composition in mine bioaerosols is important for alleviating spread of ODs.	Paśmionka et al., 2025
Risk and exposure assessment of HBAs in coal mine.	Different coal mine activities were explored for their potential to result exposure of employees to HBAs. Questionnaires were submitted to the mine site for assessment and perceptions of the employees regarding the exposure to HBAs.	The employees were observed to be prone to HBAs due to various routes of exposures such as mine dust inhaling, wastewater contact, and presence of rodents.	Mocek (2025)
Application of metabarcoding for microbial diversity profiling in cave and abandoned mine environments.	Sampled different environmental samples (i.e. about 382), including soil, water, rock, and bat and rodent droppings. Amplicon sequencing and DADA2 bioinformatics was conducted for microbiome analysis.	The observed pathogenic genera included *Salmonella* and *Legionella*. The microclimate in caves and abandoned mines harbours diverse microbiome that can affect public health.	Weingarten et al., 2026

Source: Bani and Zungu, HBA Paper, supplementary table reproduced as supplied. Interpret with the source manuscript's stated denominators and limitations

Table SI 4 Biological agents and potential health outcomes (original Bani–Zungu table)

HBA	Genus/species	Antibiotic resistant		Duration of exposure			Potential diseases/symptoms
		Yes	No	Hours/ Day	Hours/ Month	Hours/ Year	
Bacteria	• Clostridium perfringens • Clostridium tetani • Clostridium spp • Fluoribacter bozemanae • Legionella pneumophila • Leptospira interrogans • Mycobacterium kansasii • Burkholderia psuedomallei • Rickettsia typhi • Mycobacterium tuberculosis • Salmonella typhi						• Gas gangrene • Tetanus • Wound malignant ederma, enteritis • Pneumonia • Legionellosis • Leptospirosis, Weil's disease • Pulmonary mycobacteriosis • Meliodosis: acute lymphadenitis • Endemic rat typhoid fever • Pulmonary tuberculosis • Typhoid
Viruses	• Hepatitis A virus enterovirus type 72 • Dobrava-Belgrade hantavirus • Seoul hantavirus • Hepatitis B virus (HEPATITIS B, HBV)						• Hepatitis A, gastroenteritis • Hemorrhagic fever with renal syndrome (HFRS) • HFRS • Hepatitis B, liver cancer

HBA	Genus/species	Antibiotic resistant		Duration of exposure			Potential diseases/symptoms
		Yes	No	Hours/ Day	Hours/ Month	Hours/ Year	
Fungi	• Aspergillus flavus • Candida albicans • Candida tropicalis • Epidermophyton floccosum • Trichophyton rubrum • Mycotoxins (mold) • Ancylostoma duodenale • Balamuthia mandrillaris • Necator americanus • Strongyloides stercoralis						• Pulmonary mycosis, bronchial asthma • Candidiasis of the skin, nails, oral cavity • Candidiasis of the skin, nails, urinary track infection • Dermatophytosis, allergies • Dermatophytosis, allergies • Mycotoxicosis • Ankylostomatosis, diarrhea, pneumonia • Pneumonia, encephalitis, dermatitis, keratitis • Antilostomosis • Echinococcus, meningitis.

Table SI 2 summarises the mining-specific studies underpinning the literature synthesis. It contrasts environmental culture and molecular studies, including South African mycobacterial investigations, international coal mine bioaerosols and dust-suppression water. Table SI 4 lists example organisms and health outcomes as an exploratory catalogue; it is not a prevalence table, and several source classifications or organism–disease associations warrant expert checking before regulatory use.

The main literature matrix above should be read together with source Tables SI 2 and SI 4. Together they support identifying potential exposures, not assuming that all named organisms are present at each mine.

3.1 South African evidence on NTM/MOTT and mine water

Corbett and colleagues (1999) assessed nontuberculous mycobacterial disease among South African miners; Kwenda et al. (2015) molecularly characterised clinical and environmental Mycobacterium kansasii isolates from South African gold mines. This literature illustrates why NTM/MOTT should not be confused with TB: NTM are often environmental water/soil organisms with heterogeneous clinical significance; species identification and clinical assessment are essential.

Evidence of an NTM in mine water is neither evidence that all workers are infected nor proof that it caused a reported disease.

Published South African evidence offers an important distinction between tuberculosis caused by Mycobacterium tuberculosis complex and nontuberculous mycobacteria (NTM), also historically termed MOTT ("mycobacteria other than tuberculosis"). Corbett et al. (1999) isolated NTM from 118 miners in a prospective gold-mine workforce cohort, with 32 (27%) meeting the study's pulmonary NTM case definitions; the authors stressed the difficulty of separating colonisation or isolation from disease. Kwenda et al. (2015) recovered M. kansasii and other potentially pathogenic NTM from mine-associated water systems, particularly showerhead biofilms. These studies show why species-level laboratory identification, clinical evaluation and correlation with environmental sources matter; they do not establish that NTM infection is present at every mine (Corbett et al., 1999; Kwenda et al., 2015).

3.2 Dust-suppression water and Legionella

Madera-García et al. (2019) examined non-potable mine water and aerosol-associated Legionella risk in a pilot study. The findings support questioning whether untreated/stagnant water used for spraying may aerosolise viable pathogens. Before any mine claims a safe supply or adjusts treatment, it should map source water, storage, points of use, temperature, treatment, aerosol generation, maintenance and relevant worker tasks; targeted sampling would then be matched to an appropriate laboratory method. Drinking water, wash water and water sprayed for dust control are distinct exposure scenarios and require fit-for-purpose interpretations.

3.3 Rodents underground

Rodent activity at underground and surface sites merits attention in sumps, damp workings, refuse stores, workshops, food stores, shafts and change houses. Rodents may contaminate water or food with urine and faeces; their nesting material can also become aerosolised during cleaning. Leptospira is a key agent of concern where contaminated water/soil contacts skin or mucosa. Certain hantaviruses are associated with aerosolised rodent excreta, but specific viral geography and reservoir species must be confirmed and may not be assumed for any South African mine. Other hazards involve bite wounds and contaminated surfaces. Rodent sightings are evidence of infestation, not proof of a particular pathogen.

The immediate response should include source reduction, safe waste storage, sealing entry routes, safe wet-cleaning/disinfection, reporting and integrated pest management. CDC specifically cautions against dry sweeping or vacuuming droppings. A proposed funded follow-on programme could survey infestations and, where justified and legally permitted, collect rodent/environmental samples for selective microbiological and molecular testing with a veterinary/zoonoses team. Testing must answer defined risk questions and cannot in itself establish human infection.

3.4 Baboons, monkeys and wildlife

Organised labour raised concerns about aggressive baboons and monkeys around mine sites. Chacma baboons (Papio ursinus) can create physical injury and environmental contact risks through food-seeking, bites, scratches and waste/water contamination. Drewe et al. (2012) sampled 27 Cape Peninsula baboons: 56% showed antibodies reactive or cross-reactive to selected human viruses,

while no Salmonella, Shigella, Yersinia or Campylobacter organisms were isolated from the faecal specimens tested. These findings suggested a low but potential zoonotic interface risk; antibody reactivity does not prove transmission of human viruses or infection at mine sites. Viral herpes B illness is primarily a macaque-associated hazard, not a general baboon disease.

Mines should use a wildlife-incident register and safe exclusion, no-feeding, refuse and access controls, while seeking advice from authorised wildlife specialists, provincial conservation authorities and SANParks only where relevant to its jurisdiction. Animal capture, testing or relocation should not be conducted casually or without the required permits and animal-welfare safeguards.

