

Guideline



# Risk-based health surveillance and biological monitoring



Department of Consumer  
and Employment Protection  
Government of Western Australia

Resources Safety



 **MIAC**



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## GUIDELINES

A guideline is an explanatory document that provides more information on the requirements of legislation, details good practice, and may explain means of compliance with standards prescribed in the legislation. The government, unions or employer groups may issue guidance material.

Compliance with guidelines is not mandatory but they could have legal standing if it were demonstrated that the guideline is the industry norm.

## Foreword

This guideline is issued by Resources Safety under the *Mines Safety and Inspection Act 1994*, and has been endorsed by the Mining Industry Advisory Committee.

### The Act

The *Mines Safety and Inspection Act 1994* (the Act) sets objectives to promote and improve occupational safety and health standards within the minerals industry.

The Act sets out broad duties, and is supported by regulations, together with codes of practice and guidelines.

### Regulations

The Mines Safety and Inspection Regulations 1995 (the regulations) provide more specific requirements for a range of activities. Like the Act. The regulations are enforceable and breaches may result in prosecution, fines, or directions to cease operations and undertake remedial action.

### Application

The provisions of this guideline apply to all mines as defined in section 4(1) of the Act.

## WHO SHOULD USE THIS GUIDELINE?

Everyone who has a duty to prevent, as far as practicable, hazards on mines should use this code. This includes employers, employees, self-employed people, safety and health representatives and safety and health committees.

# 1 Introduction

Epidemiological and toxicological studies indicate that exposure to some minerals currently being mined in Western Australia, or present as significant contaminants in mined ores, can cause serious health effects such as cancer, reproductive effects, kidney or liver damage, and neurological disturbances. These health effects are in addition to the well-known effects of particulates and fibres on the respiratory system, like asbestosis, pneumoconiosis and emphysema.

This guideline will assist in meeting the requirements in the *Mines Safety and Inspection Act 1994* (the Act) and the Mines Safety and Inspection Regulations 1995 (the regulations) relating to biological monitoring and the additional health surveillance required when employees are exposed to hazardous substances other than silica and dust.

It focuses on how to measure employees' real exposures to chemicals using biological monitoring to assess whether the exposures have negatively impacted their health, and the implementation of risk-based health surveillance to address any issues that may arise following exposure to a specific chemical. Particular attention is paid to toxic metals being mined or present as significant ore contaminants in Western Australia, or used at mining operations.

The guideline differentiates risk-based health surveillance from the MineHealth health surveillance system prescribed in the regulations.

The legislative provisions that apply are listed in Appendix 1.

Appendix 2 provides a glossary of terms and abbreviations used in this guideline and applicable forms, available from the Resources Safety website.

## 2 Assessing exposure risk

Any mining or exploration company whose operations have the potential to disturb, mine, concentrate, process or handle toxic materials or use hazardous chemicals must identify, assess and monitor employees' exposures and the effects of these hazards.



The first step is to identify all hazardous chemicals in the workplace, including toxic metals already present in the ore. The next is to determine the potential and actual exposure levels for all employees who may come in contact with the hazardous chemicals.

Some selective leaching and mineral concentration processes may also concentrate undesired contaminants. Hazardous contaminants should be tested for throughout the process to identify whether employees could be exposed to elevated concentrations.

Exposure may occur through inhalation, ingestion (from contaminating food or drink) or absorption through the skin. As the most common route of occupational exposure occurs via the respiratory system, assessing the exposure risk is usually done by sampling the air within the breathing zone of the worker. Also known as *personal exposure monitoring*, this technique indicates how much of the chemical or contaminant is present in the air (airborne concentration) that could be inhaled.

The rate and amount of contaminant taken up by the body depends on factors such as:

- size and nature of the contaminant;
- atmospheric conditions;
- breathing rate of the worker;
- whether a respirator is worn;
- whether the chemical can enter the body via routes other than breathing, such as through skin or ingestion; and
- individual differences such as personal hygiene habits, age, gender and fitness level.

Actual exposures can be determined using biological monitoring. It is important to understand the meaning and limitations of biological monitoring results, as presence within the body does not necessarily correlate with occupational exposures or symptoms or damage to health (Section 4.2).

Risk-based health surveillance involves specific medical tests or health assessments that measure the degree of damage done to an employee's health, based on potential workplace exposures. As different chemicals cause specific health effects it is important to obtain specialist

advice from an occupational hygienist, occupational physician or clinical toxicologist before implementing any health surveillance program.

### 3 Legislative basis for health surveillance

The Act requires employers to establish and maintain a system for the surveillance of the health of their employees. Specific details on how to comply with this requirement are outlined in the regulations.

If a risk assessment determines there is a reasonable likelihood that employees may be exposed to hazardous substances at levels exceeding accepted values, there is a requirement for specific health monitoring to assess actual exposures and the effects of these exposures on mining employees.

The term 'health surveillance' commonly includes complementary application of biological monitoring with specific health assessments based on exposure risk. However, the regulations use this term to describe the **MineHealth health surveillance system** that specifically screens for health effects related to *exposures to noise, fibres and particulates by most mining employees*. This is differentiated in the regulations from **risk-based health surveillance**, which focuses on monitoring health effects that may follow *exposures to hazards other than noise fibres, dusts and silica* (respirable quartz).

Risk-based health surveillance, which may also involve biological monitoring, is used to monitor for possible health effects that may arise following occupational exposures at concentrations above accepted exposure standards. Such effects may include systemic poisoning, dermatitis or other specific occupational disorders or diseases like occupational asthma, white-finger and occupational cancers.

While it is the employer's responsibility to identify, assess and manage the risk of exposures to hazardous chemicals, the State Mining Engineer may direct that biological monitoring and additional health surveillance be carried out for specified employees. In addition, the State Mining Engineer may, and will from time to time,



request the results of these tests. This information must be submitted on the biological monitoring result form (Appendix 3).

Medical practitioners and approved persons also have specific regulatory responsibilities to the employee and employer. They are required to:

- notify and explain the results of biological monitoring and health surveillance to the employee; and
- notify the employer of the outcome of the assessment and advise on the need for remedial action if any is required.

For example, an elevated result may require that an employee minimises his or her exposure by doing low-risk work, and may require additional testing before returning to their substantive position. Alternatively, further medical tests may be necessary before the employee may return to their job. In some circumstances, employees may require additional dietary counselling or more specific training and supervision to ensure safe work practices are followed upon return to work. The notification of outcome of health assessment pro forma (Appendix 4) can be used as a template to notify the employer of any recommendations relating to remedial actions.

If an employer receives advice from an employee, or a person on behalf of the employee, that the employee has an occupational disease, the employer must notify the Mines Occupational Physician, as soon as practicable, by completing the notification of occupational disease form (Appendix 5). The regulations describe an occupational disease as a disease of a kind referred to in Schedule 3 of the *Workers' Compensation and Injury Management Act 1981*, or any other condition that results from exposure in a workplace to agents or substances to the extent that normal physiological mechanisms are affected and the employee's health is impaired as a consequence.

## 4 Risk-based health surveillance

### 4.1 Application to WA mining operations

Risk-based health surveillance, sometimes including biological monitoring, assesses possible health effects that

may arise if occupational exposures exceed accepted or adopted exposure standards.

The specific risk-based health surveillance is determined by the type of chemical or physical agent that an employee is exposed to at work, such as:

- ionising radiation;
- carcinogenic, mutagenic or reproductive toxins (heavy metals); and
- allergenic substances such as grain dust.

This guideline focuses on the heavy metals being mined or present as significant contaminants in minerals mined or processed by Western Australian mining operations.

If biological monitoring has been undertaken for routine exposure screening and measured biological levels reach or exceed recommended action levels, a suitable and sufficient health assessment by a competent person is indicated. Best practice also incorporates such an assessment as part of an annual health review for employees at risk of significant exposure. More detail on biological monitoring and accepted standards is provided in Chapter 6.

A competent person may be an occupational physician or clinical toxicologist with experience in assessing and diagnosing occupational diseases associated with hazardous substance exposures. Depending on the types of health effects that may be caused by the particular substance, individuals may be referred for other medical tests to assess potential biochemical or neurological effects.

Further guidance on appropriate health surveillance is found in *Guidelines for Health Surveillance* [NOHSC:7039(1995)] and *Guidance Note for the Assessment of Health Risks Arising from the Use of Hazardous Substances in the Workplace* [NOHSC:3017(1994)], available from the Australian Safety and Compensation Council (ASCC).

The notification of occupational disease form (Appendix 5) must be completed and submitted to the Mines Occupational Physician as soon as possible if a health examination indicates that an employee has contracted an occupational disease. Early detection of such health effects can prevent the development of severe or irreversible medical symptoms and disease.



## 4.2 Pre-placement assessments

Where risk assessment suggests that risk-based health surveillance is recommended for specific work, employees' baseline health and biological loading should be assessed *before* they undertake the high exposure risk work. These pre-placement tests provide a level against which future exposure is compared.

Substances with relatively long biological half-lives, such as lead and mercury, may persist in blood or urine for some time after exposure has ceased. Where employees are at risk of occupational exposure to lead or mercury, pre-placement monitoring is recommended to identify any previous exposures, irrespective of whether they were occupational or non-occupational.

Pre-placement biological monitoring tests can also be used to identify individuals who may be exposed to hazardous substances during leisure activities (e.g. lead through making fishing sinkers) and other non-occupational situations. In these instances, individual counselling is recommended to minimise both occupational and non-occupational exposures. Targeted counselling that provides information about the hazards and how to control them is recommended.

In conjunction with pre-placement biological monitoring, specific medical examinations may also be required to identify whether potential employees have an existing condition that predisposes them to further adverse health effects from the particular substance. Predisposed individuals may experience symptoms following exposure to relatively low concentrations. For example, individuals with pre-existing kidney damage, anaemia, neuropathies or reproductive problems, or who are pregnant or breast-feeding are at greater risk of adverse health effects following exposure to heavy metals at work. In these circumstances, the consulting medical practitioner may recommend that the employees be excluded from work with a high risk for heavy metal exposure. Similarly, individuals with significant pre-placement biological levels may need to be excluded from work that has a higher exposure risk unless, and until, the circumstances change and their respective biological levels decline sufficiently. A medical practitioner will need to make this judgement on a case-by-case basis.

## 5 What is biological monitoring?

Biological monitoring means testing for the presence of a hazardous substance, its metabolites (by-products) or a biochemical change in a person's biological materials (e.g. body tissue, blood, urine, breath) to determine how much chemical has entered the body following exposure. For example, lead is often measured in blood, mercury can be measured from a urine sample, cadmium exposure has been tested from hair and fingernails, and alcohol can be detected in exhaled breath.

Early detection of elevated exposures or signs of adverse health effects allows companies to proactively implement timely remedial and preventative actions that minimise further harmful exposures to personnel.

As well as measuring the presence of a chemical within the body, biological monitoring can be used to detect the biological effects of the chemical, by monitoring reversible and irreversible biochemical changes. For example, zinc protoporphyrin is produced in place of haemoglobin in red blood cells following elevated lead exposures. It can be measured in conjunction with blood lead levels to determine the degree of biochemical damage caused by lead.

Biological monitoring is commonly used as a screening tool where risk assessment indicates that some employees may be exposed to concentrations of potentially harmful chemicals. It is also useful to identify real exposures of chemicals absorbed into the body of employees who believe they may have been over-exposed to a chemical to assist in the medical treatment.

