Guidance on Worker Exposure to Hazardous Substances in the Extractives Sector

April 2021

Introduction

Healthy workers are essential to the success of mining, quarrying and tunnelling companies. Workforce protection should be built on:

- ensuring that a workplace culture of safety & health is embraced by all;
- recognising that occupational illnesses are preventable;
- ensuring that occurrences of any occupational disease do not reoccur; and
- promoting the setting and implementation of a consistent set of standards to prevent occupational illness or injury.

Hazards, such as dust and toxic chemicals in the workplace, need to be identified, and the risks associated with them from any possible exposure needs to be adequately controlled.

The pro-active control of hazards is a well-recognised feature of modern extractive operations and this document gives guidance on good practice management of some of the significant worker exposure hazards in the sector.

WorkSafe NZ publish Workplace Exposure Standards (WES) and Biological Exposure Indices (BEI) annually. It's important to note that the WES and BEIs in WorkSafe's special guide1 are guidance values - not prescribed standards. The values proposed are also considered to be health-based WES which means they are based on minimising health risk and don't take into consideration practicability of achieving or measuring the value.

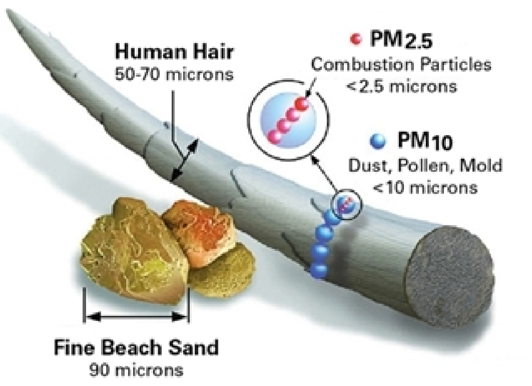
This guide has been prepared using best practice WES and BEI from around the world and where practicable WorkSafe WES and BEI targets should be applied, as generally they will give greater levels of worker protection.

[1] WorkSafe special guide on WES and BEI - https://www.worksafe.govt.nz/topic-and-industry/monitoring/exposure-standards-and-biological-exposure-indices

Respirable Crystalline Silica (RCS)

Silica dust is created when materials containing silica are cut, crushed, ground, drilled or otherwise disturbed.

Exposure to very fine silica dust – Respirable Crystalline Silica (RCS) – is dangerous and can cause serious lung disease. This very fine dust, usually less than 2.5 micron in size (PM2.5), can be breathed in and is rarely visible to the naked eye.



To ensure worker health and safety, it is important to eliminate RCS from a workplace, or minimise worker exposure to it.

Not all quarries and not all processes will lead to exposure to RCS. The level of risk to workers will differ depending on the concentration of RCS in the rock source, processing methods, how the site is designed and operated, and the effectiveness of controls deployed at the site.

The Australian Institute of Occupational Hygienists (AIOH) recommend that sites apply an 8-hour time-weighted average (TWA) Worker Exposure Standard (WES) of 0.1 mg/m3 for RCS, as long as worker exposures are at all times limited to as low as reasonably practicable below this limit. The principal reason for this position is that current and historical evidence, indicates that if enforced, it appears to be protective of the incidence of silicosis, and it is consistent with published threshold levels of effect. It is also consistent with research in other countries and is a measurable level that is conducive to encouraging industry to strive to meet it.

American research has determined that the threshold for turning on possible disease processes appears to be above 0.1 mg/m3 and may be as high as 0.4 mg/m3. Consequently, if silica exposures are maintained at or below 0.1 mg/m3, the risk of developing silicosis or other fibrotic lung pathologies should be negligible or non-existent[2].

Recommended WES levels for RCS are:

- **Action point for Worker Exposure – 0.05 mg/m3**
  - Action needs to be taken for any exposure over 0.5 mg/m3
- **Maximum Worker Exposure – 0.1 mg/m3**

Exposure monitoring

It is important that you conduct exposure monitoring to identify worker exposure and determine the level and length of exposure. Exposure monitoring must be carried out, or supervised by, a competent person (such as an Occupational Hygienist) who has the knowledge, skills and experience in the appropriate techniques and procedures, including interpretation of results. Exposure monitoring must be conducted in accordance with AS 2985. Multiple samples allow better understanding of exposure. Professional associations are a useful source for competent persons (e.g., HASANZ, NZOHS).

[2] Cox, L.A. Jr., Risk Analysis Implications of Dose Response Thresholds for NLRP3 Inflammasome-Mediated Diseases: Respirable Crystalline Silica and Lung Cancer as an Example. Dose-Response: An International Journal, April-June 2019:1-21. Available on-line at https://journals.sagepub.com/doi/10.1177/1559325819836900.)

Controls for managing exposure to RCS

The MinEx booklet '*Managing worker exposure to dust in mines and quarries*'[3] outlines controls for managing worker exposure to RCS.