High-risk supporting functions should not be overlooked: mine laundry workers may sort heavily soiled overalls, boots, gloves and fabrics before cleaning. The HBA HIRA should cover receiving bags, sorting tables, contaminated laundry baskets, washing machine doors, seals and drums, wastewater drains and the clean/dirty flow. Processes can expose workers by skin contact, contaminated wounds, splashes or aerosolised lint. Control effectiveness should be assessed using wash-cycle records (time, actual water temperature, detergent/disinfectant concentration, load size, drying and maintenance) and, where indicated, targeted pre/post-cleaning swabs. CDC infection-control guidance documents risk during sorting and recommends minimal agitation, bagging at source, PPE and separation of soiled and clean handling; it is a relevant technical benchmark, not automatically a legal standard for mine laundries (CDC, Laundry and Bedding).

3.5 Canteen, food handlers, healthcare and non-work sources

Risk identification should encompass kitchens, canteens, food preparation and transport, clean-water supply, sanitation, waste and food handlers, using established food-safety controls. Mine clinics and first-aid stations require bloodborne and respiratory infection-prevention practices, safe sharps handling, waste management and appropriate HBA risk assessment. Workers may also encounter infectious agents in households, public transport, communal accommodation, recreational water and nearby communities. An infection introduced from outside work may still spread at work; attribution requires clinical investigation and exposure history rather than an assumption that every disease is mine-acquired.

**Distinct potentially exposed worker categories. **Canteen staff, kitchen cleaners and food handlers may handle food, water, refuse and contaminated utensils, with gastrointestinal illness risk if enteric pathogens are present. Mine clinic nurses, first-aiders, laboratory and healthcare-waste personnel may face bloodborne and respiratory pathogens, contaminated sharps and clinical surfaces; clinical infection prevention and secure waste management remain essential. Laundry sorters, washers and change-house cleaners may encounter soiled PPE or contaminated wash surfaces as noted above. These roles should be explicitly named in task-based HIRA and consultation even when they are not part of production operations. Non-work sources—including households, communal accommodation, public transport, recreational water, food purchased outside the mine and surrounding community animal exposure—must be considered in clinical attribution, while recognising that infections introduced outside work can still be transmitted within workplace settings (WHO, Drinking-water; CDC, Environmental Infection Control).

For laundry workers, lacking organism-specific data makes it harder to validate a pathogen-specific cleaning cycle, but it does not justify abandoning established hygienic laundering procedures. The immediate requirement is to use validated cleaning processes compatible with fabrics and equipment,

maintain clean/dirty separation and protect sorters; follow-on microbiological sampling should be directed at an explicit risk decision (CDC, 2024).

4.0 Findings: survey, records and practices

4.1 Respondent profile and mine environments

The paper reported 36 respondents: 21 employees (58.3%), seven management personnel (19.4%) and eight OHS management personnel (22.2%). These were mineworkers from different employment categories and organisational levels, not a sample confined to OHS staff. The paper's supplementary commodity table contains internal response-total inconsistencies, so this report does not manufacture a commodity distribution that does not reconcile. The six-site descriptive mine mix is reported separately from the survey's respondent commodity classifications.

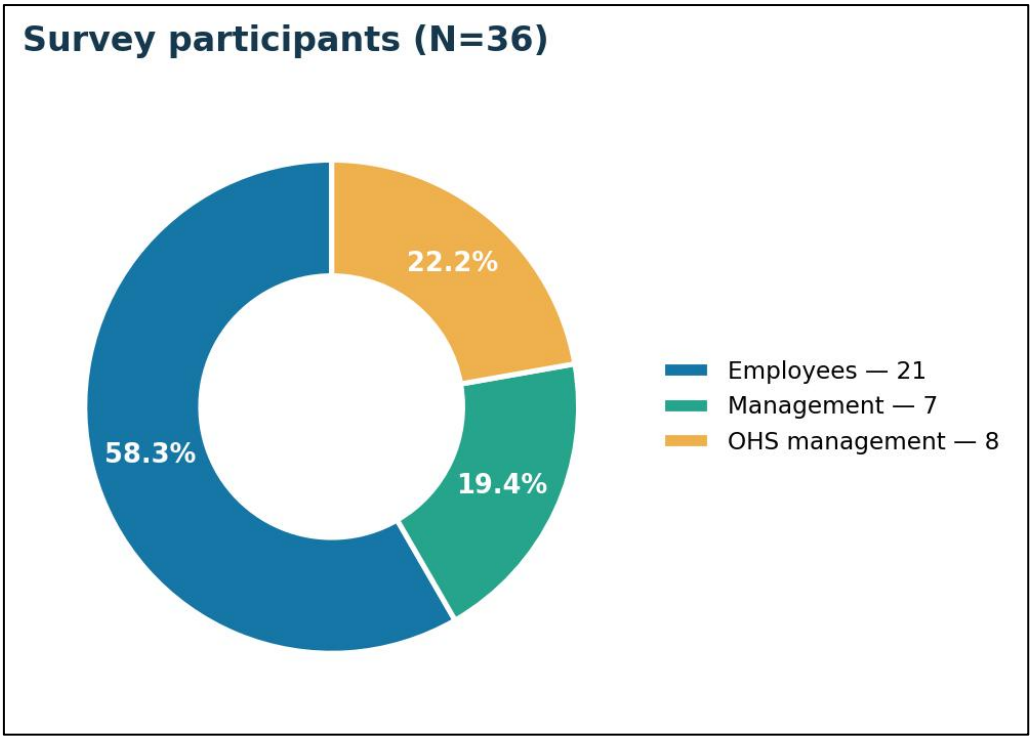


Figure 1 Respondent categories

Table SI 5 Respondent occupational and work profile (N=36)

Criterion (total number of responses)	Option	Participation outcome (%= number of responses)
Participant (36)	• Employee • Management • OHS Management	58.3 = 21 19.4 = 7 22.2 = 8
Type of employment (34)	• Permanent • Part-time • Fixed-term • Contractor	73.5 = 25 2.9 = 1 5.9 = 2 5.9 = 2

Criterion (total number of responses)	Option	Participation outcome (%= number of responses)
Years of employment (32)	• ≤ 1 year • 1-4 years • 5-10 years • ≥ 10 years	6.3 = 2 15.6 = 5 18.8 = 6 59.4 = 19
Type of Mine (32)	• Surface • Underground • Surface and underground	37.5 = 12 34.4 = 11 25.0 = 8
Commodity (35)	• Platinum Group metals • Gold • Coal • Diamonds	2.8 = 1 47.2 = 17 5.6 = 2 5.7 = 2
Size of the Mine (35)	• Small (≤ 50 employees) • Medium (50-200 employees) • Large (≥ 200 employees)	14.3 = 5 20.0 = 7 62.9 = 22
Years of Mining operation (30)	• ≥ 1 year • 1-10 years • ≥ 10 years	0.0 = 0 12.9 = 4 86.7 = 27

Figure 1 illustrates that respondents represented different occupational categories rather than OHS professionals alone. Table SI 5 presents the underlying profile and differing valid denominators, with 21 employees, seven management respondents and eight OHS management respondents (n=36). The figure and table should be interpreted as a small descriptive sample, not workforce prevalence estimates.

4.2 Awareness and formal identification

Twenty-eight of 36 participants (77.8%) reported awareness of bacteria, fungi and viruses as biological hazards. Only nine (25.0%) reported that HBAs had been identified in their mine; 18 (50.0%) said they had not and nine (25.0%) were uncertain. These data show a gap between general awareness and formal workplace identification; they do not independently confirm whether a HIRA document existed at each operation.