Regular screening of real exposures with the use of biological monitoring is recommended in circumstances where a chemical or contaminant:

- can cause serious health effects;
- is not adequately controlled to levels below adopted exposure standards;
- can also enter the body through skin or by ingestion; and
- where companies rely on employees to use personal protective equipment (PPE) to control exposures.

Biological monitoring is one of several effective medical tests that can be used for health surveillance of employees exposed to hazardous chemicals. Other tests that may



be used in health surveillance include spirometry (lung function), audiometry (hearing), biochemical tests (e.g. kidney or liver function), cardiac function tests (heart function), nerve conduction velocity and electromyography tests (nerve and muscle function) and neurobehavioural tests (nerve and brain function). The type of test used will depend on the occupational hazards that the employee is exposed to.

## 6 Biological monitoring methodology

### 6.1 Application to WA mining operations

In the resources industry, biological monitoring is principally used where employees are exposed to heavy metals such as arsenic, lead, mercury, vanadium, cadmium, chromium, cobalt, manganese and thallium. This list is limited to those chemicals present in Western Australia or having an acceptable test or adopted exposure standard. They occur within ore as either the primary mineral or a contaminant.

Mining employees may also be exposed during routine work procedures. For example, toxic metals, such as chromium and manganese, can be a significant constituent of some specialised welding rods.

New technologies may lead to exploitation of currently low-grade or undiscovered orebodies that also contain significant concentrations of other toxic chemicals. Alternatively, improved biological monitoring techniques or new toxicological information may mean there is a case for previously untested chemicals to be included in future biological monitoring programs. If employees are exposed to a substance that is classified as a hazardous chemical, but there is no standard or commonly used biological monitoring test, Resources Safety recommends that employers consult with an occupational hygienist or occupational physician about how best to manage exposures.

The major outcome of biological monitoring is to control exposure to levels as low as reasonably practicable (ALARP) in order to prevent work-related disease. Heavy metals can

cause serious immediate health effects (*acute* responses) when workers are exposed to very high concentrations. An example of an acute health effect from inhalation exposure is metallic fume-fever. Severe respiratory symptoms, accompanied by elevated temperatures, may occur soon after elevated exposures to welding fumes containing heavy metals. Ingestion of high concentrations of hazardous chemicals often causes violent and immediate gastrointestinal disturbances.

Exposure to lower levels of heavy metals over an extended time may also lead to severe and irreversible *chronic* health effects, commonly involving the nervous system, liver and kidneys. Some heavy metals are considered to be carcinogenic (cancer-causing).

Chronic health effects start some time after exposure and can last for an extended period. The response is dose-dependent, and is related to the individual's personal exposure, inherent susceptibility factors, metabolic rate, and work and hygiene habits.

Personal exposure monitoring to airborne contaminants and biological monitoring are complementary procedures used to:

- prevent occupational disease by identifying the potential for excessive inhalation and absorption of toxic chemicals before any significant adverse health effects occur;
- assess the risk to employees' health; and
- evaluate the effectiveness of workplace controls, such as personal protective equipment and engineering control methods.

## **6.2 What level of exposure is safe and how is it measured?**

Personal exposure monitoring measures the concentration of contaminant dusts, vapours and chemicals in the air that a worker breathes. This concentration is compared to an exposure standard to determine the likelihood that the exposure may impact upon health. Exposure standards are based on toxicological studies investigating observed health effects of the chemical at different doses in animals or in-vitro, or from epidemiological studies. The laboratory studies link an airborne concentration with observed health effects, absorbed amounts of the chemicals in affected tissues, or both.



Fast-acting toxic chemicals are generally assigned a *short term exposure limit* (STEL) or a peak limitation, which indicates concentrations that must not be exceeded to prevent immediate irritation or sensitisation. For slower acting chemicals or those that slowly store up in body tissues (bioaccumulation), a *time weighted average (TWA) exposure standard* (ES) is applicable. In Australia, a TWA ES refers to a concentration that most people can tolerate if they are exposed for an eight hour shift, for five days every week for their entire working life. It does not necessarily represent a safe level for everyone. Conversely, there is significant variation in a normal human population so exposures greater than the TWA ES will not necessarily elicit adverse health effects in all individuals.

Biological monitoring provides a concentration of the chemical (or a metabolite of it) in the selected body fluid. This can be compared with the relevant *biological exposure index* (BEI). The American Conference of Governmental Industrial Hygienists (ACGIH) annually publishes BEIs based on the most recently reviewed toxicological research. The BEI represents the expected concentration of the chemical in the body fluid when a person is exposed to an airborne concentration equivalent to the TWA ES. Accepted BEIs and TWA ESs for the most common heavy metals encountered in Western Australian mining operations are listed in Appendix 6.

Biological monitoring usually involves measuring the concentration of the chemical in biological substances (e.g. blood, tissue, breath). However, the only available test for some chemicals is for a metabolite of the hazardous substance. For example, either phenylmercapturic acid or muconic acid may be measured in urine to detect benzene exposures. Carbon monoxide poisoning can be confirmed by measuring carboxyhaemoglobin in blood. Alternatively, other biomarkers that measure the effect of a substance can be used. For example, nerve conduction velocity tests in conjunction with neurobehavioural tests can be used to monitor the effects of mercury or inorganic solvent exposures.

In some cases, where risk assessment indicates that employees may be exposed to elevated levels of a hazardous substance from air, ingestion or skin absorption, and there is no validated or widely accepted biological monitoring procedure, some companies have undertaken specific epidemiological research to develop appropriate

biological monitoring analyses. This work is done in consultation with and guided by expert occupational physicians, hygienists, toxicologists and chemists. In these circumstances, it is recommended that the Mines Occupational Physician be consulted about acceptable protocols and action levels.

### 6.3 Limitations

Biological monitoring detects the uptake of hazardous substances after exposure. It indicates when controls have failed and the chemical has entered the body, but does not indicate which controls were ineffective. Thus, biological monitoring must always accompany an appropriate environmental or personal exposure monitoring program, or both.

The utmost care is required during sample collection to avoid contamination that will produce misleading results. The interpretation of results may also be confounded by:

- diet — e.g. from bioaccumulation of heavy metals such as mercury and arsenic in canned fish;
- geographical factors — e.g. samples may be affected if they are not correctly packed in well insulated containers when transport times are extended; and
- the variability of occupational and non-occupational exposures — e.g. from welding, soldering or handling lead paints.

Currently, the major impediment to a wider application of biological monitoring is the lack of knowledge regarding reliable and valid laboratory procedures for measuring many hazardous substances. Interpretation of results is difficult unless there is some understanding of how the chemical exerts its toxic properties in the body and what is actually being tested. For example, contaminants measured in urine represent the component that is being excreted from the body after recent exposures. It does not indicate the amount or proportion of the absorbed dose that is being stored in tissues, nor does it provide the overall concentration of the chemical still in the body (overall body burden). It does provide information about the relative size and absorption rates of the most recent exposures.

To prevent results from being used in a discriminatory manner, knowledge of associated ethical and confidentiality considerations is also required in the application of



biological monitoring in the workplace. The results should be treated as measurements made in clinical practice whereby appropriate safeguards protect the interests of the individual. However, as monitoring is undertaken to provide an indication of the level of absorption of a workplace hazardous substance, it is important that the data be made available to people who will investigate and, when necessary, improve the work environment.

It is recommended that the informed written consent of each individual employee is obtained before quantitative results are released to employers. Employees have a regulatory duty to cooperate with biological monitoring and health surveillance if exposures could exceed accepted levels. With invasive procedures such as blood sampling, it is also important that the sampling procedure involves no undue risk to the employee. Of course, if there is a less invasive test and there is no advantage in using one method over the other, then the least invasive method is recommended. The decision to use any biological monitoring protocol should be based upon specific medical advice from an occupational physician informed about employees' exposure risks.

There is regulatory requirement for the consulting medical practitioner or approved person who has performed the biological monitoring test or health assessment to provide the employee with the results and explain what they mean. In addition, the employer must be notified of the outcome of the assessment, along with information regarding remedial action that may be required. Privacy and confidentiality relating to any health surveillance record are also regulated.

A biological monitoring program must be well planned and part of a larger program that includes environmental monitoring. Participating employees must understand its requirements and objectives, and be informed about how the results will be handled. Appropriate confidential feedback detailing the result, what it means and appropriate counselling for elevated results are necessary for each test.

There is no form prescribed for notifying the employer of the outcome of an employee's health assessment, including biological monitoring, but Appendix 4 recommends a format to assist medical practitioners and approved persons.

## 6.4 Sampling strategies

Particular sampling strategies must be followed when conducting biological monitoring because the rates at which substances are absorbed into the body and distributed to different tissues, metabolised and excreted can differ markedly between substances.

The sampling strategy depends on the biological half-life of the substance in the biological material being measured. The biological half-life of a substance or its metabolite gives an estimation of the time taken for the concentration to fall to 50 per cent of its original value after the end of exposure. It can be measured in minutes, hours, days, months or years.

Biological monitoring of substances with a shorter biological half-life provides useful information about recent exposure. For example, the biological half-life of arsenic in urine is one to two days, so the arsenic concentration in urine will indicate current or very recent exposure. For employees exposed on a continuous basis, arsenic levels will build up in the body over the work week and then decrease significantly during a break from the exposure of a couple of days or more. For this reason, it is recommended that samples are taken at the end of the work week (i.e. when levels are expected to be at their highest).

On the other hand, the timing for the collection of blood lead samples is considered to be “not critical” as the half life of lead is about 35 days and there will be no significant difference after a few days. However, it is important to note that most exposure standards (TWA and BEIs) relate to the more common five-day working week followed by a two-day weekend. As there are a number of roster lengths with extended break periods used in Western Australia, it is recommended that testing be undertaken near the end of the shift period to determine exposure levels during the shift. Alternatively, individuals who have demonstrated elevated levels may also need to be tested after an extended break to ensure that their levels have reduced during the break.

## 6.5 Collection of samples

Sample collection requires careful consideration and attention. If samples are not representative, or are not correctly collected or stored, the analytical results can be meaningless or misleading.



The analysis of blood or urine should be carried out only by competent laboratories with sufficient equipment, personnel, and expertise to undertake the analyses required, either according to the relevant Australian Standard or by an alternative method that has been demonstrated to have equivalent precision and accuracy. Accreditation by the National Association of Testing Authorities (NATA) and participation in an inter-laboratory quality control scheme are recommended. It is also worth considering the turnaround time when choosing laboratories.

### Urine samples

'Spot' urine samples (i.e. samples taken at a particular time, representing urine output for the previous two to four hours) are generally used for urine sampling. However, if there is a questionable result, a result within 10 per cent of the BEI or one that exceeds the BEI, then a 24-hour sample (a combination of all voidings during a 24-hour period) is recommended to verify the initial result.

Samples are usually collected in 70 millilitre (mL) sample specimen jars, with the recommended sample being at least 50 mL. Each sample should be labelled with the employee's name, time and date of collection.

The relevant Australian Standards for collection and analysis of urine samples include:

- AS 4985:2002 *Collection and stabilization of urine samples for quantitation of trace and toxic elements*; and
- AS 4205.2:1994 *Analysis of urine for trace elements – Determination of copper, cadmium and lead – Flame atomic absorption spectrometric method*.

For routine screening, collecting samples at the same time relative to the exposure will ensure subsequent samples are comparable and representative. Collection at the end of the work shift or roster is usually recommended.