Effective controls include:

- Dust suppression using water, fog and other suppression agents
- Enclosed and adequately sealed cabins and offices
- Dry dust extraction
- Separation of workers from dust exposure

Health monitoring

PCBUs are required to provide health monitoring for all workers who may be exposed to RCS dust. You should engage an occupational health practitioner from one of the following to perform health monitoring:

- New Zealand Occupational Health Nurses' Association (http://www.nzohna.org.nz, from the HASANZ Register);
- Australian and New Zealand Society of Occupational Medicine (https://anzsom.org.nz) to perform health monitoring;
- A respiratory physician; or
- A GP who has completed a postgraduate course in spirometry.

Monitoring should include:

- Collection of workers' demographic medical and occupational histories
- Records of workers' exposure
- Respiratory questionnaire
- Respiratory function tests
- In some cases, chest x-ray or other radiological procedure

You must have workers' consent before you monitor their health. Ask your workers for their views when making decisions about health monitoring.

[3] Managing worker exposure to dust in mines and quarries. 2019 https://www.minex.org.nz/assets/Uploads/Managing-worker-exposure-to-dust-in-mines-and-quarriesweb.pdf

Diesel emissions (oxides of nitrogen)

The concentration of NO, NO_2 and CO in underground mines and tunnels arises predominately from the use of explosives and from vehicles and mobile machines equipped with diesel engines. In the underground mining sector, the use of diesel engines, in the short to medium term, will remain necessary. During the last few decades of diesel engine operation, a significant amount of research and improvements were made in the area of work environment and effective diesel engine operation, namely:

- Development and use of modern low emission engines
- Improved fuel quality
- Improved exhaust control technology
- Improved ventilation design and control

Engine exhaust emissions consisting of NO and NO_2 are generally referred to as nitrogen oxides (NOx) and Diesel Particulate Matter (DPM), represent the most difficult diesel engine emissions to control.[4]

Worker Exposure Standards (WES) are health-based limits below which adverse health effects are unlikely to occur for any given substance after short-term or daily exposure over a working lifetime. They are established on the basis of an independent evidence-based scientific assessment of scientific information and take into account the availability of measurement techniques. (European Commission Directive.)

Current recommendations:

- **Nitrogen monoxide WES: 8h – TWA: 2 ppm**
- **Nitrogen dioxide WES: 8h – TWA: 0.5 ppm, 15 min – STEL: 1 ppm**

The exposure of workers will mainly occur in active mining and extraction areas due to the machinery and explosives used. Therefore, there is potential for higher worker exposure particularly after blasting operations, in the vicinity of the mucking & haulage machines, and in areas with return ventilation which contain exhaust & explosive fumes.

Exposure monitoring

It is important that you conduct exposure monitoring to identify worker exposure and determine the level and length of exposure. Exposure monitoring must be carried out, or supervised by, a competent person who has the knowledge, skills and experience in the appropriate techniques and procedures, including interpretation of results.[5] Worker exposure monitoring requires real time data and therefore hand monitors should be used to measure the shift TWA. The accuracy of these monitors is plus or minus 0.5ppm, and as such may be an unreliable measure for exposures below 1ppm.

Controls for managing exposure to NOx and DPM

Mining and tunnelling operators must ensure that the ventilation and transport system does not allow workers to be exposed to diesel emissions that could cause injury or ill-health. If one or more diesel engines are operating in a ventilating current, the volume of air must be at least the larger of:

- 0.05 cubic metres per second for each kilowatt of the maximum combined output capability of the engines;
- 3.5 cubic metres per second.

---

[4] Best practices in reducing NOx and CO gases in the extractives industry. http://www.euromines.org/files/euromines_brochure_best-practices_final.pdf

[5] Approved Code of Practice- Air Quality in Extractives https://www.worksafe.govt.nz/topic-and-industry/extractives/guidance-position-statements/air-quality-extractives-industry/

Duty holders need to use diesel engines that emit the lowest emission so far as is reasonably practicable. All engines need to be regularly maintained according to the manufacturer's specifications.

Explosives used in today's mining industry have been steadily developed over the years and now emit much less NO and NO_2 compared to previous generations of explosives. The significant reduction of exposure to nitrogen oxides resulting from blasting is naturally associated with higher emissions of carbon monoxide, due to the chemistry of the explosives. Carbon monoxide (CO) is also released by the detonation of explosives. CO is not a problem after large surface blasts because it quickly dissipates in the atmosphere to safe levels. CO dangers are more of a problem for construction, trench, tunnelling and underground blasting. If a mine worker enters a blast site too soon after a blast, the CO emanating from the muckpile poses a serious risk to the worker.