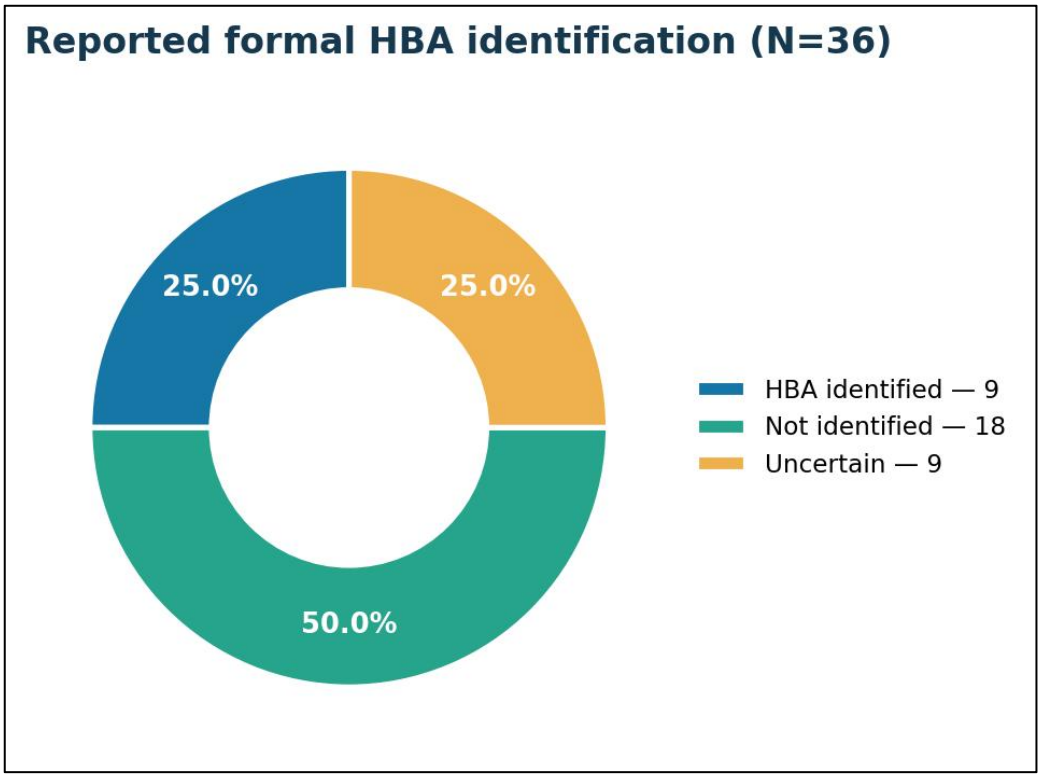


Figure 2 Reported HBA identification (N=36)

As displayed in Figure 2, only nine of the 36 respondents reported formal identification of HBAs, whereas 18 said no and nine were uncertain. This identification gap is consistent with the documentary review; it does not imply every mine was missing every biological control.

4.3 Possible environmental sources and routes

Mine dust was most often selected as a perceived HBA source (28/36; 77.8%), followed by underground water (13/36; 36.1%), soil or excavation debris (12/36; 33.3%), mosquitoes/insects (11/36; 30.6%) and rodents (8/36; 22.2%). These are *perceptions of potential sources*, not pathogen-detection results. The paper additionally recorded process water, decomposing timber, water–oil mixtures and mine microclimate conditions as risk-relevant items. High temperatures and humidity are environmental conditions rather than HBAs.

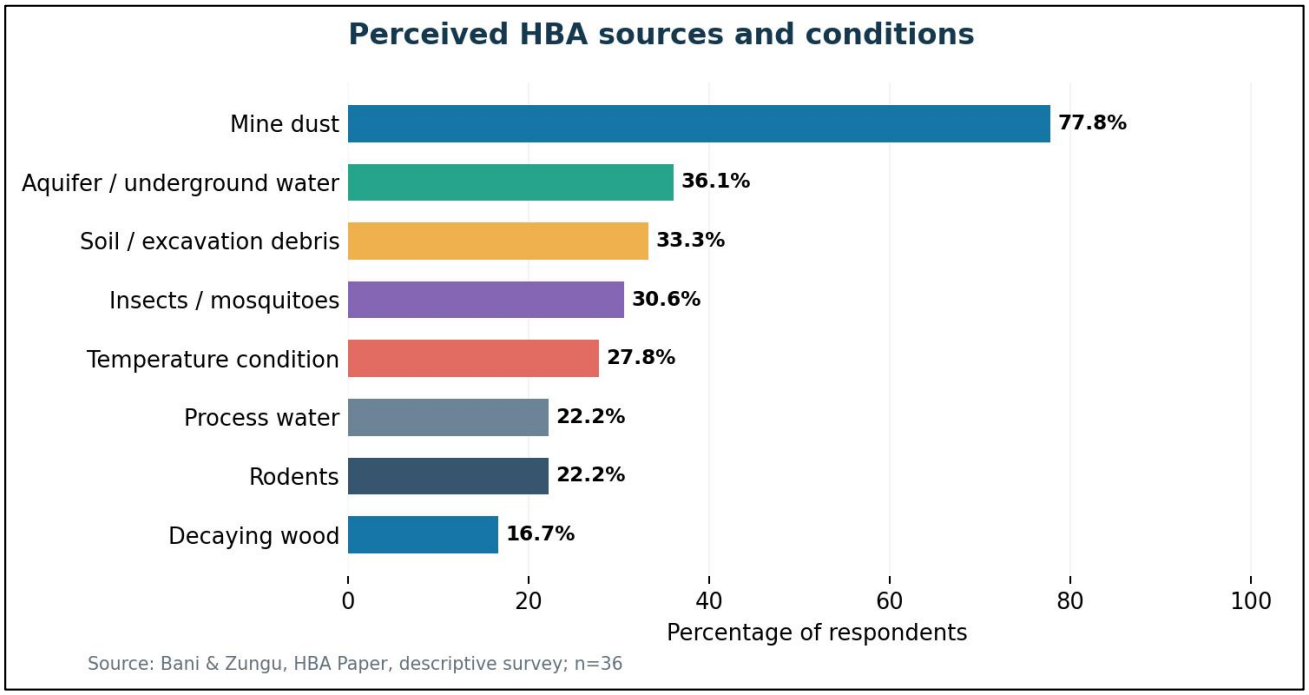


Figure 3 Selected potential sources/conditions, from HBA paper supplementary source table − multiple responses permitted (N=36)

Dust inhalation was selected by 31/36 (86.1%), while oral ingestion of dust or mine wastewater was reported by 12/36 (33.3%), and dermal contact by 14/36 (38.9%). Separate “dust inhaling” and “dust respiration” questions overlap conceptually and must not be interpreted as independent pathogen exposures.

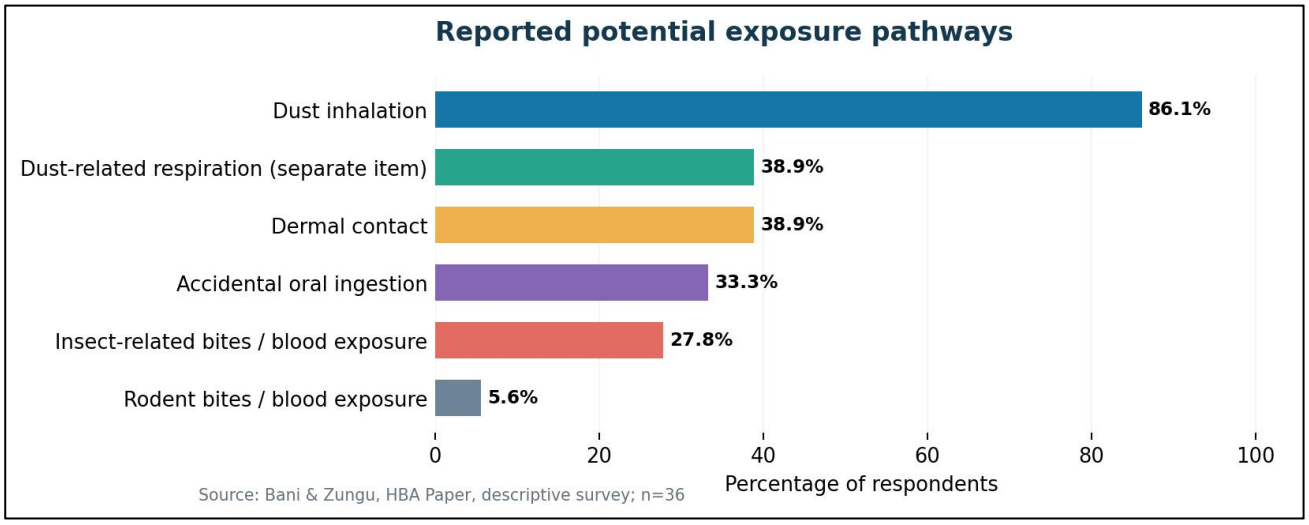


Figure 4 Perceived contact pathways from HBA paper supplementary source table; item labels retained conceptually (N=36)