The concentration of chemicals in spot urine samples normally varies depending on fluctuations in fluid intake and health status — it is usually corrected for dilution by measuring the amount of the chemical or its metabolites in the urine compared with creatinine. Creatinine is a substance that is naturally excreted from the body through urine at a constant rate (depending on body weight),

regardless of the amount of fluid consumed. Therefore urine results are usually expressed as micrograms per gram of creatinine ( $\mu\text{g/g}$  creatinine). Using this expression standardises the urine results and controls the effects of dilution.

Contamination of samples can occur during collection, transport to the laboratory and during analysis. Particular precautions must be taken to prevent contamination when specimens are taken at the work site since the contaminant is likely to be prevalent at such a location. It is important to ensure that:

- before giving samples, employees wash their hands thoroughly with soap and water in a contaminant-free environment;
- samples are collected in suitable contamination-free containers; and
- specimens are stable during transport to the laboratory.

Urine samples should be transported in a container such as a small esky with a freezer block, and analysed as soon as possible after collection. They should be frozen or at least refrigerated if they cannot be analysed promptly (within five days). Specific guidance should be sought from the analytical laboratory.

### Blood samples

Blood samples must be taken by a phlebotomist suitably trained in accepted procedures for the collection, storage and transportation of biological samples. Occupational health nurses, paramedics and doctors are recommended.

All blood samples should be taken in accordance with Australian Standard AS 2636:1994 *Sampling of venous and capillary blood for the determination of lead or cadmium concentration*.

## 7 Action levels

When biological monitoring for a particular chemical demonstrates a level at or above the BEI, a suitable and sufficient investigation is required to:

- identify the source and method of exposure;



- measure atmospheric and surface concentrations; and
- review the efficacy of control measures.

This risk assessment should be carried out by a competent person in accordance with the *Guidance Note for the Assessment of Health Risks Arising from Hazardous Substances in the Workplace* [NOHSC:3017(1994)]. Follow-up testing is recommended within a specified time that depends on the biological half-life of the particular chemical.

A medical check-up is required when follow-up testing confirms the level remains above the BEI. At this time, additional biological monitoring may be requested. This may involve analysis to detect any early biochemical effects (e.g. measuring elevated zinc protoporphyrin in blood as an early indicator of anaemia following lead exposures).

Following a review of the recent toxicological literature and international guidance on lead, mercury and arsenic, Resources Safety recommends, as a precautionary measure, individuals with a sustained biological level at or above the BEI be temporarily removed from further exposure (i.e. medically removed), and have an annual medical examination assessing general health, with a specific check for health effects attributed to the chemicals of exposure. The medical removal acts as a preventative and protective mechanism against impaired health. If an employee experiences medical symptoms or biological monitoring has produced a confirmed result at or above the 'removal level', the employee must be transferred to a job with significantly reduced exposure risk.

The employee should be examined by a medical officer (with possible referral to an occupational physician or clinical toxicologist) as soon as practicable following medical removal. All historic and current biological monitoring and personal exposure results (approximating atmospheric exposure concentrations) should be taken to each medical appointment to assist the consulting doctor. Specific tests may be required before the doctor is able to determine whether any significant health impairment has occurred from the occupational exposure.

The employee will be able to return to the high-risk job upon approval from the consulting doctor. Usually the consulting doctor will stipulate a 'return level' at which he or she considers it safe to return to work. This may vary from the recommended level in this guideline, and will depend on the length of exposure, type of job, and age and health status of the individual. The Mines Occupational Physician may be consulted for further information on return criteria.



## 8 Control measures and safe work practices

Heavy metal exposures can be well controlled by implementing appropriate control measures and establishing safe work practices. The *National Standard for the Control of Inorganic Lead at Work* [NOHSC:1012(1994)] and *National Code of Practice for the Control and Safe Use of Inorganic Lead at Work* [NOHSC:2015(1994)], available from the ASCC, provide useful generic guidance for minimising exposure to all heavy metals.

Briefly, these involve:

- providing information and training;
- applying the hierarchy of control, including provision of appropriate personal protective equipment as the last line of defence;
- provision of hot and cold washing facilities;
- on-site clothes washing service;
- designated 'clean' eating, drinking and smoking facilities away from 'dirty' high-risk exposure areas or tasks;
- consultation and counselling for staff with elevated exposures; and
- regular and routine monitoring and maintenance of all facilities and programs.

Appendix 7 provides a checklist of recommended safe work practices to prevent and monitor exposure of employees to hazardous substances, including heavy metals.

## 9 Biological monitoring for specific chemicals

### 9.1 Inorganic lead

In Western Australian mining operations, lead is commonly found in fire assay laboratories and where lead nitrate or litharge is added during gold processing. Lead is also the principle commodity mined at several locations, and is present as a contaminant or deleterious compound in many other ore deposits. The most common form of mineralised lead in Western Australia is galena (lead sulphide), although cerrusite (lead carbonate) also occurs.

Most forms of inorganic lead are readily absorbed and distributed throughout the body when inhaled or ingested. Absorption is strongly affected by nutritional status (iron and calcium deficiencies increase absorption) and whether ingestion occurs with food or on an empty stomach. Therefore employee habits, such as smoking, gum-chewing or nail-biting, or poor personal hygiene prior to eating will strongly influence the amount of lead absorbed. Employees exposed to lead must remain diligent in washing hands before eating or drinking to minimise their exposure. Smoking should be prohibited where there is a risk of lead exposure.

Repeated exposures can cause a gradual accumulation of lead, particularly in soft tissue (i.e. liver, kidneys, lungs, brain, spleen, muscles, and heart) and bones. The biological half-life of lead depends on where it is stored in the body. The half-life for lead stored in blood or soft tissue (which accounts for about 10% of absorbed lead) is 35 to 40 days. Most lead stored in blood is attached to the haem molecule of red blood cells. The remaining portion of absorbed lead is contained in the bones, where the levels decrease very slowly, and the half-life is about 20 years.

Blood lead levels are primarily an indicator of soft tissue concentrations and represent recent exposure (over the past month). Consequently, blood lead levels do not necessarily correlate with the total body burden of lead. After removal from exposure, blood lead levels usually decrease progressively. However, for individuals who have had long-term chronic exposure and have extensive body burden, blood lead levels may remain elevated because of the progressive release of lead from tissue deposits.

Symptoms of chronic overexposure include neurological and behavioural effects such as anxiety, weakness, headaches, tremors, excessive tiredness, depression, decreased libido, impotence and other indicators of nervous system damage. Symptoms may be very subtle and not recognised as being due to lead exposure. Anaemia, kidney damage and reproductive effects in both men and women can also be caused by lead. Developing foetuses and infants are at most risk of neurological and renal damage at very low blood lead concentrations. An additional safety factor is applied to females capable of reproducing in order to protect the developing child in any current or future pregnancies.

An assessment prior to commencing lead work should be undertaken to determine the worker's suitability for employment in a lead-risk job. This should include a baseline blood lead estimation. Regular biological monitoring of employees who work with lead has proven to be a very effective means of identifying employees who require additional training or specific counselling about acceptable work and hygiene practices. Experience indicates it takes about three months for new employees to learn and adopt work practices that minimise lead uptake.

Regular air monitoring and blood screening are recommended to identify and evaluate the source and extent of lead exposures. Blood samples may be collected at any time during the shift or work week. For comparison of measured results with the guidance presented here, it is recommended that all blood lead results are reported by the laboratory as micrograms of lead per 100 mL of whole blood ( $\mu\text{g Pb}/100\text{ mL}$ ), which can also be described as micrograms of lead per decilitre of whole blood ( $\mu\text{g}/\text{dL}$ ).

Figure 1 outlines recommended action levels for all employees working in lead-risk jobs. Lower action levels are recommended for females of reproductive capacity to protect developing foetuses of any current or future pregnancies. The values provide guidance on currently accepted action levels, but may be subject to change as new epidemiological and toxicological information becomes available and is accepted. Thus a precautionary approach is recommended.

Effective control of lead exposures is demonstrated when:

- atmospheric concentrations are below the occupational TWA ES ( $0.15\text{ mg}/\text{m}^3$ ); and



- blood lead levels are maintained at or below the BEI (i.e. 30 µg Pb/dL for males and females not of reproductive capacity, 10 µg Pb/dL for females of reproductive capacity).

The action levels incorporate significant safety factors and do not equate with onset of toxic effects. The aim of the safety factor is to protect employees from being poisoned. Some individuals may be more, and others less, susceptible to the toxic effects of lead due to their genetic makeup or previous exposures to lead or other toxic substances with similar target tissues. In addition to measuring blood lead levels, there are also tests available to assess the potential adverse biological effects of lead. The most common and convenient biochemical test that measures the effects of lead on haemoglobin synthesis is blood zinc protoporphyrin (ZPP). However, free erythrocyte protoporphyrin, urine coproporphyrins, blood delta aminolaevulinic acid dehydratase activity and urine delta aminolaevulinic acid may also be measured.

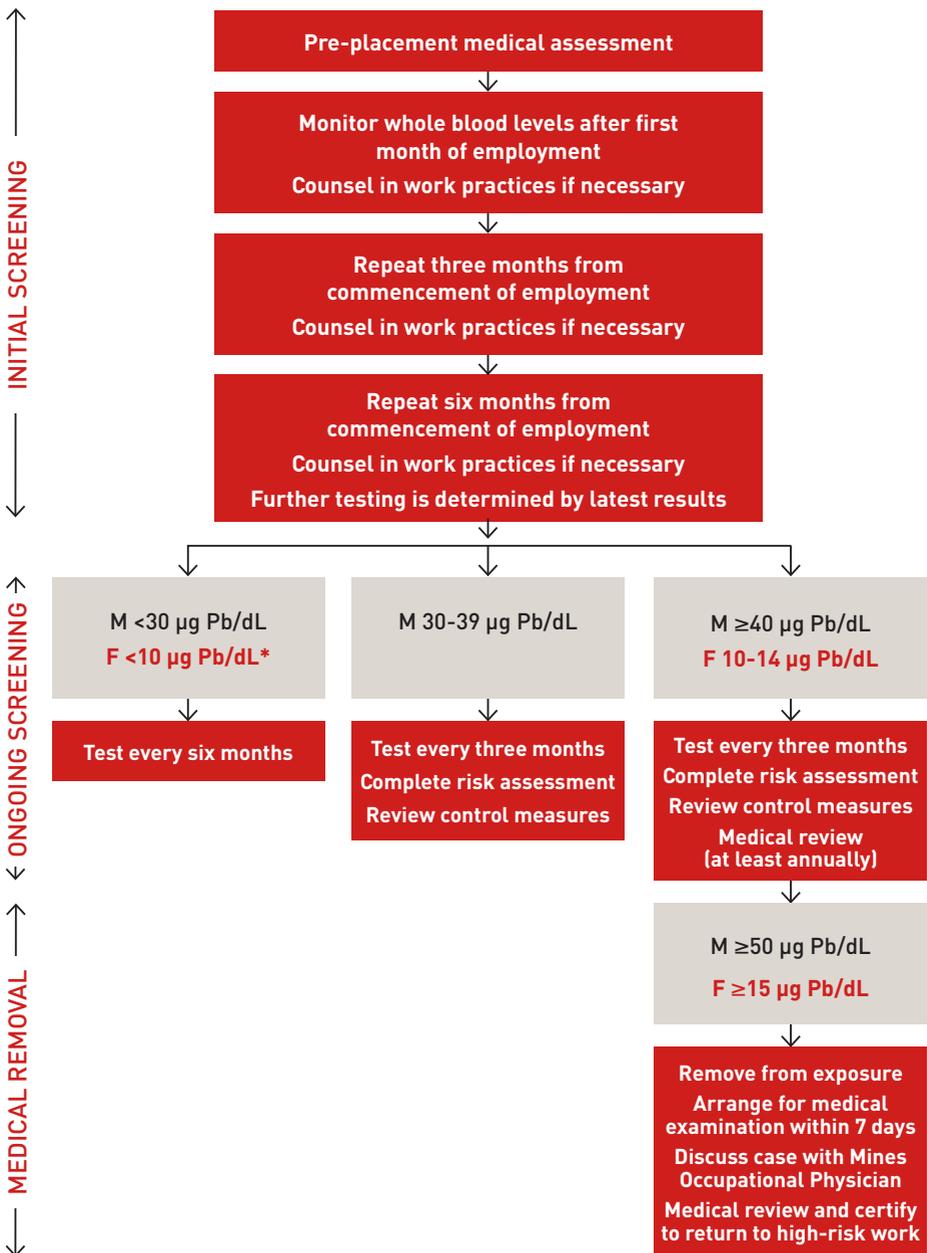
As blood ZPP measures the effects of lead on haemoglobin and hence red blood cell production, it acts as an indicator of the actual toxicity of lead exposures. Changes in blood ZPP usually lag behind elevated blood lead concentrations, with similar delays in recovery after the blood lead level has dropped. Consequently, blood ZPP levels give a better indication of the total body burden, with more explicit information on the actual lead toxicity over the preceding three to four months.