There may be opportunities to improve ventilation in working areas by efficient removal of blasting fumes using a combination of regulated airflow, crosscut optimising, fan performance and brattice walls.

Health monitoring

No formal health surveillance is required by PCBUs of those exposed to oxides of nitrogen, however, if employees are concerned about the short or long-term health effects of exposure, they should discuss the problem with their supervisor. If management notices that employees are suffering irritancy effects following exposure to NOx or DPM, it may indicate that the controls have failed, and prompt action is required.[6]

Arsenic (inorganic)

Arsenic is a widely distributed element found as part of the natural environment. It occurs in trace quantities in rock, soil, water and air. It is a common contaminant in most mineral ores.

Work-related exposure to inorganic arsenic, especially in mining, copper smelting and pesticide work, has been associated with an increased risk of cancer. Basal cell carcinomas, squamous cell carcinomas (Bowen's disease) of the skin and lung carcinomas have been associated with chronic arsenic exposure.

No threshold has been established for carcinogenicity and a No-Observed-Adverse-Effect-Level (NOAEL) has not been identified (Safe Work Australia, 2019). It is generally accepted that the Limit of Detection (LOD) for an 8-hour shift could be as low as 0.00008mg/m3, however in practice the LOD is more likely to be between 0.0003 – 0.0005 mg/m3 for a 12-hour shift. Safe Work Australia states that there is uncertainty regarding the quantification of 0.01mg/m3, however as a limit for worker exposure, evidence suggests that a **WES of 0.01mg/m3** is appropriate.

Biological exposure standard for inorganic arsenic

High biological arsenic levels are not necessarily occupationally derived. Seafood may contain small amounts of dimethyl arsenic acid (DMAv) which may contribute to a worker's total urinary inorganic arsenic levels. Smokers also may have higher background total urinary inorganic arsenic levels.

Evidence suggests that arsenic and its metabolites may accumulate in the body over the work week and therefore if there is a chance of worker exposure to arsenic, health monitoring for arsenic should be considered before the worker starts work so that changes to the worker's health can be detected. The following is the recommended Biological Exposure Standard:[7]

[6] Control of diesel engine exhaust emissions in the workplace. https://www.hse.gov.uk/pUbns/priced/hsg187.pdf
[7] Safe Work Australia Guide for Arsenic https://www.safeworkaustralia.gov.au/search/site?search=arsenic

- **Total urinary inorganic arsenic (MMAv + DMAv + As(III) + As(V)): 35 µg/L**

Health monitoring

In order to protect workers, sites should look at both the individual increase of urinary arsenic during the work week/schedule, as well as the significance of urinary speciation.

Given the biological half-life of inorganic arsenic is 1-3 days, any occupational exposure will have been excreted from the body at the start of the next working week. By measuring high-risk workers at the start and end of their working week, sites will be able to determine the occupational contribution of biological arsenic levels to the best of their abilities.

Health monitoring should be conducted by a registered medical practitioner and should include a urine test, as well as skin and neurological checks. Where the results of a medical examination indicate the worker is displaying

symptoms of exposure to arsenic or where results of biological monitoring indicate exposure that may cause adverse health effects, the registered medical practitioner should consider recommending the worker be removed from arsenic-related work.

Workers with health conditions or continuing symptoms due to arsenic exposure should be advised to seek continuing medical examinations as organised by the registered medical practitioner supervising the health monitoring programme.

Chromium VI Compounds

Chromium VI Compounds may be present at mining sites, liberated as a form of chromium during welding processes and/or present in spent coal or fly ash. The chromium may be existing in the substrate being welded or may be within the welding rod/wire (consumable). Chromium VI compounds are locally and systemically toxic to humans, causing skin, eye and respiratory tract irritation, and occupations involving the use of chromium VI compounds are associated with increased risks of lung cancer; and locally and systemically toxic to laboratory species causing respiratory tract irritation and localised tumours [bronchial carcinoma; sarcoma].

The chromium present in many materials used every day, such as food, detergents, leather and paints, is capable of eliciting the allergic response. Reports of skin lesions and eczema lasting years are not uncommon, leading to a significant amount of work time lost and changes of occupation. Changes in occupation did not necessarily improve skin conditions and often resulted in negative social and economic impacts. As there is no specific treatment for chromium induced skin issues, prevention of sensitisation is recommended as the best solution.

Worker exposure monitoring

It is important that you conduct exposure monitoring to identify worker exposure and determine the level and length of exposure. Exposure monitoring must be carried out, or supervised by, a competent person who has the knowledge, skills and experience in the appropriate techniques and procedures, including interpretation of results.

The common test method used is the NIOSH Method 7600 which has not been updated or reviewed since 1994. The accuracy range is 0.001 mg/m3 to 5 mg/m3 for a 200-L air sample.

The current WES in New Zealand for chromium VI is 0.00002 mg/m3 however the existing analytical method for determining chromium VI is not adequate for this level.