Table SI 7 Potential sources, activities and exposure pathways (N=36)

Criterion (total number of responses)	Option	Participation outcome (% = number of responses)
Potential sources of HBAs (36)	• Soil debris from excavation of rocks containing microorganisms and macroorganisms	33.3 = 12
	• Mine dust	77.8 = 28
	• Decaying and decomposing wood material	16.7 = 6
	• Water from rocks (aquifers), underground water courses, and reservoirs	36.1 = 13
	• Processing water (mine technology, firefighting, dewatering)	22.2 = 8
	• Water-Oil medium (power hydraulic cylinders)	13.9 = 5
	• Temperature (25 – 37 ˚C)	27.8 = 10
	• Relative Humidity (70-90%)	13.9 = 5
	• Insects (e.g. mosquitoes)	30.6 = 11
	• Spiders	2.8 = 1
	• Rodents	22.2 = 8
Activities leading to exposure to HBAs (36)	• Mechanical mining	33.3 = 12
	• Manual mining (drilling, blasting)	47.2 = 17
	• Operation of electric, hydraulic, and diesel machinery and equipment	27.8 = 10
	• Operation of drainage systems	13.9 = 5
	• Installation of sidewalk lights	11.1 = 4
	• Surface operation (dust)	38.9 = 14
	• Underground operation	11.1 = 4
Routes of exposure to HBAs (36)	• Dust inhaling	86.1 =31
	• Dust respiration	38.9 = 14
	• Accidental oral ingestion of dust or mine wastewater	33.3 = 12
	• Dermal or skin contact with dust or mine wastewater	38.9 = 14
	• Eye contact with dust or mine wastewater	2.8 = 1
	• Longer use of PEE (e.g. latex gloves)	19.4 = 7
	• Falling accidents	22.2 = 8
	• Blood-borne (carnivorous/biting rats)	5.6 = 2
	• Blood-borne (insects)	27.8 = 10

Figures 3 and 4 show the survey's perceived source categories and possible exposure routes. Table SI 7 provides the original responses, including water, dust, rodents, manual and mechanical tasks, oral contact, skin contact and aerosol inhalation. These are respondent perceptions rather than microbiological confirmation.

The plotted bars in Figure 3 reflect possible sources identified by respondents, whereas Figure 4 displays perceived exposure pathways. Dust is not in itself a biological agent: a biological component of dust requires separate investigation from silica and coal-dust health hazards.

4.4 Hygiene, preventive measures, SOP and occupational health services

Facilities reported included bathrooms/showers (30/36; 83.3%), a clean eating area/kitchen (21/36; 58.3%) and provision of hand sanitiser (11/36; 30.6%). Regular clean PPE was reported by 27/36 (75.0%) and mandatory PPE change by 21/36 (58.3%); ventilation was reported by 31/36 (86.1%). These measures contribute to basic prevention but do not establish that relevant HBA-specific controls were effective.

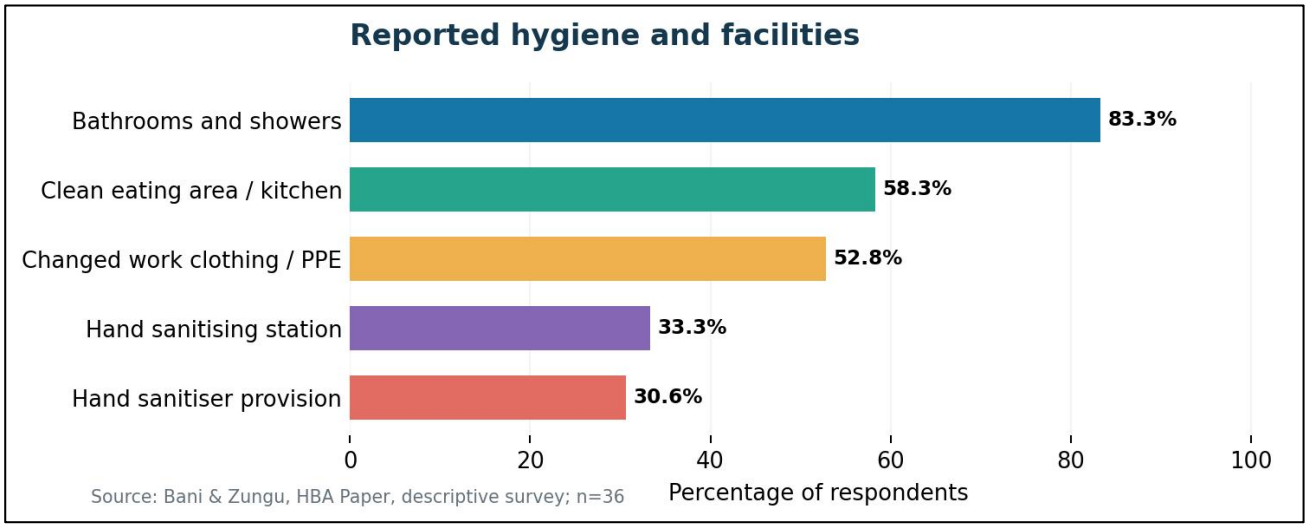


Figure 5 Reported hygiene provisions (N=36)

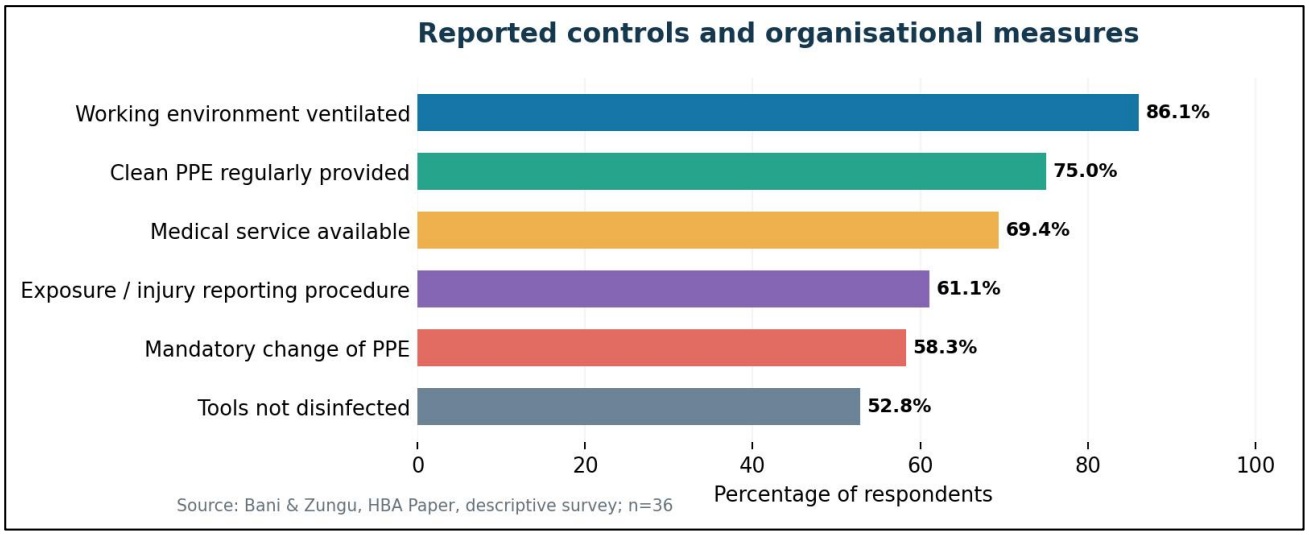


Figure 6 Technical and organisational controls (N=36)

For the HBA SOP question, the paper's main Results text gives the valid denominator of 28: five respondents (17.9%) had access, 12 (42.9%) had no access, and 11 (39.3%) were uncertain. Earlier project summaries reported a conflicting denominator of 35. The original paper's n=28 is retained in this figure pending checking the raw export.