Following an elevated or prolonged lead exposure, it is recommended that an employee is medically removed from the lead-risk task. Used in conjunction with adequate medical examination, blood ZPP is a useful test to demonstrate recovery before an employee is certified to return to lead-risk work. Testing and interpretation of blood ZPP results should be made by a competent laboratory and doctor, respectively.

*Note: To convert µmol Pb/L (micromole lead per litre) in the red blood cell component of blood to µg Pb/dL whole blood, multiply by 8.7 for females and 9.3 for males.*

## 9.2 Metallic mercury

Metallic mercury is a silver grey liquid that may be found as a contaminant or deleterious material in minerals mined



Note: This is a guide only. Adjustments may be necessary depending on circumstances of each case. Contact the Mines Occupational Physician for clarification.

**Figure 1 Flow diagram showing biological monitoring for employees exposed to lead**

**M** Action level for employees other than females with reproductive capacity

**F** Action level for females with reproductive capacity

**\*** Pregnant or breast-feeding employees require removal and exclusion from lead-risk job

in Western Australia. It is also found as cinnabar, a red-coloured mercury sulphide. Although mercury is generally not desired, some mineral processing methods concentrate mercury. Mercury may also be added in amalgamation processes to selectively bind minerals. It is a common contaminant in gold and silver refineries.

Metallic mercury readily vapourises into the atmosphere at normal temperatures, but its vapour pressure increases rapidly with increased temperatures. This property is used to separate and collect the mercury from the desired minerals. When present in lower concentrations, it may also be collected using appropriate ventilation and scrubbing equipment during smelting or roasting processes.

Inhaling mercury vapour is the main route of entry into the body, with as much as 80 per cent absorbed into susceptible body tissues. Other forms of inorganic mercury do not pose such a significant inhalation risk as they do not vapourise readily. Ingestion and skin contact do not pose a significant route of entry for inorganic mercury, but they are the main route of entry for the organic forms, such as methylmercury. Irrespective of the chemical form of mercury present, diligent hygiene practice is essential to minimise overall exposure and prevent it entering the body.

Once absorbed, mercury is distributed throughout the body, with the majority accumulating in the kidneys and brain. Mercury has a biological half-life of about 60 days, with most being excreted in urine.

Chronic exposure to mercury vapour primarily affects the central nervous system and kidneys. The onset of chronic poisoning is insidious, with non-specific as well as specific symptoms in some cases. Non-specific symptoms include weakness, fatigue, loss of weight and disturbance of gastrointestinal functions.

At sufficiently high exposure levels, a characteristic mercurial tremor appears as fine trembling of the muscles, interrupted by coarse shaking movements every few minutes. In progressive cases, it may develop into a generalised tremor involving the entire body, with violent chronic spasms of the extremities. A condition known as mercurial erethism will develop alongside the tremor symptoms. This condition is characterised by withdrawal from contact with others, increased excitability, loss of memory and insomnia, which may develop into depression.

Gingivitis (inflammation of the gums) can also result from chronic exposure to mercury vapour. This condition is usually associated with poor oral hygiene.

Urine samples are generally used to estimate exposure to mercury vapour. The BEI for mercury is 35 micrograms of mercury per gram of creatinine (35 $\mu$ g Hg/g creatinine). Urine mercury levels are typically less than 10  $\mu$ g Hg/g creatinine for people not occupationally exposed to mercury. Since the biological half-life is about two months, urinary mercury values are indicative of average exposure during the past month, rather than exposure at the time of urine collection.

The sampling time for mercury is not critical, but morning (prior to shift) urine collection is recommended to reduce the possibility of contamination. In addition, because mercury excretion in the morning is higher than excretion at other times of the day, sampling at the same time of day on each occasion will reduce variability in results. A 24-hour urine collection sample is useful, but usually not practical, to overcome these difficulties. However, in the case of an elevated spot test, a 24-hour sample should be taken without delay to confirm the earlier result.

If an employee develops symptoms or records a urine mercury result above 35  $\mu$ g Hg/g creatinine, it is recommended that the individual be medically removed from any further mercury exposure until they have been medically assessed and certified to return to mercury-risk work by an occupational physician. A blood test may be requested to gain more information. Further advice is available from the Mines Occupational Physician.

The recommended medical monitoring procedures for mercury-exposed employees should be undertaken at the pre-placement assessment to provide a baseline for comparison with future annual assessments.

The recommended mercury-risk health surveillance includes a complete medical, occupational and reproductive history and symptom questionnaire. Symptoms of the earliest signs of mercury poisoning should be checked, such as personality changes, weight loss, irritability, fatigue, nervousness, loss of memory, indecision and intellectual deterioration. Tremors and loss of coordination should also be investigated.



Medical examination should specifically assess the nervous system, kidneys, lungs, gastrointestinal system, eyes and skin. A baseline handwriting sample should be taken at the pre-placement medical examination for comparison to identify signs of tremor. Laboratory evaluation should include a complete urinalysis and measurement of urine mercury.

Referral to a specialist physician may be required to undertake neurobehavioural testing to detect early signs of mercury toxicity, if applicable. Similarly, early kidney damage may be detected by assessing urine for the presence of low molecular weight proteins. Analysis for beta-2-microglobulin and N-acetyl-B-D-glucosaminidase (NAG) may be recommended. Guidance on acceptable values is not given here because interpretation is best done by a trained occupational physician or other specialist physician with toxicology expertise.

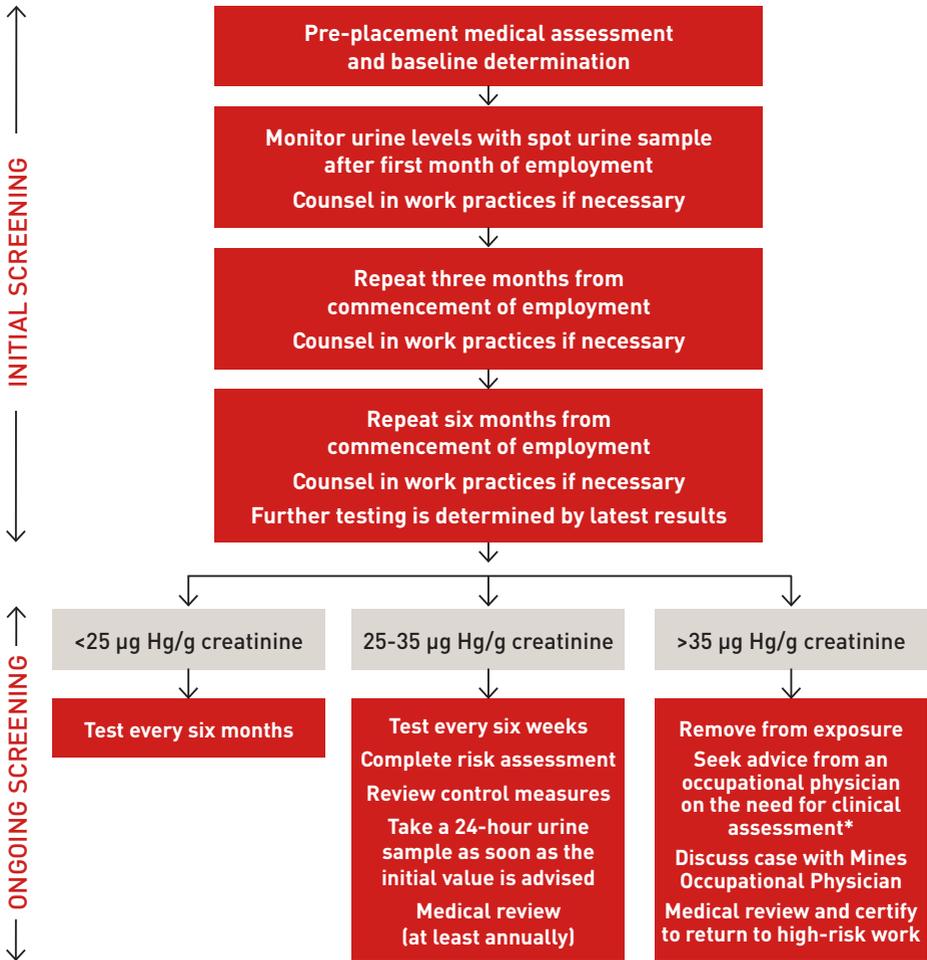
The major sources of non-occupational mercury exposure are inhalation of contaminated ambient air and ingestion of contaminated water or food. Dental amalgam has also contributed to very low levels of contamination in the general population. Bioaccumulation in contaminated marine populations such as shell-fish and fish are the most common source of dietary mercury poisoning. Organic mercury (e.g. methylmercury) is most commonly found in fish, and nearly all of it is absorbed by the body. Organic mercury is poorly excreted by the kidney, but may cause elevated blood mercury levels.

Figure 2 describes the recommended procedures when carrying out biological monitoring for exposure to mercury vapour.

### **9.3 Inorganic arsenic**

Arsenic is widely distributed in the Earth's crust. It occurs in its elemental form, and as inorganic and organic compounds. Elemental and inorganic arsenic are highly toxic. Arsine gas is the most acutely toxic arsenic compound, and can be produced when acid reacts with arsenic compounds or by the hydrolysis of metallic arsenides. In contrast, organic arsenic is less toxic.

In Western Australia, inorganic arsenic, as arsenopyrite, is the most common occupational source of arsenic. It has been identified in the smelting of gold, nickel and tin



Note: This is a guide only. Adjustments may be necessary depending on circumstances of each case. Contact the Mines Occupational Physician for clarification.

**Figure 2** Flow diagram showing biological monitoring for employees exposed to mercury

\* Specific medical tests may be required to identify early adverse health effects following mercury exposure — some guidance is provided in Section 7.2 but an occupational physician or clinical toxicologist should be consulted

where the ore contains arsenopyrite as an impurity. Arsenic trioxide ( $\text{As}_2\text{O}_3$ ) is commonly produced during roasting and smelting processes and, due to its toxicity, is collected from the stack dusts. However, dust containing arsenic can be inadvertently released into the atmosphere during maintenance of scrubbing equipment and waste handling.