Good practice suggests that a worker should not be exposed to an airborne concentration of chromium VI in excess of:

- **0.05 mg/m3 calculated as an 8-hour (TWA)**

Sites are recommended to take additional action if monitoring identifies a concentration of airborne chromium VI of 0.025 mg/m of air (2.5 µg/m3) calculated as an 8-hour time-weighted average.

Controls for managing exposure to chromium VI

Sites should implement a range of controls to mitigate exposures to chromium VI as far as reasonably practicable. These controls should include but not be limited to:

- Trained and competent workers.
- Designated hot works/welding areas.
- Review of welding consumables and where possible chromium free alternatives should be sourced.
- Use of powered air purifying respirators (PAPRs) during welding activities, to minimise welding fume exposures.
- Local exhaust ventilation (LEV) installations.
- Mobile extraction units.
- A range of powered air purifying respirators (PAPRs) for use including training powered air purifying respirators (PAPRs) pertaining to their correct use and maintenance.

Health monitoring

A physical examination and urinary testing by a registered health professional may be required if the results of air monitoring indicate frequent or potentially high exposure (levels above 0.025 mg/m3). Chromium compounds are readily absorbed through the skin and air monitoring results may not be a true indication of exposure.

Where a medical examination indicates the worker is displaying symptoms of exposure to chromium VI or where results of biological monitoring indicate exposure that may cause adverse health effects (that is, a urinary chromium VI level greater than 10 µmol/mol creatinine), the registered medical practitioner should consider recommending the worker be removed from chromium-related work.

As smoking, diet and previous work history may significantly contribute to urinary chromium levels, it may be difficult to attribute the source of chromium exposure in certain workers solely to workplace exposure. In these circumstances, the above recommendations should still be made.

Sulphur Dioxide

Sulphur dioxide (SO_2) is a toxic, colourless gas or vapour with the characteristics of a strong, irritating, and foul odour. It is non-flammable and reacts easily with other substances to form harmful compounds, such as sulfuric acid, sulphurous acid and sulphate particles.

Sulphur dioxide is a by-product from activities related with the burning of fossil fuels (coal, oil) such as at power plants or from copper smelting. In nature, it can be released to the air, for example, from volcanic eruptions.

Brief contact to high levels of sulphur dioxide can be life threatening. Exposure to 100 parts of sulphur dioxide per million parts of air (ppm) is considered immediately dangerous to life. An incident of healthy non-smoking miners who breathed sulphur dioxide, released as a result of an explosion in an underground copper mine, developed burning of the nose and throat, breathing difficulties, and severe airway obstructions. If contact occurs to the eyes from liquid sulphur dioxide, (from, for example an industrial accident) can cause severe burns, resulting in vision loss. On the skin it produces burns. Other health effects include headache, general discomfort and anxiety. Those with impaired heart or lung function and asthmatics are at increased risk.

Prolonged contact to low levels of sulphur dioxide can also affect your health. Repeated or continued exposure to moderate concentrations can cause inflammation of the respiratory tract, wheezing and lung damage. Lung function changes have been observed in some workers exposed to 0.4–3.0 ppm sulphur dioxide for 20 years or more. However, these workers were also exposed to other chemicals, making it difficult to attribute their health effects to sulphur dioxide exposure alone. Additionally, exercising asthmatics are sensitive to the respiratory effects of low concentrations (0.25 ppm) of sulphur dioxide.

Good practice suggests that a worker should not be exposed to an airborne concentration of sulphur dioxide in excess of:

- **Concentration of 2ppm or 5.2 mg/m3 (TWA) averaged over a 40-hour work week;**
- **Short-term Exposure Limit (STEL) of 5ppm or 13 mg/m3 time weighted avg. over 15 mins.**[8]

Worker exposure monitoring

It is important that you conduct exposure monitoring to identify worker exposure and determine the level and length of exposure. Exposure monitoring must be carried out, or supervised by, a competent person who has the knowledge, skills and experience in the appropriate techniques and procedures, including interpretation of results.

Workers should be removed from any area where SO_2 levels exceed the STEL above until the levels of exposure are reduced below targeted levels.

If a worker has experienced inhalation of SO_2 at levels above the STEL for 15 mins or more, medical observation is recommended for 24 to 48 hours after exposure, as pulmonary edema may be delayed.

Health monitoring

There are no studies to date that clearly indicate any carcinogenic effects in humans or animals as a result of SO_2 exposure. Studies have investigated workers in the copper smelting and pulp and paper industries, but the results were inconclusive since the workers were also exposed to arsenic and other chemicals.

Respiratory health surveillance as listed under the section on Respirable Crystalline Silica is appropriate for workers exposed to elevated levels of SO_2.

[8] SafeWork Australia Worker Exposure limits