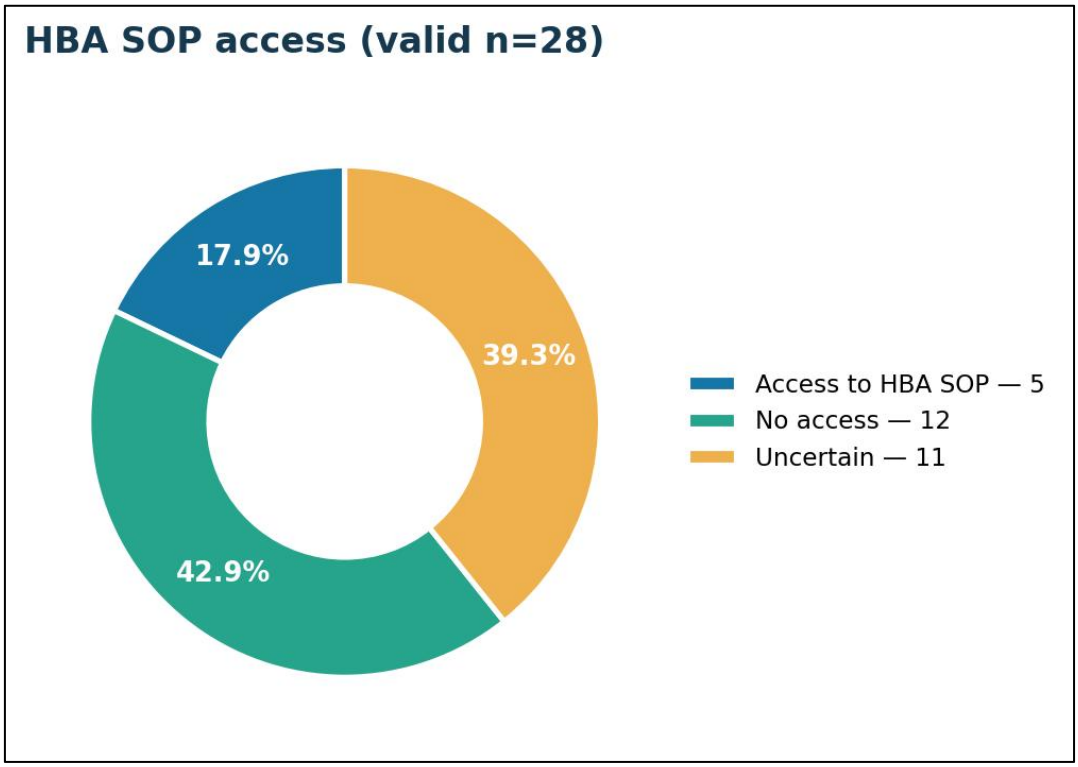


Figure 7 HBA-specific SOP access (N=28)

Figures 5–7 summarise hygiene, technical practices and SOP accessibility; source Table SI 7 describes the associated pathways, while Table SI 6 provides the original sanitation and health-symptom responses. The SOP pie chart uses the manuscript's reported denominator of 28 (five yes, 12 no, 11 uncertain). Other versions of the M3 report contain conflicting denominators; the original survey export should govern final reconciliation.

Figures 5 and 6 show existing sanitation, preventive and organisational arrangements. Figure 7 demonstrates the limited reported access to dedicated SOPs; these data support clearer biological-risk procedures and training, not a conclusion that generic safety systems were absent.

4.5 Symptoms and illnesses reported by respondents

Table SI 6 Sanitation provisions and reported symptoms (N=36)

Criterion (total number of responses)	Option	Participation outcome (% = number of responses)
Basic Sanitation/Hygiene services (36)	Provision of hand sanitizer	30.6 = 11
	Hand sanitizing station	33.3 = 12
	Nearby bathrooms and showers	83.3 = 30
	Changing of PEE	52.8 = 19
	Clean eating space/Kitchen	58.2 = 21
PREVIOUS symptoms/medical diseases (35)	Fever/Cold/Flue	62.9 = 22
	Chest pains	22.9 = 8
	Joint pains	20.0 = 7
	Headache	48.6 = 17
	Skin irritation/nail infection (Dermatophytosis)	5.7 = 2
	COVID-19	31.4 = 11
	HIV/AIDS	0.0 = 0
	PTB/TB	0.0 = 0
	Pneumonia	5.7 = 2
	Hearing loss	0.0 = 0
	Silicosis	0.0 = 0
CURRENT symptoms/medical diseases (35)	Fever/Cold/Flue	25.7 = 9
	Chest pains	17.1 = 6
	Joint pains	14.3 = 5
	Headache	17.1 = 6
	Skin irritation/nail infection (Dermatophytosis)	8.6 = 3
	COVID-19	8.6 = 3
	HIV/AIDS	0.0 = 0
	PTB/TB	0.0 = 0
	Pneumonia	0.0 = 0
	Hearing loss	0.0 = 0
	Silicosis	0.0 = 0

The supplementary paper reports previous fever/cold/flu symptoms in 22/35 (62.9%), headache in 17/35 (48.6%) and self-reported prior COVID-19 in 11/35 (31.4%). Currently reported fever/cold/flu was 9/35 (25.7%), chest pain 6/35 (17.1%), headache 6/35 (17.1%) and skin irritation/nail infection 3/35 (8.6%). These self-reports are neither verified diagnoses nor occupationally attributed conditions. The paper's wording suggesting that fever was probably due to airborne microbes is a hypothesis, not an established finding.

Table SI 6 describes reported current and previous symptoms in the survey; symptoms were not clinically diagnosed as caused by biological agents. Table SI 3, located with the documentary findings below, outlines laboratory methods proposed by the framework, including culture and molecular testing. These should not be reported as completed testing at champion mines.