Inorganic arsenic is mainly absorbed via the respiratory tract following inhalation. However, if employees don't wash effectively before smoking, eating or drinking then there may also be gastrointestinal effects, including nausea, diarrhoea and constipation. Small amounts of arsenic may be absorbed through the skin causing characteristic darkening of the skin or the appearance of small warts or corns.

The most common health effects associated with occupational exposure to inorganic arsenic compounds are localised, such as irritation of the skin, eyes, mouth, throat and lungs. An increased risk of cancer of the skin and lungs has been reported in employees who have been chronically exposed to inorganic arsenic. In 2004, arsenic was classified as a known human carcinogen by the International Agency for Research on Cancer.

Systemic effects have also been reported after both acute and chronic exposures. In addition to gastrointestinal effects, circulatory and peripheral nerve disorders have been reported in smelter workers following chronic exposures to arsenic. Elevated acute exposures to inorganic arsenic and arsine have caused death.

About 60 per cent of absorbed inorganic arsenic is rapidly metabolised in the liver to form less harmful organic arsenic, which is excreted via the kidneys in urine. Excreted metabolites of inorganic arsenic include trivalent ( $\text{As}^{3+}$ ) and pentavalent ( $\text{As}^{5+}$ ) arsenic compounds, monomethyl arsonic acid (MMA) and dimethyl arsinic acid (DMA). Arsenobetaine contributes to total urine arsenic but is exclusively related to ingested organic arsenic, which is commonly associated with seafood and red wine — it is also known as 'fish arsenic'. Following ingestion, arsenobetaine is not metabolised and is rapidly excreted within 24 to 48 hours.

Health surveillance should incorporate a medical examination concentrating on the peripheral nervous system and skin for employees exhibiting sustained elevated levels. A detailed work history is necessary to

evaluate previous exposures.

Interpretation of the biological monitoring results used to assess occupational exposure to arsenic can be complicated, and should be left to an occupational physician or clinical toxicologist. The results are confounded in employees who have recently ingested organic arsenic in seafood or smoke heavily. All forms of arsenic clear from the blood within one to two hours, so blood tests are only useful following a known exposure and when wanting to identify the extent of absorption to assist immediate treatment.

Absorption of arsenic compounds is reflected in urine within 24 hours, but elimination through urine is rapid and therefore concentrations in urine are very time dependent. For employees exposed to arsenic on a continuous basis, arsenic levels in urine will increase over the work week, so sampling at the end of the last shift of the work week, when the concentration will be highest, is recommended to determine the overall body burden. Sample results will only reflect exposure during the week immediately prior to sampling.

For employees who are intermittently exposed to arsenic (e.g. once every fortnight), urine samples should be taken at the end of the shift where exposure occurred, or within three to four hours of the exposure ceasing.

Biological monitoring of employees occupationally exposed to inorganic arsenic can be carried out by measuring either 'total' or, more specifically, 'inorganic arsenic plus methylated metabolites' in urine. Total arsenic is measured by a simpler and more economical analytical technique for screening purposes. However, it is necessary to ensure that employees abstain from eating seafood and red wine for at least 72 hours before the test to exclude possible contamination by ingested organic arsenic. When spot-urine sample screening indicates total arsenic levels above 35 micrograms of total arsenic per litre of urine ( $35 \mu\text{g As/L}$ ), the individual should be counselled to determine whether they have recently eaten any seafood. It is also recommended that the urine sample be analysed further to specifically measure for inorganic arsenic plus its methylated metabolites because total arsenic may overestimate



the occupational exposure. Measuring inorganic arsenic alone will significantly underestimate the exposure, since about 60 per cent will rapidly be methylated in the liver.

Speciation analysis is more complex but is recommended to confirm the proportion of absorbed arsenic due to occupational exposure and that from ingestion of the less harmful inorganic arsenic. Seek medical advice from an occupational physician or clinical toxicologist if the confirmed concentration of inorganic arsenic and its methylated metabolites in urine exceeds 35 µg As/L. Further specific medical assessment may be advised. It is recommended that an occupational physician or clinical toxicologist certify when it is appropriate for the individual to return to arsenic-risk work.

Exposure levels above 25 µg As/L should trigger a prompt and thorough review of work practices and control measures. Employees with sustained levels above 35 µg As/L should be removed from further exposure and referred for medical review. Return to arsenic-risk work must be certified by an occupational physician or clinical toxicologist.

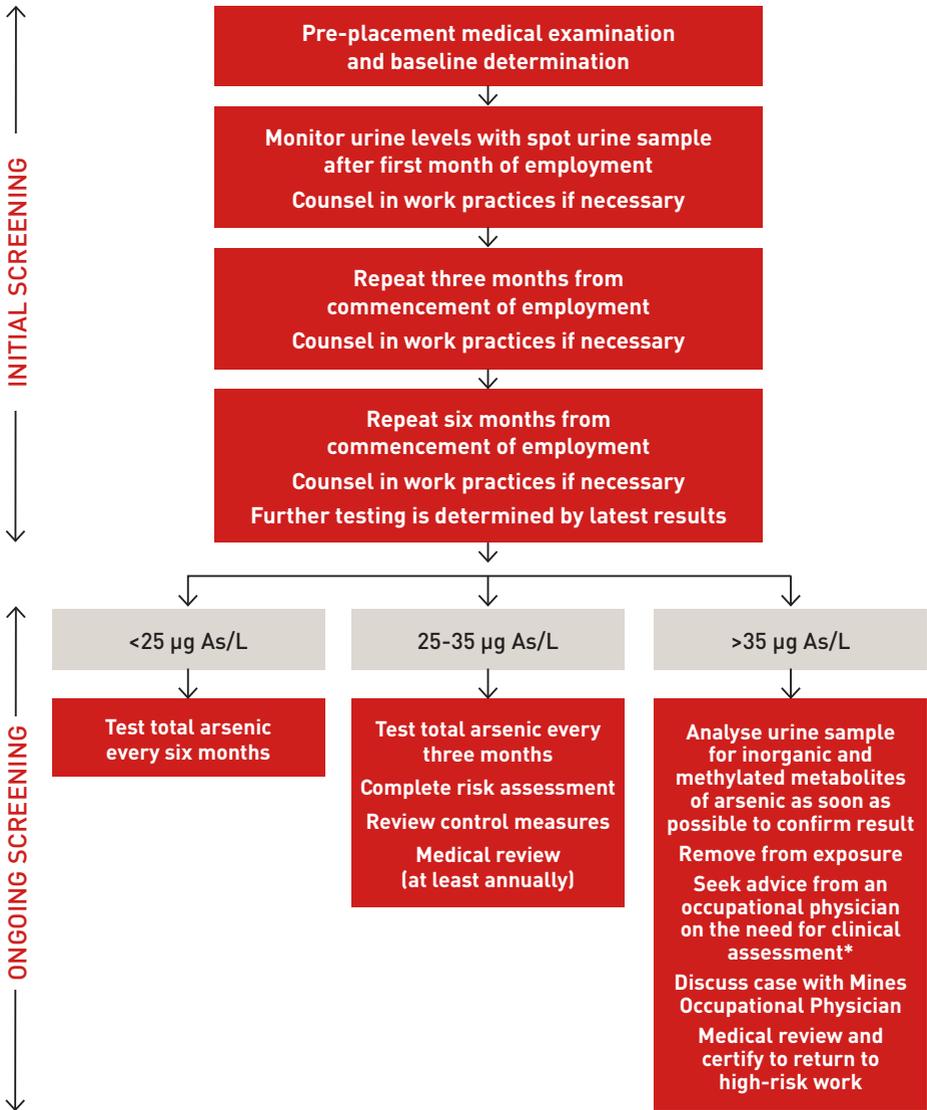
Figure 3 shows the recommended procedures when carrying out biological monitoring for exposure to arsenic, using total arsenic levels for general screening, and inorganic arsenic and its methylated metabolites in urine for confirmation of occupational exposure levels.

## 9.4 Thallium

Thallium malonate formate (TMF) may be used in the mineral sands industry as a heavy liquid medium for the separation of heavy mineral fractions.

Relatively little is known about thallium with respect to health effects but it is recognised that soluble thallium compounds are extremely toxic, primarily affecting the nervous system and body hair, and intoxication is cumulative. Poisonings from industrial exposures, however, have been reported rarely and have not been fatal.

Industrial exposure to excessive amounts of thallium has produced symptoms such as abdominal pain, fatigue, irritability, weight loss and pains in the legs.



*Note: This is a guide only. Adjustments may be necessary depending on circumstances of each case. Contact the Mines Occupational Physician for clarification.*

**Figure 3** Flow diagram showing biological monitoring for employees exposed to inorganic arsenic

\* Specific medical tests may be required to identify early adverse health effects following inorganic arsenic exposure — some guidance is provided in Section 7.3 but an occupational physician or clinical toxicologist should be consulted

Thallium is easily absorbed through inhalation, ingestion and the skin. It is mainly excreted by the kidneys and has a biological half-life in urine of between 15 and 30 days.

Urine sampling may be used to estimate exposure to thallium. A BEI of 50 micrograms of thallium per gram of creatinine (50 µg Th/g creatinine) is currently recommended. The concentration in the urine of unexposed people is usually less than 1 µg Th/g creatinine, with levels exceeding this suggesting occupational absorption.

Figure 4 describes the recommended procedures when carrying out biological monitoring for exposure to thallium.

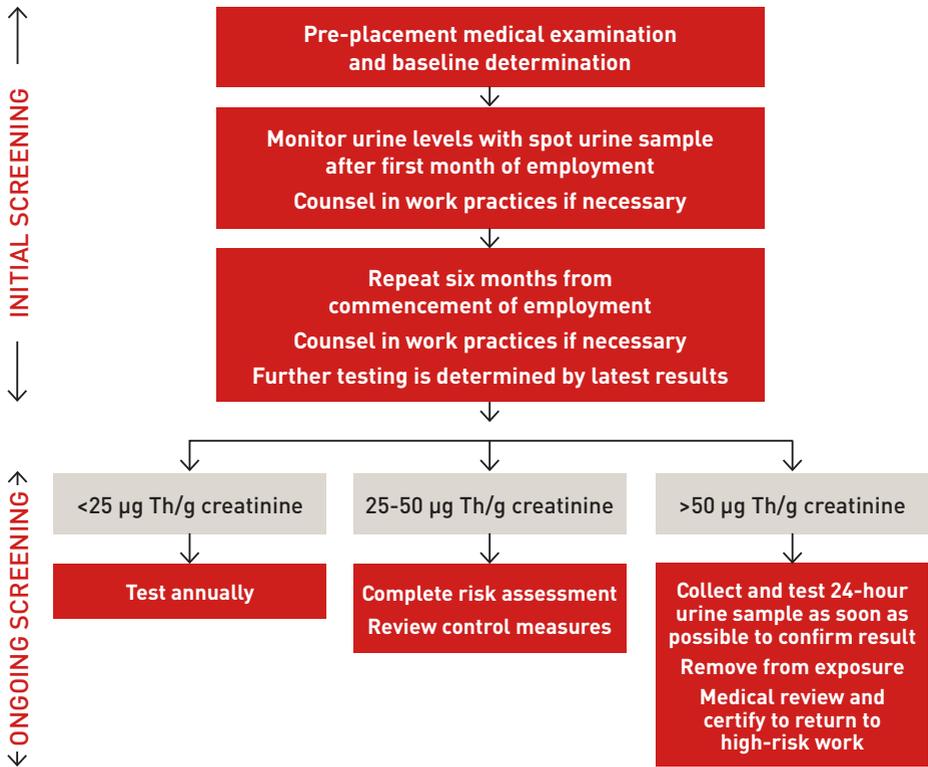
## 9.5 Vanadium

Vanadium is a silver-grey metal used in ferrous metallurgy as an alloy to improve tensile strength and reduce the brittleness in steel products. It exists most commonly as ferrovandium, vanadium pentoxide and metavanadates. It is also used as a catalyst in the chemical industry in the production of sulphuric acid and plastics.

Employees involved in the crushing, leaching, drumming and bagging operations, and cleaning and maintenance of equipment where vanadium is mined and processed have the greatest risk of exposure to dusts containing vanadium. All vanadium compounds are toxic, and vanadium pentoxide is the most toxic.

Ingestion of low-level contamination in food is the main source of vanadium exposure in the general population, with levels between one and 20 micrograms of vanadium per litre of urine (20 µg V/L). However, only a very small proportion (0.1–2%) of ingested vanadium is absorbed by the gastrointestinal tract.

Inhalation is the main route of uptake from occupational exposures. Irritated eyes and respiratory tract (nose, throat and lungs) are the most common health effects. The symptoms are asthma-like and include acute bronchitis, bronchospasm, dyspnoea, persistent and productive cough, and wheezing. Eye irritation, including conjunctivitis, nasal catarrh and



*Note: This is a guide only. Adjustments may be necessary depending on circumstances of each case. Contact the Mines Occupational Physician for clarification.*

**Figure 4 Flow diagram showing biological monitoring for employees exposed to thallium**

nasal bleeding, also occur after repeated exposures. Kidney and liver damage have been reported at very high exposure levels, but are uncommon. Skin absorption of vanadium has been linked to itchy dermatitis when mining the ore. Symptoms usually cease when exposure to vanadium stops. However, some individuals develop long-term sensitisation to vanadium such that exposure to very low concentrations brings on asthma-like symptoms. Other chemicals involved in ferrovandium and vanadium pentoxide production, such as strong acids, ammonia and small particulates, will also cause these symptoms. It is important, therefore, that exposure to all contaminants on a vanadium plant is as low as reasonably practicable.

Among the local effects caused by vanadium exposure, some individuals experience so-called 'green tongue' with no observable health effects. There may be similar staining in other moist or sweaty locations of the body, and this may cause skin irritation if not washed promptly. Maintaining high levels of personal hygiene will minimise skin irritation effects.

Vanadium is usually rapidly cleared from the respiratory tract following inhalation. Absorbed vanadium is also rapidly excreted, with a half-life between 15 and 40 hours. However, there is evidence of accumulation in the kidneys, liver, spleen and bones following chronic exposures. Absorbed vanadium compounds are retained in skeletal bones the longest, with a biological half-life of about two weeks.

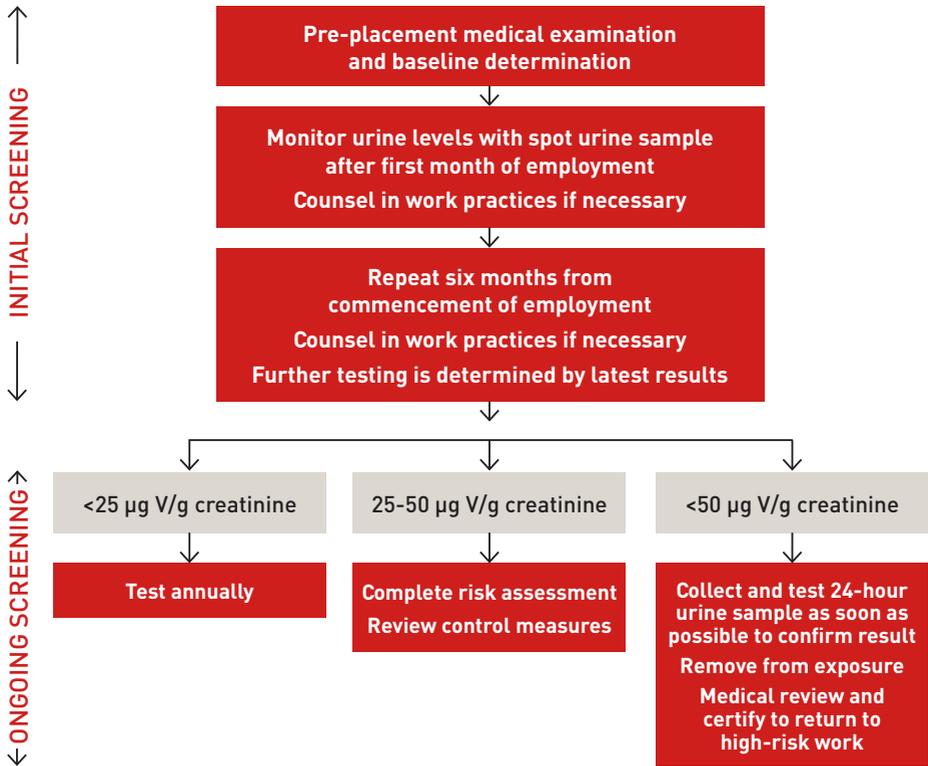
Exposure to vanadium can be measured by collecting urine samples at the end of the shift. The BEI is 50 µg V/g creatinine. A high result indicates poor control, which should be remedied as soon as possible.

Figure 5 describes recommended procedures when carrying out biological monitoring for exposure to vanadium.

## 9.6 Chemicals under review

In addition to the metals discussed in Sections 9.1 to 9.5, there are other metals that may affect the health of exposed employees in Western Australian mining operations.

Cadmium, chromium (VI) and cobalt may occur as mineral contaminants and components of welding rods.



*Note: This is a guide only. Adjustments may be necessary depending on circumstances of each case. Contact the Mines Occupational Physician for clarification.*

**Figure 5** Flow diagram showing biological monitoring for employees exposed to vanadium

Biological monitoring for these metals may be a useful adjunct to assess employee exposures because standard tests are available and the ACGIH publishes BEIs for them. Maintenance and workshop employees may receive significant doses of these metals while undertaking welding activities. An adequate risk assessment will identify if further exposure monitoring is required. If airborne sampling indicates that personal exposures are likely to exceed the exposure standard, biological monitoring is recommended to assess the potential for health effects in exposed individuals. Appendix 6 lists occupational exposure standards and BEIs for cadmium, chromium (VI) and cobalt.

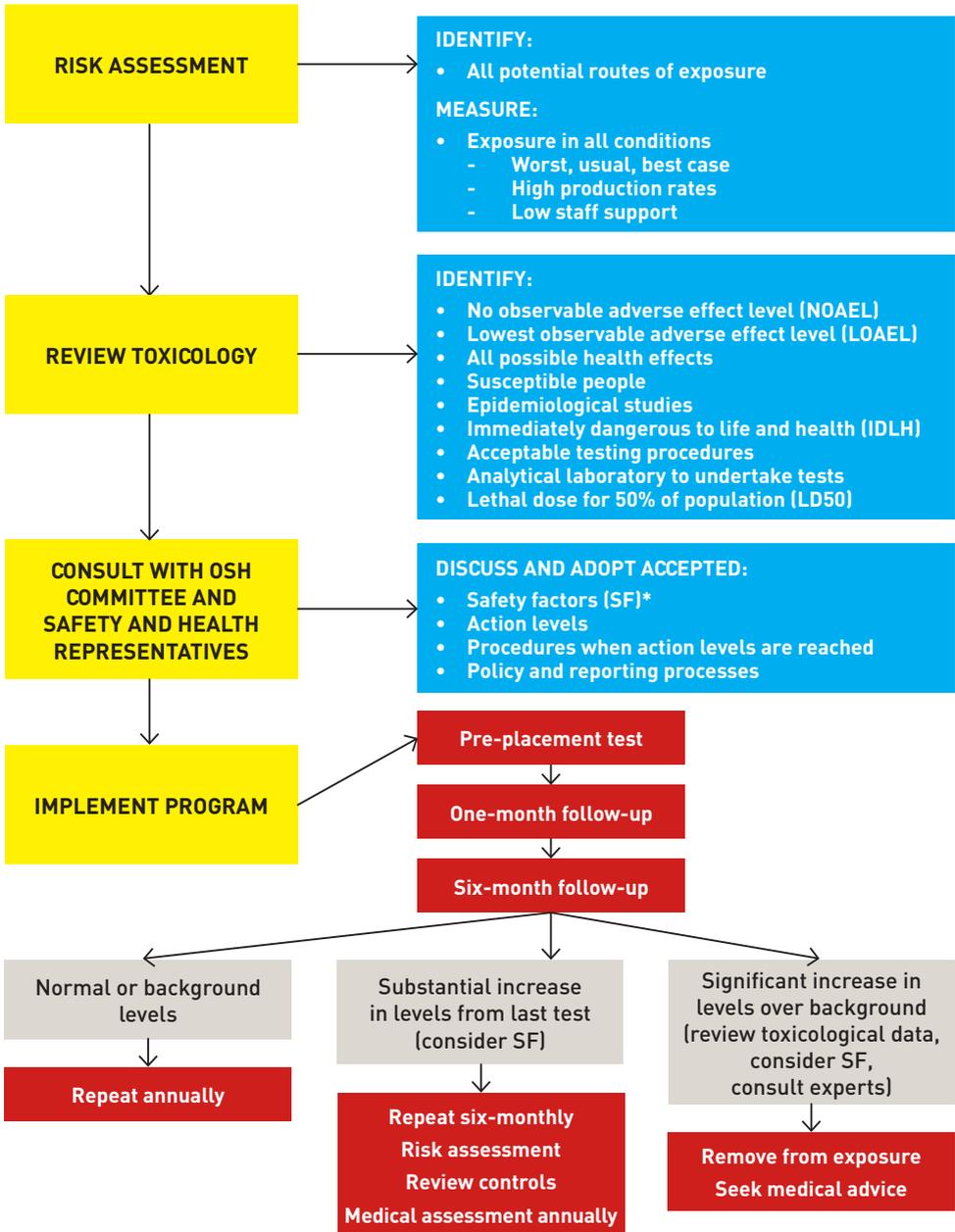
Although ACGIH has not published BEIs for aluminium, manganese, molybdenum, nickel, selenium and tin, there has been significant research recently into their toxicology with the aim of producing a standard test to assess the biological uptake of chemicals (i.e. actual exposures) using biological monitoring.

Some mining companies in Western Australia have undertaken their own research into the health effects of metals that their employees are exposed to. In the absence of an adopted BEI, 'corporate action levels' have been assigned following consultation with occupational safety and health experts, occupational physicians, epidemiologists, occupational safety and health committees, and safety and health representatives. A generic approach is outlined in Figure 6 for biological monitoring where there is no published BEI (e.g. manganese, nickel).

As new exposure monitoring tests become available as standard procedures, the techniques are gradually adopted by regulators around the world. Similarly, exposure standards and BEIs may change as new information becomes available. The latest information is usually available from the ACGIH ([www.acgih.org](http://www.acgih.org)) in the *Notice of Intended Changes*.