4.6 Mine documentation, observations and available laboratory results

Table SI 3 Proposed sampling and laboratory analysis

Sample	Sampling	Lab analysis		Results	
		Culture based	Molecular	Culture based	Molecular bases
Water: Aquifers Process water Wastewater Observe water usage	Aseptically, using sterile schott bottles (1 L). Cooler box (≤ 4 °C), delivery to the lab within 24 hours.	• Serial dilution and spread plate on Agar (Tryptic soy, Nutrient and mf-C) for bacteria. • Spread plate on Sabouraud and Potato Dextrose agar for fungi. • Plaque assay for viruses (host cells will be explored).	• DNA extraction (e.g. Zymo Research/ QIAGEN kits) • PCR (specific primers). • Sequencing. Bioinformatics • (Metabarcoding and Metagenomics) • 16 rRNA primers for bacteria • ITS1/ITS4 primers for fungi • Multiplexing for viruses	CFU/ml (Bacteria and Fungi) PFU/ml (Viruses)	Relative abundance (%) Phylum, Genera, Species
Sediment/Dust: Workspace Tools PPE	Aseptically, using sterile falcon tubes. Sterile swabs. Cooler box (≤ 4 °C), delivery to the lab within 24 hours.	• Culture in sterile nutrient broth. • Serial dilution and spread plate on Agar (Tryptic soy, Nutrient, m-FC, McCartney) for bacteria. • Spread plate on Agar (Middlebrook 7H10/7h11 and Lowenstein-Jensen Medium) for *Mycobacterium.* • Spread plate on Sabouraud and Potato Dextrose agar for Fungi. • Plaque assay for viruses.	Resuspending the samples in saline solution (IX Phosphate buffer solution) and conduct as described above.	CFU/g (Bacteria and Fungi) PFU/g (Viruses)	Relative abundance (%) Phylum, Genera, Species

Sample	Sampling	Lab analysis		Results	
		Culture based	Molecular	Culture based	Molecular bases
Surface swabs: Workspace (surface and underground) Social/Clean space Bathroom	Aseptically, using Sterile swabs. Cooler box (≤ 4°C), delivery to the lab within 24 hours.	• Use of specialised solid media as described above.	Resuspended swabs in IXPBS, then conduct as described above.	CFU/cm^2 (Bacteria and Fungi) PFU/cm^2 (Viruses)	Relative abundance (%) Phylum, Genera, Species
Air: Workspace Social/Clean space Bathroom	Exposure of solid media (agar plates) in the air for specific duration (e.g. 10 minutes).	• Incubation and colony counting of the exposed agar plates		CFU/plate/time	

The documentary assessment found limited verifiable evidence of complete HBA-specific source–task–pathway–worker HIRA, policies, SOPs, microbiological monitoring and closed-loop control verification. One reviewed 2024 mine-wide HIRA mentioned COVID-19 and a separate health-facility assessment was available, but neither demonstrated comprehensive mine-wide coverage of other biological hazards. Some underlying mine records were unavailable or awaiting consent for annexure disclosure; this must be described as an evidence-access limitation, not categorical proof of absent controls. The records considered included 26 surface swabs from one mine, separate change-house checks at another and selected drinking/service-water results. These pre-existing, non-standardised findings could indicate site hygiene issues, but they cannot identify the full spectrum of pathogens or establish worker infection. Available follow-up documentation did not consistently show assigned corrective actions, verification of interventions or communication of relevant exposure results to OMPs and affected workers.

In Table SI 3 the proposed sampling of water, dust/sediments, surface swabs and air addresses the evidence gap identified in mine records. However, the original MHSC scope covered guidance development rather than comprehensive new sampling; site-specific pathogen investigation requires separate approval, consent/permissions, biosafety review and laboratory funding.

5.0 DMPR Inspectorate and Organised Labour consultation

5.1 DMPR Mine Health and Safety Inspectorate online engagement, 8 October 2026

The online engagement identified limited dedicated HBA inspection/monitoring guidance and called for practical records to support source identification, exposure assessment, escalation and verification. Inspectorate discussion also underscored the difference between workplace-acquired infection and household/community acquisition, while recognising that workplace controls may still be necessary for person-to-person spread after an infection has been introduced from outside the mine. These points should be checked against and attributed to the formally confirmed meeting record before publication.

5.2 Organised labour workshop, 20 November 2026

Stakeholder-reported issue	Interpretation and required response
1. Limited HBA awareness, particularly sources, exposure routes and workers at risk.	✓ Mining-specific practical education for all worker categories, not solely OHS personnel; clear HIRA prompts.
2. HBA-specific HIRA not consistently integrated.	✓ Source–task–route–person assessment, including contractors, cleaners, food handlers, laundry and maintenance workers.
3. Reported seizure-like/epileptic attacks without previous known history, described across commodity groups.	✓ Verify whether cases exist or have increased; confidential clinical and epidemiological investigation; do not assume pathogen causation.
4. Aggressive baboons/monkeys and other wildlife on site.	✓ Incident records, safe avoidance and exclusion, refuse management and authorised wildlife partners.
5. Poor coordination among hygienists, health/safety officers and OMPs.	✓ Shared HBA review pathway, defined responsibilities, referral and communication, laboratory-result-to-action register.

6. Insufficient capacity building for worker representatives.	✓ Structured training, practical simulations and checks of understanding.

The WHO epilepsy fact sheet describes infectious causes of epilepsy, including meningitis, encephalitis and neurocysticercosis, alongside structural, metabolic, immune, genetic and unknown causes. The stakeholder-reported seizure-like events across mining commodities therefore justify confidential clinical validation and consideration of multiple possible causes, including heat stress, toxicants and metabolic disorders; they cannot be assigned to mine HBAs without evidence (WHO, Epilepsy).

5.3 Scientific interpretation of unexplained seizure-like events

WHO identifies structural, genetic, infectious, metabolic, immune and unknown causes of epilepsy; brain infections such as meningitis, encephalitis and neurocysticercosis can cause seizures (WHO, Epilepsy fact sheet). South African primary healthcare clinical guidance additionally requires investigation of hypoglycaemia, electrolyte disturbance, intoxication/poisoning, trauma, vascular and other neurological conditions. A seizure-like event is not automatically epilepsy; nor does a clustering concern establish an occupational biological cause. Project CoE 220802 did not collect verified neurological diagnoses, incidence rates, organism data or exposure-linked case histories.

Recommended next steps are urgent clinical referral for any new seizure event; confidential verification of reported cases, first-onset status and denominators; time–place–occupation analysis; review of heat stress, medical, toxicological and infectious causes; and focused environmental investigation only where a credible pathway emerges. No claim should be made that baboons, rodents, dust or unknown HBAs caused the reported events.

5.4 Wildlife-associated issues and non-work sources

The workshop reports supported inclusion of animal activity in HIRA, particularly at surface mine infrastructure, waste/food stores and shared water sources. A wildlife management response should include physical safety measures, waste and food control, avoidance of animal feeding and bites, escalation of injuries to OMPs and veterinary/conservation consultation. At the same time, cross-boundary risks must be identified: residential water, commuting, household rodents, community sanitation and recreational exposures can introduce illness; the workplace may still require prevention where further transmission is possible.

6.0 Integrated study limitations and evidence gaps

6.1 Overview and interpretation

The limitations resulted from the commissioned research design, access to mine records, availability of microbiology, the size and coverage of the descriptive survey and the nature of stakeholder evidence. They define what the study could—and could not—conclude. The limitations arose from the scope and design of the commissioned study, incomplete access to mine records, limited microbiological data, the size and coverage of the descriptive survey, and the nature of the stakeholder evidence. Within these limits, the study documented gaps in HBA identification, monitoring and management at the participating mines. These findings can inform the development of the guideline.

Given these limitations, the **possible sources of HBAs, potential exposure pathways and associated health effects** presented in this report were drawn primarily from the reviewed literature and relevant studies. Where findings converged, observations at the participating mines, participants' self-reported experiences and perceptions, and evidence from stakeholder consultations corroborated the **local relevance of the potential sources and exposure scenarios** described in the literature. This convergence supports their inclusion in the guideline as priorities for risk assessment.

The findings cannot be generalised statistically to the South African mining industry. The available data do not establish which specific pathogens were present across the participating mines or support estimates of pathogen prevalence or infection rates. The study did not systematically measure individual HBA exposure or link exposure data to clinically confirmed health outcomes. It therefore cannot establish whether HBA exposure was associated with, or caused, reported symptoms or illnesses at the participating mines.