## 10 Continual improvement of risk-based health surveillance

Continual improvement in the identification, assessment and management of hazards that may impact health, safety or well-being is an important criterion to demonstrate



**Figure 6 Implementation of a biological monitoring program where there is no BEI**

\* Safety factors are values assigned by the company to protect health. The higher the SF, the higher the protection level. For example, a safety factor of 1 implies that the control measure meets but does not exceed safety requirements, with no room for variation nor error. A very high safety factor could imply 'over engineering' or 'over administration', resulting in controls that are difficult to implement or maintain.

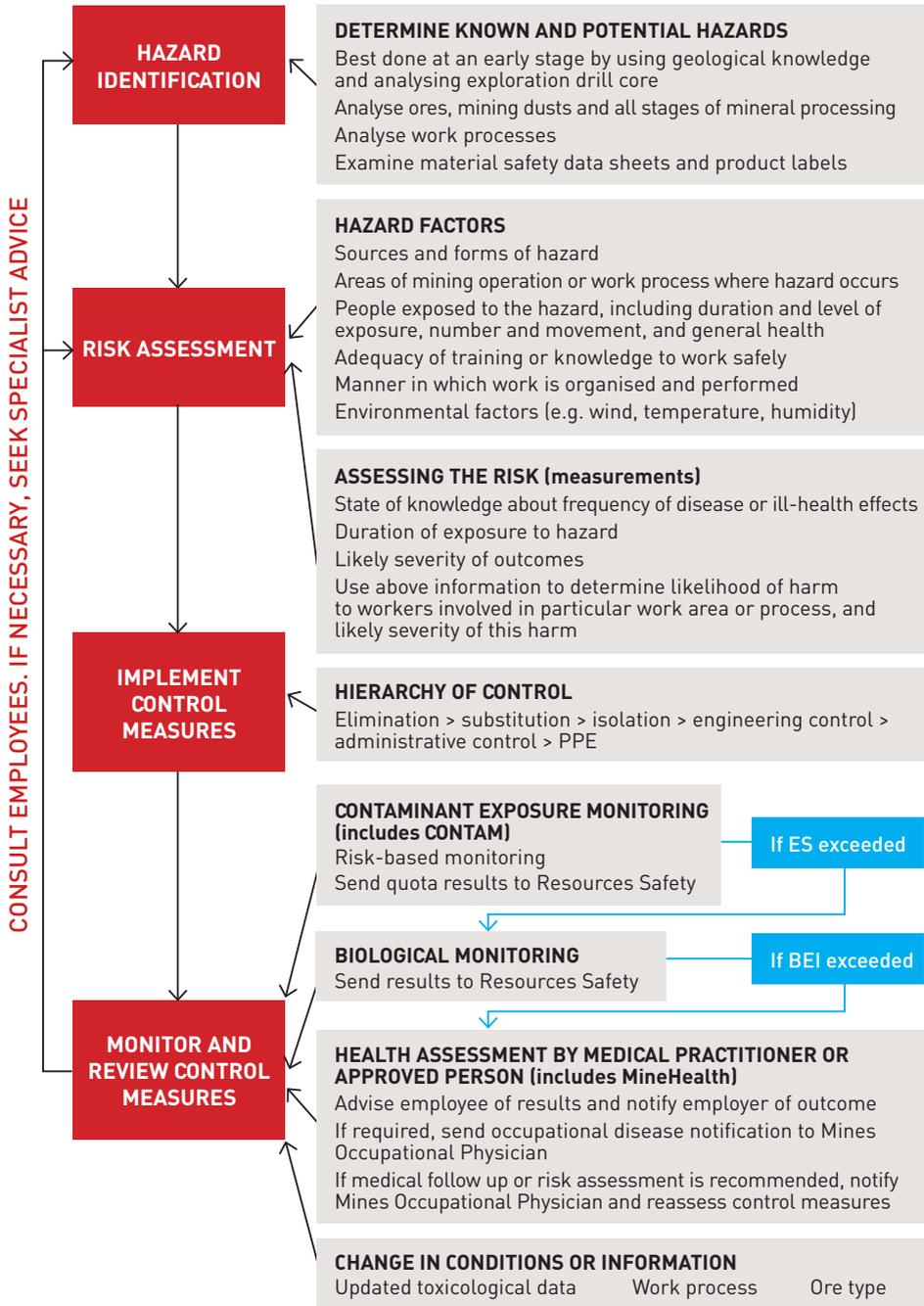
the quality of an employer. Of course, there are also regulatory requirements that employers provide and maintain a working environment where employees are not exposed to hazards.

This guideline outlines the process of monitoring uptake of hazardous substances that may have entered the body following ingestion, inhalation or absorption through the skin. It does not discuss how to measure concentrations on surfaces or skin, or in clothes, food or air. An occupational hygienist should be consulted for information regarding atmospheric monitoring.

The over-riding goal of any exposure monitoring or health surveillance program is to identify hazards that employees may face while undertaking their daily duties. Where exposure measurements indicate levels that may impact on health, control measures to reduce these levels must be implemented promptly.

Figure 7 summarises the implementation of risk-based health surveillance, including assessment, exposure monitoring and control implementation. Risk-based health surveillance should be reviewed regularly and whenever conditions change, and control measures revised until exposure levels are as low as reasonably practicable and no adverse health effects are detected.

Appendix 3 of Resources Safety's guideline on general duty of care in Western Australian mines provides a useful summary of the risk-based approach to managing safety and health in general.



**Figure 7 Overview of risk-based approach to health surveillance and some issues to consider**

# 11 Further information

## General

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NATIONAL OCCUPATIONAL HEALTH AND SAFETY COMMISSION, 1994: National Code of Practice for the Control and Safe Use of Inorganic Lead at Work [NOHSC:2015(1994)]: available from the Australian Safety and Compensation Council <<http://www.ascc.gov.au>>

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## Appendix 1 — Legislative provisions

Listed below are the sections of the *Mines Safety and Inspection Act 1994* and *Mines Safety and Inspection Regulations 1995* that are relevant to this guideline.

*Note: The only authorised versions of the Act and regulations are those available from the State Law Publisher ([www.slp.wa.gov.au](http://www.slp.wa.gov.au)), the official publisher of Western Australian legislation and statutory information.*

### **Mines Safety and Inspection Act 1994**

s. 75 Health surveillance of mine employees

### **Mines Safety and Inspection Regulations 1995**

#### **Part 3, Division 4 Health surveillance**

##### **Subdivision A — Preliminary**

r. 3.23 Interpretation

##### **Subdivision B — Health surveillance system**

- r. 3.24 Effect of Subdivision
- r. 3.25 Initial health assessment
- r. 3.26 Periodic health assessment
- r. 3.27 Additional health assessment
- r. 3.28 Biological monitoring
- r. 3.29 Categories of employees who do not require health surveillance
- r. 3.30 Employer responsible for arranging health surveillance

##### **Subdivision C — Information on health surveillance**

- r. 3.31 Medical practitioner to provide results of health assessment
- r. 3.32 Authorised medical officer to provide x ray results
- r. 3.33 Department to keep records
- r. 3.34 Mines occupational physician



- r. 3.35 Health surveillance records to be confidential records
- r. 3.36 Employee may request a copy of record
- r. 3.37 Employer may find out whether employee has previously been assessed
- r. 3.38 Confidentiality
- r. 3.39 Notice of occupational disease
- r. 3.40 Remedial action

### **Part 7, Division 3 Hazardous substances**

- r. 7.20 Interpretation
- r. 7.21 Material Safety Data Sheets
- r. 7.22 Containers to be appropriate
- r. 7.23 Disposal of containers
- r. 7.24 Labels
- r. 7.25 Register of hazardous substances
- r. 7.26 Enclosed systems
- r. 7.27 Risk assessment
- r. 7.28 Means of reducing risk of exposure to hazardous substances
- r. 7.29 Workplace atmospheric contaminant monitoring to be provided
- r. 7.30 Health surveillance

## Appendix 2 — Glossary

<b>Action levels</b>	provide trigger points for specific recommendations in order to reduce exposures and protect employees from being poisoned by hazardous substances.
<b>Atmospheric monitoring</b>	is used to measure the concentration of a chemical present in the atmosphere where employees work. The sampling methods employed depend on the purpose of the testing. Personal exposure monitoring and in situ sampling can be used to assess exposure risks at different locations and during different operating conditions.
<b>Biological exposure index (BEI)</b>	refers to a level of a chemical measured in biological material (e.g. blood, urine, hair, fingernails) and represents a level that will not cause adverse health effects in most people. It represents the expected concentration of the agent in the biological material if an individual is exposed to an airborne concentration equivalent to the time-weighted average exposure standard for that chemical.
<b>Biological half-life</b>	refers to the average time that it takes for the absorbed concentration of a chemical to reach 50 per cent of the initial concentration in the biological medium in question, if no further exposure occurs.
<b>An epidemiological study</b>	is a statistical study on human populations that attempts to link human health effects to a specified cause.
<b>Exposure standard (ES)</b>	refers to all time-weighted average exposure standards, short term exposure limits and peak limitations adopted by the Mines Safety and Inspection Regulations 1995. Unless the particular chemical is specifically listed in regulation 9.11, refer to the national exposure standards available from Australian Safety and Compensation Council's (ASCC) Hazardous Substances Information System (HSIS), an online database at <a href="http://hsis.ascc.gov.au">hsis.ascc.gov.au</a>



<b>Heavy metals</b>	are metallic chemicals with a relatively high density that are toxic, highly toxic or poisonous at low concentrations. Examples include arsenic, mercury, lead, cadmium, chromium and thallium.
<b>Medical removal</b>	is a protective mechanism to remove an employee from further exposure to a hazardous substance following biological monitoring or health surveillance information indicating significant exposure has occurred above the BEL or has caused poisoning.
<b>Personal exposure monitoring</b>	measures the time-weighted average concentration of a chemical within an employee's breathing zone. It gives an indication of how effective control measures are. Compliance with the regulations requires atmospheric concentrations to be maintained below the exposure standard.
<b>Removal level</b>	refers to an accepted biological level at which an employee should be removed from the high exposure-risk task.
<b>Risk assessment</b>	is an investigation to identify possible sources of exposure and whether the control measures currently employed are effective. It includes measurements to determine the amount of material present in a form that may enter an employee's body, and a review of the tasks and controls employed.
<b>Short term exposure limit (STEL)</b>	represents an airborne concentration averaged over 15 minutes that should not be exceeded at any time in a normal working day.
<b>Time-weighted average (TWA) exposure standard (ES)</b>	is an airborne concentration that represents a safe level for employees who are exposed to the chemical for an eight-hour day, five-day working week for an entire life-time. Adjustments to this exposure standard are required for deviations to the standard working day.

# Appendix 3 — Biological monitoring result form





Department of Consumer  
and Employment Protection  
Government of Western Australia

Resources Safety 

Resources Safety  
303 Sevenoaks Street  
Cannington WA 6107  
www.dcecp.wa.gov.au/ResourcesSafety  
contaminantmanager@dcecp.wa.gov.au

## Biological monitoring result form

Regulation 3.28 — Mines Safety and Inspection Regulations 1995

**Part A — Company details**

Company  Site name   
 Form completed by  Position   
 Telephone no.

**Part B — Employee details**

Surname  Given names   
 Date of birth / /   Male  Female  Company employee  Contractor employee  
 Contract company  Health surveillance number

**Part C — Results**

Date of collection / /

Type of specimen  Whole blood  Urine  Other

Contaminant  Lead  Arsenic — total or inorganic (please circle)  Mercury  Thallium  
 Vanadium  Other

Time collected  Not critical  Not critical, prior to shift  End of work week  
 End of shift at end of work week  Other

Result   µg/100 mL (whole blood)  mg/L  µg/g creatinine  
 Other

Laboratory conducting analysis  Chemistry Centre  PathCentre  
 Other

Reason for test  Routine  
 Special (e.g. monitoring conducted after removal from exposure)  
 Pre-employment — previous exposure within last 6 months?  Yes  No

Occupation code  Location code

Comments

Return forms to the Director — Health Management Branch, Resources Safety, 303 Sevenoaks Street, Cannington WA 6107

CONFIDENTIAL

RSDMarsic\_01mp

## Appendix 4 — Notification of outcome of health assessment

**Notification of outcome of health assessment - pro forma**

There is no specific notification form required when a medical practitioner or approved person is advising an employer of the outcome of an employee's health assessment, including biological monitoring. However, this form is designed to ensure that the notification process is completed satisfactorily without unnecessary delay, and is a useful guide for those notifying for the first time. If medical follow-up or risk assessment is recommended, please send a copy of the form to the Mines Occupational Physician at Locked Bag 14, CLOISTERS SQUARE WA 6850.

EMPLOYER (Principal)		
Company / organisation name:		
Site address:		
Site phone:	Site fax:	Contact name:
LABOUR HIRE (If worker is employed through Agency)		
Company / organisation name:		
Address:		
Phone:	Fax:	Contact name:
EMPLOYEE / WORKER (tick relevant box)		
Name:		
DOB:	<input type="checkbox"/> Male <input type="checkbox"/> Female	
Address:		
Current job:	Phone:	Mobile:
HEALTH ASSESSMENT		
MINEHEALTH (tick relevant boxes)		
INITIAL <input type="checkbox"/>	RESPIRATORY QUESTIONNAIRE	OK <input type="checkbox"/> Review <input type="checkbox"/>
	LUNG FUNCTION	OK <input type="checkbox"/> Review <input type="checkbox"/>
PERIODIC <input type="checkbox"/>	AUDIOMETRY	OK <input type="checkbox"/> Review <input type="checkbox"/>
	CHEST X-RAY	OK <input type="checkbox"/> Review <input type="checkbox"/>
<p><i>Identify any early or obvious signs of adverse medical symptoms that require either medical follow-up or further occupational hygiene assessment at the workplace to identify the potential source(s) of the observed health effects.</i></p> <p><i>If there is a need for any future medical follow-up, indicate above and record what activities you have undertaken so far. For example, if an employee's responses to the respiratory questionnaire and spirometry results indicate a prospective diagnosis of chronic obstructive pulmonary disease that requires referral to a specialist, tick 'Review', make a comment like 'suspected COPD' and record any remedial action that is recommended or undertaken already.</i></p>		
<b>Remedial action taken / recommended</b>		



BIOLOGICAL MONITORING & ADDITIONAL HEALTH SURVEILLANCE (tick relevant boxes)				
Contaminant	Test date	Result	Further action (Y/N)	Detail medical follow-up required
LEAD <input type="checkbox"/>				
MERCURY <input type="checkbox"/>				
ARSENIC <input type="checkbox"/>				
NICKEL <input type="checkbox"/>				
VANADIUM <input type="checkbox"/>				
CADMIUM <input type="checkbox"/>				
MANGANESE <input type="checkbox"/>				
OTHER <input type="checkbox"/> (list)				

Please request previous test results from employer to assess the risk from occupational exposures.  
 Is the employee new to high-exposure risk activities?  
 How long has the employee been exposed?  
 Has the employee been exposed to this or similar hazardous substances at other workplaces? If so, where and when?  
 If results are within 10% of the BEI or greater, specific action is recommended in Resources Safety's guideline on risk-based health surveillance and biological monitoring. If further action is required, please outline recommendations for remedial action and note what has already been done in the section below.

**Further advice and comments**

PERSON COMPLETING FORM (tick relevant box)

Full name:

Medical practitioner    Approved person    Other (describe)    Provider or approved person number:

Address:    Phone:    Mobile:

Signature:    Date:

# Appendix 5 — Notification of occupational disease form



Department of Consumer  
and Employment Protection  
Government of Western Australia

Resources Safety 

Resources Safety  
Locked Bag 14  
Cloisters Square WA 6850  
www.docep.wa.gov.au/ResourcesSafety

## Notification of occupational disease

Regulation 3.29 — Mines Safety and Inspection Regulations 1995

**Part A — Company details**

Company  Site name   
 Form completed by  Position   
 Telephone no.  Email

**Part B — Employee details**

Surname  Given names   
 Date of birth /   Male  Female  Company employee  Contractor employee  
 Contract company  Health surveillance number

**Part C — Disease details**

Description of disease

Person diagnosing disease *(Doctor or approved person)*

Date diagnosed /

Comments

Employer representative *(please print)*

Signature  Date /

Return to the Mines Occupational Physician, Resources Safety, Locked Bag 14, Cloisters Square, WA 6850

**Note:** 'occupational disease' means —

(a) a disease that is referred to in Schedule 3 — Specified industrial diseases of the *Workers' Compensation and Injury Management Act 1981*; or

(b) or any other condition that results from exposure in a workplace to agents or substances to the extent that the normal physiological mechanisms are affected and the health of the employee is impaired as a consequence.

SAMPLE ONLY

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## Appendix 6 — Exposure standards for personal exposure and biological monitoring



Substance	TWA ES (8 hrs)	Recommended sampling time	Biological media	ACGIH BEI (2007)	Comments
Arsenic (total and inorganic)	0.05 mg/m <sup>3</sup>	End of shift at end of work week	Urine	35 µg As/L (inorganic arsenic plus methylated metabolites in urine)	Seek medical advice if total arsenic exceeds 35 µg As/L
Cadmium and inorganic compounds		Not critical	Urine	5 µg Cd/g creatine	Seek medical advice when BEI exceeded
Cobalt		End of shift at end of work week	Urine	15 µg Co/L	Preferably collect samples at the same time of day on each occasion
Chromium (VI) (water-soluble fume, total)		End of shift at end of work week	Urine	25 µg Cr/L	Preferably collect samples at the same time of day on each occasion
Lead	0.15 mg/m <sup>3</sup>	Not critical	Blood	30 µg Pb/dL (whole blood) 10 µg/dL (whole blood) for females of reproductive capacity	<p>Medical removal levels:</p> <ul style="list-style-type: none"> <li>• 50 µg Pb/dL blood for all employees (excluding females of reproductive capacity)</li> <li>• 5 µg Pb/dL blood for females of reproductive capacity</li> </ul> <p>Medical assessment and certification to return to lead-risk work</p>
Mercury	0.025 mg/m <sup>3</sup>	Not critical	Urine	35 µg Hg/g creatine	<p>Preferably collect samples at the same time of day on each occasion</p> <p>Medical removal above BEI</p>
Thallium		Not critical	Urine	50 µg Th/g creatine	Preferably collect samples at the same time of day on each occasion
Vanadium	0.05 mg/m <sup>3</sup> as respirable dust and fume	End of shift at end of work week	Urine	50 µg V/g creatine	Preferably collect samples at the same time of day on each occasion

Note: Urine specimens that are highly dilute or concentrated are generally not suitable for monitoring. The World Health Organisation (WHO) adopts guidelines for acceptable creatinine concentrations of between 0.3 and 3.0 g/L of urine, or urine is to have a specific gravity between 1.010 and 1.030.

## Appendix 7 — Controlling exposure to toxic metals in the workplace

Control measures must prevent exposure, or where this is not practicable, minimise exposure to levels below the exposure standard. So far as reasonably practicable, employees must implement management measures that minimise exposure to all hazardous chemicals by applying the hierarchy of controls. This means PPE must not be the only form of control provided as it is only effective when used properly, kept clean and well maintained. It is also essential that employees understand the limitations of its use and are fully compliant with all other programs designed to control exposure.

The following list of best practice control measures will assist in establishing appropriate programs to minimise exposure.

### Information

- Provide information to job applicants about high-risk work.
- Ensure material safety data sheets (MSDSs) are readily accessible and employees are encouraged to review them.

### Training and induction

- All employees should be inducted ensuring that they fully understand the risks associated with all toxins they may be exposed to.
- Continually review the level of understanding by at-risk employees and regularly review the training methods.

### Supervision

- In addition to modelling excellent safety behaviour, supervisors must continually guide staff to minimise their exposures.

## Engineering controls

- Minimise generation of dust, fumes and vapours through engineering measures.
- Modify process temperatures or velocities.
- Enclose the process to ensure emissions are captured.
- Ventilate to extract hazardous chemicals away from the breathing zone of the employee.
- Ensure safe handling during maintenance of collection systems, such as baghouses, scrubbers or filtration units.



## Administrative controls

- Work organisation to include safe work practices, incorporating specific hygiene programs.
- Job rotation to limit the time a single employee is exposed to hazardous substances.
- Implement hygiene programs:

### *Designated clean and dirty areas*

- Clean areas such as offices, first aid and medical facilities, control rooms, stores and eating facilities or cribs must be kept free from contamination.
- Employees must not enter clean areas unless they have removed contaminated clothing.
- Soiled boots must be removed, cleaned or covered before entry into clean areas.
- Thoroughly wash face, fingernails, hands and forearms before eating or entering clean office areas.
- Vehicles in designated dirty areas must be washed down over an approved sump before leaving site, or moving into clean areas.
- Following initial and ongoing risk assessments of all higher risk activities, some areas will be designated, and appropriately signposted (Australian Standard AS 1319:1994 *Safety signs for the occupational environment*) as 'dirty areas'.

- Eating, drinking and smoking are prohibited in dirty areas.
- Open windows in vehicles or ‘clean enclosures’ are prohibited in dirty areas.

#### *Washing and changing facilities*

- Separate dirty (to undress and shower) and clean (to dress into clean clothes) changeroom and washing facilities.
- Employees to shower before leaving work to return either home or to residential accommodation.
- Contaminated work-clothes must not be worn off-site.
- On-site clothes washing facilities, with appropriate disposal of grey water.

#### *Cleaning*

- At least daily cleaning of floors and workbenches, around doorways of buildings, bath and changeroom facilities.
- Sweeping is prohibited — wet cleaning and vacuuming only.

### **Personal protective equipment**

- Respiratory protective equipment (RPE)
  - RPE should be properly selected for the individual and the task (Australian Standard AS 1715:1994 *Selection, Use and Maintenance of Respiratory Protective Devices* and Australian Standard AS 1716:2003 *Respiratory Protective Devices*).
  - RPE should be readily available for all employees in designated dirty areas.
  - Employees should be trained in how to clean and maintain RPE to ensure it is fully functional.

- Employees should be trained and supervised to correctly use appropriate RPE when required.
- Regular fit-testing should be incorporated into the RPE program.
- Protective clothing:
  - Protective clothing should be issued, maintained, and replaced at no cost to employee.
  - Protective clothing must reduce exposure to employees' bodies (including hands), ensuring environmental stressors are considered and heat stress is appropriately managed.
  - Personal preferences should be accommodated where possible to ensure that the PPE is used effectively.



### Emergency response

- Contingency planning for a leak, spill or uncontrolled release of hazardous substances is recommended.
- Emergency procedures to include:
  - first aid management of acute exposures
  - emergency containment
  - procedures for safe disposal
  - sufficient stores of PPE for emergency responders.
- Evacuation plans for non-responders to be excluded from contaminated area.



Resources Safety  
Locked Bag 14  
CLOISTERS SQUARE WA 6850

**General queries**

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