6.2 Scope of the official MHSC TOR: no comprehensive primary pathogen testing

The original MHSC call required a literature review, identification of gaps and practical recommendations, development of guidance and implementation tools, a stakeholder workshop and final reporting. It did not specify an adequately funded multi-site programme to collect environmental samples and isolate, identify or quantify microbial species. Its request to determine prevalent biological hazards therefore could not be fully answered by this guidance-oriented design. Potential organisms drawn from foreign or earlier mining studies are not confirmed findings for the six participating South African mines. Proposed laboratory methods presented in the original framework and Tables SI 2–4 are proposals or evidence from cited studies, not laboratory work completed under this TOR. An MHSC/SIMRAC scope extension or separately commissioned project is necessary before systematic primary testing.

6.3 Incomplete HBA-specific HIRA, policy and SOP evidence

Mine inspection and documentary review did not consistently yield accessible, complete HBA-specific hazard registers, source–task–route assessments, written policies, SOPs, environmental monitoring plans or implementation records. The presence of some generic HIRA and a COVID-19 entry demonstrates that biological agents were not universally absent from every record; however, the available documents did not establish complete coverage. Missing records, documents withheld pending permission and ineffective control systems must be differentiated. Lack of documentation limits verification of who was assessed, the activities and shifts covered, how exposure risk was rated and how controls were monitored. The guideline should establish minimum documented evidence and worker access to relevant procedures.

6.4 Insufficient and non-standardised environmental and laboratory evidence

The study reviewed limited existing surface-swab, change-house and water-quality records, including 26 swabs from one mine, but did not sample all relevant environments using a common study protocol. Available tests were unevenly distributed, sometimes limited to indicator organisms, and did not comprehensively characterise pathogenic bacteria, fungi, viruses or parasites. An indicator count is not a diagnosis; a negative test for one organism does not establish absence of all pathogens. Consequently, no valid mine-to-mine pathogen prevalence comparison or comprehensive exposure map could be derived. Dust-suppression water, sumps, ventilation air,

sediments, contaminated PPE, food areas, medical facilities and animal contamination were not uniformly sampled.

6.5 Weak linkage between test results, interventions and occupational medicine

Where relevant laboratory results were available, supporting records did not consistently demonstrate a complete route from sample collection and competent interpretation to risk reassessment, OMP notification, corrective measures, employee consultation, follow-up testing and verified closure. A microbiology result cannot prevent disease unless there is a documented decision, responsible person and control verification process. This limitation is particularly important for water systems, sanitation, laundering and potentially exposed workers. It supports a mandatory multidisciplinary laboratory-results review and action register in the final guideline.

6.6 Under-characterisation of non-production and contract worker groups

The study included mineworkers from different occupational and organisational categories, including OHS personnel, but did not measure exposures for each task or occupation. Laundry sorters and handlers of soiled PPE, change-house cleaners, plumbers, food handlers, canteen staff, clinical and waste personnel, maintenance workers and contractors may be exposed through tasks not captured in general production HIRA. Laundry conditions were not evaluated by pathogen-specific pre/post-wash testing or formal documentation of wash time, water temperature, disinfectant concentration and textile compatibility. Without identification of relevant organisms, mines cannot claim agent-specific inactivation, though validated generic hygienic laundering procedures remain appropriate. Future studies should evaluate all affected shifts and outsourced workers.

6.7 Rodent and primate exposure: no animal/pathogen surveillance

The literature and organised labour identified rodents, baboons and monkeys as potential occupational concerns, especially where faeces, urine, contaminated water, waste, food or direct bites and scratches are involved. No rodent trapping, species verification, veterinary investigation or targeted pathogen identification was completed under the approved situational protocol. Animal presence does not demonstrate infection or worker transmission. Evidence concerning individual organisms also varies by animal species and geography. Any follow-on capture or biological testing needs a defined scientific purpose, veterinary and animal-ethics approval, biosafety plans and competent conservation authority permissions. Immediate wildlife safety and food/waste controls do not depend on laboratory confirmation.

6.8 Worker-reported symptoms and seizure-like events lack clinical attribution

The descriptive survey used self-reported symptoms and did not constitute medically verified disease surveillance. Organised labour expressed concern about apparently increasing seizure-like events across commodities, but the project did not validate case records, denominators, diagnoses, temporal patterns or alternative causes. Some infections (such as meningitis, encephalitis or neurocysticercosis) can cause seizures; so can heat stress, metabolic disturbances, chemical exposures and other neurological conditions. Accordingly, the study cannot conclude that seizures increased, that they were epilepsy or that an HBA caused them. Prompt clinical management, confidential case verification and multidisciplinary investigation should be prioritised before occupational causal attribution.

6.9 Occupational and non-occupational source attribution

Infections may originate in households, community sanitation, public transport, recreational water, food sources and healthcare settings, or within the mine. The study did not conduct comparative community sampling or linked epidemiological investigations to distinguish introduction of pathogens from subsequent workplace transmission. The DMPR discussion underscored this attribution challenge. Regardless of where an infection originates, employers should assess risks of onward occupational exposure where work conditions make transmission plausible; classification of source does not replace prevention.

6.10 Sample size, representativeness and survey-data quality

The situational analysis covered six selected mines and included 36 survey respondents. Site selection was influenced by access, and some occupational and commodity subgroups had few respondents. These limitations restrict comparisons between groups and prevent statistical generalisation to the South African mining industry (SAMI). Participation across employee, management and occupational health and safety roles broadened the range of perspectives captured. This descriptive approach was aligned with the situational analysis specified in the project terms of reference.

Participants' self-reports and the available mine records helped identify **potential HBA sources, perceived exposure routes and gaps in current risk-management practices**. However, the study did not systematically measure individual exposure or link verified exposure data to clinically confirmed health outcomes. As a result, the findings **cannot establish whether HBA exposure was associated with, or caused, any reported symptoms or illnesses at the participating mines**. The findings can inform the draft guideline and help prioritise questions for further investigation.

6.11 Literature transferability and limitations of quantitative microbial risk estimation

The literature review included relevant South African evidence on tuberculosis and NTM/MOTT, but many studies of waterborne and airborne microorganisms were conducted internationally. Differences in geology, mine design, water quality, work practices, climate and laboratory methods limit direct transfer to the champion mines. The four-stage framework and its $D=C\times N$ expression are useful conceptual prompts but cannot independently calculate infection probability: an adequate quantitative microbial risk assessment requires actual organism-specific measurements, appropriate dose and route, exposure frequency and a validated dose-response relationship. The unedited framework source tables are retained for provenance; they are not a substitute for clinical/taxonomic verification.

6.12 Ethics, site permissions and governance constraints

Category 1 very-low-risk approval supported the descriptive survey and situational analysis. It did not itself authorise invasive clinical specimen collection, capture and sampling of wild animals, or a new primary microbiology programme. Additional sampling may require ethics/biosafety review, site consent, laboratory agreements, data-protection measures and wildlife/animal-welfare authorisations. The availability of some mine reports as annexures also remained dependent on

written disclosure permissions. These constraints should be described as governance requirements rather than treated as negative results.

6.13 Mine-composition and administrative reconciliation

The initial project plan specified two gold, two platinum, one coal and one underground base-metal operation. Subsequent study records describe a diamond mine instead of the base-metal operation. The substitution may be appropriate, but the rationale, date and MHSC approval require documentary reconciliation. Likewise, actual milestone and consultation dates should be checked against the final project record. These administrative matters do not automatically invalidate results but affect fidelity to the approved research plan.

6.14 Integrated conclusion and implications for the recommendations

Overall, the project established a useful descriptive baseline and highlighted important deficits in systems for identifying and responding to biological hazards. It did not establish sector-wide pathogen prevalence, confirm actual workplace pathogen reservoirs or demonstrate causation of worker illnesses. The strongest response is two-track: immediately strengthen HBA HIRA, worker training, basic water and hygiene controls, multidisciplinary roles and incident follow-up, while commissioning additional risk-based environmental, laboratory and occupational health research under a separate approved scope. Section 7 should name responsible actors and verification evidence for each priority intervention.

7.0 Prioritised high-level actionable recommendations

The actions below respond directly to the limitations in Section 6: they separate immediate workplace protection from a new, separately authorised environmental and pathogen-identification programme. Priority should be given to accountable roles, measurable outputs and feedback to workers and occupational medical practitioners. **Table 7.1** summarises the proposed action areas, while the following narrative identifies candidate sampling settings.

Table 7.1 Priority response to study limitations (proposed implementation matrix)

Evidence gap/priority	Accountable lead(s)	Actionable deliverable
TOR excludes primary microbiology	MHSC/SIMRAC & research team	Approve additional funded protocol, site permissions, competence and ethics/biosafety review.
HBA HIRA and SOP evidence gap	Mine manager + occupational hygienist + worker representatives	Site source–task–route HBA register, signed SOPs and documented periodic review.
No comprehensive pathogen distribution	Occupational hygiene + competent laboratory	Risk-triggered sampling of water, aerosols, dust, PPE and selected surfaces with action thresholds.
Unverified laundry cleaning efficacy	Laundry supervisor + hygienist + OMP	Document contaminated PPE handling, detergent concentration, wash

Evidence gap/priority	Accountable lead(s)	Actionable deliverable
		temperature/time, post-clean checks.
Wildlife/rodent hazards	Mine environmental management + qualified wildlife/veterinary authority	Immediate waste/no-feeding/encounter controls; authorised targeted animal sampling if justified.
Food handling and medical service risks	Canteen manager + infection-prevention team + OMP	Food safety, hand hygiene, sharps/waste controls, targeted surveillance and incident reporting.
Seizure-like concerns unverified	OMP + clinical specialists + OHS	Confidential case verification, medical assessment, exposure review; no unsupported HBA attribution.
Weak laboratory-to-action loop	Hygienist + OMP + safety officer	Joint results interpretation, control owner, due date and repeat verification.
Limited training and worker feedback	Mine OHS team + organised labour	Practical induction/refresher training, feedback register, competency checks.
Priority	**Proposed action and accountable functions**	**Evidence of implementation**
1. HBA governance and HIRA	Mine manager appoints HBA coordinator; hygienist, OMP, occupational health, safety and worker reps review source–route–task risks	HBA registers and approved task-based risk assessments
2. Funded pathogen mapping	Seek MHSC/SIMRAC scope amendment or follow-on project; qualified laboratory and ethics/site approvals; focus on credible high-risk settings	Approved sampling and laboratory protocol with quality assurance and funding
3. Water and dust suppression	Assess source/treated water, storage and aerosolising equipment; target Legionella/NTM where justified	Water safety plans and documented risk-based testing decisions
4. Rodents and wildlife	Implement integrated pest/wildlife control; expert-led permitted testing where risk and evidence justify it	Rodent sighting trends, safe-cleaning protocols and veterinary reports
5. PPE laundry and cleaners	Cover sorting of contaminated workwear, washable surfaces and machinery; verify detergents, dosing, temperature, cycle times and worker protection	Laundry HIRA and validation records, pre/post cleaning tests where justified
6. Canteens and clinics	Food safety audits, water hygiene, sharps and infection-prevention policies; include food handlers, cleaners and clinic personnel	Inspections, training and incident-follow-up records

Evidence gap/priority	Accountable lead(s)	Actionable deliverable
7. Clinical signals	OMP-led confidential assessment of unexplained seizures, occupational exposures and possible clusters	Verified case assessment, referral and surveillance review
8. Closed-loop laboratory action	Require hygienist interpretation, OMP referral where indicated, correction and repeat assurance	Results-to-action register; documented closure and worker feedback
9. Worker capacity	Training for mineworkers of all levels, organised labour, contractors and OHS personnel	Competency checks and coverage by role/shift
2. Formal Recognition and Adoption of the Comprehensive HBA Guideline	Given that the primary output of MHSC Project CoE 220802 was the development of a comprehensive guidance document for identifying, monitoring and managing HBAs in the SAMI, it is recommended that **MHSC facilitate its consideration through the Mining Occupational Health Advisory Committee (MOHAC) and the Mining Regulation Advisory Committee (MRAC)**, with a view to its formal recognition and adoption as a national HBA guideline for the South African Mining Industry, subject to the applicable approval processes.	Formal consideration and potential adoption of a nationally recognised, standardised HBA guideline to strengthen the identification, assessment, monitoring and management of biological hazards across the SAMI.
10. Inspectorate implementation	Develop minimum evidence checklists and practical inspection guidance aligned with the Mine Health and Safety Act (MHSA) and the proposed HBA guideline.	Consistent regulatory oversight, standardised inspection requirements and auditable implementation indicators.

The recommended separately funded sampling phase should prioritise exposure-based decisions, not indiscriminate pathogen screening. Candidate matrices include sump, process and dust-suppression water; aerosol-generating spray equipment; selected mine dust or ventilation bioaerosols; showers and sanitary facilities; laundry sorting areas, contaminated workwear, washer seals and wastewater; canteen water and food-contact surfaces; health facilities and waste-handling settings; and sites of actual rodent or wildlife contamination. Laundry assessments should document the type and quantity of soiled PPE, worker handling tasks, clean/dirty separation, detergent/disinfectant identity and concentration, time, wash temperature, and post-wash verification. The laboratory and OMP should agree in advance what findings would change HIRA, controls, health surveillance and communication. Any animal trapping or sampling requires veterinary/conservation oversight and applicable permissions.

8.0 Milestone 4: Comprehensive Guidance Document and implementation toolkit

Milestone 4 translated the documented gaps, the technical review and stakeholder evidence into a comprehensive, practical HBA guideline for the SAMI *(Annexure 1)*. The guideline should cover legal basis and application; source and pathogen identification; worker/task exposure mapping; HBA-specific HIRA; a decision-tree for when environmental sampling and competent laboratory analysis

are necessary; interpretation of culture, molecular and indicator results; evidence-based hierarchy of controls; safe water use, sanitation and laundering; wildlife and rodent risk management; occupational health surveillance and investigation; non-occupational versus workplace transmission; and the responsibilities of management, occupational hygienists, mine safety officers, occupational health practitioners, OMPs and organised labour. The guidance must make clear that its proposed pathogen-specific recommendations remain provisional until suitable site-level laboratory evidence is generated.

The supporting implementation strategy should phase in site HBA screening, task-specific HIRA, SOP adoption, workforce education, monitoring decision trees, laboratory QA and chain-of-custody controls, clinical referral, corrective-action tracking, pilot audits and a feedback mechanism across mining commodities. Proposed toolkit records include source inventory, worker/task mapping, HBA risk register, sampling and result interpretation forms, standard operating procedures, worker referral and reporting forms, training materials, corrective-action register, audit checklist and management review dashboard. These are guideline implementation tools and not evidence that a specific pathogen was found in the six mines.

9.0 Conclusion

The integrated findings identified clear shortcomings in demonstrated HBA awareness, documented task-specific HIRA, SOP accessibility, monitoring, results-to-intervention procedures, staff coordination and practical training. The scientific literature provides a defensible inventory of potential mine-related agents, reservoirs and health effects, while the survey and consultations identify where risk-management systems require improvement. However, the TOR did not commission systematic primary pathogen identification; the small survey and incomplete mine-specific records cannot establish the prevalence of pathogens, definitively attribute reported seizures or other disease to occupational exposure, or validate species-specific controls. The most important outcome is therefore a practical guideline and toolkit accompanied by a strong recommendation for a separate, appropriately approved, adequately funded programme of environmental microbiology, occupational hygiene and clinically linked follow-up. The programme should report its findings to mine OHS teams, OMPs, worker representatives and regulators, and verify that corrective measures have been completed.

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