



Australian Government



## HAZARDOUS MATERIALS MANAGEMENT

*Leading Practice Sustainable Development  
Program for the Mining Industry*

September 2016



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Leading Practice Sustainable Development Program for the Mining Industry.

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# FOREWORD

The *Leading Practice Sustainable Development Program for the Mining Industry* series of handbooks has been produced to share Australia's world-leading experience and expertise in mine management and planning. The handbooks provide practical guidance on environmental, economic and social aspects through all phases of mineral extraction, from exploration to mine construction, operation and closure.

Australia is a world leader in mining, and our national expertise has been used to ensure that these handbooks provide contemporary and useful guidance on leading practice.

Australia's Department of Industry, Innovation and Science has provided technical management and coordination for the handbooks in cooperation with private industry and state government partners. Australia's overseas aid program, managed by the Department of Foreign Affairs and Trade, has co-funded the updating of the handbooks in recognition of the central role of the mining sector in driving economic growth and reducing poverty.

Mining is a global industry, and Australian companies are active investors and explorers in nearly all mining provinces around the world. The Australian Government recognises that a better mining industry means more growth, jobs, investment and trade, and that these benefits should flow through to higher living standards for all.

A strong commitment to leading practice in sustainable development is critical for mining excellence. Applying leading practice enables companies to deliver enduring value, maintain their reputation for quality in a competitive investment climate, and ensure the strong support of host communities and governments. Understanding leading practice is also essential to manage risks and ensure that the mining industry delivers its full potential.

These handbooks are designed to provide mine operators, communities and regulators with essential information. They contain case studies to assist all sectors of the mining industry, within and beyond the requirements set by legislation.

We recommend these *leading practice* handbooks to you and hope that you will find them of practical use.



**Senator the Hon Matt Canavan**

Minister for Resources and Northern  
Australia



**The Hon Julie Bishop MP**

Minister for Foreign Affairs



# 1.0 INTRODUCTION

## 1.1 Scope and background

Hazardous materials management is one of 17 themes in the Leading Practice Sustainable Development Program for the Mining Industry. The program aims to identify the key issues affecting sustainable development in the mining industry and to provide information that identifies sustainable approaches for the industry. The focus of this book is occupational health and safety as well as environmental issues associated with hazardous materials, such as minerals, process chemicals, dangerous goods, radioactive materials and wastes. The book has been written as a primary resource document with links to the many websites on legislation, guidelines and industry best practice.

Leading practice sustainable development management is an evolving discipline. It is important that it be flexible in developing solutions that match site-specific requirements. Although there are underpinning principles, leading practice is as much an approach and an attitude as a fixed set of practices or a particular technology.

The primary audience for this handbook is people working in mining, exploration and mineral processing who will come into contact with hazardous materials through their work activities. People with an interest in leading practice in the mining industry who will also find this information valuable include regulators, staff of non-government organisations, mining communities and students. It has been written to encourage people to play a critical role in continuously improving the mining industry's sustainable development performance.

## 1.2 Structure

The *Hazardous materials management* handbook has six sections:

- **Principles** has a particular focus on definitions, identifies sources of relevant Australian legislation and introduces the Globally Harmonised System (GHS) for defining hazardous chemicals.
- **Materials of concern** discusses many hazardous materials that may be encountered during mining (such as arsenic, lead, silica and more), materials imported to the site (such as processing chemicals), and substances and mining wastes that are generated during mining and processing.
- **Explosives** provides information on the codes covering explosives, including best practice during transport.
- **Transportation of hazardous materials** summarises legislation, particularly the revised marine transport codes affecting the shipping of mineral cargoes.
- **Managing risk** details actions required by legislation covering occupational health and safety (OHS) and the handling and storage of dangerous goods.
- **Performance management** presents information about techniques such as monitoring, reporting and auditing.

There are 17 handbooks in this series. Some discuss the management of hazardous substances, including the handbooks on:

- tailings management
- cyanide management
- preventing acid and metalliferous drainage.

The following handbooks deal with general principles of handling and managing hazardous materials:

- Mine closure
- Water stewardship
- Evaluating performance: monitoring and auditing
- Risk management.

While the primary consideration of hazardous materials management is worker health and safety, this handbook recognises the potential for impacts during mining and mineral processing on the natural environment and communities. All these impacts need to be identified, assessed and controlled to minimise and prevent adverse effects during the mine life cycle.

## 2.0 PRINCIPLES

### Purpose

This section includes the various definitions that may be applied to hazardous materials, the regulatory regime and the principles on which the identification and management of hazardous materials are based.

#### Key messages

- The Globally Harmonised System of Classification and Labelling of Chemicals is replacing the Safe Work Australia approved code for the classification of hazardous substances and will be mandatory after 1 January 2017.
- The correct classification is fundamental to hazard management.
- Not all hazardous materials are dangerous goods.
- New definitions for health and environmental hazards have been included in regulations.
- The risk-based approach to achieve compliance with the various regulations covering all types of hazardous substances requires the input of competent people.

### 2.1 Hazardous materials

Hazardous materials' is a term frequently used to cover one or more of:

- hazardous chemicals
- hazardous substances
- dangerous goods
- hazardous or controlled waste materials
- radioactive materials.

#### 2.1.1 Hazardous chemicals

Until 2002, there were several international schemes and definitions for describing chemicals with hazardous properties affecting people, the environment and assets. Under the auspices of the UN Economic Commission for Europe, an agreed set of protocols was approved to enable a consistent and transparent approach to classifying hazards of chemicals, known as the Globally Harmonized System of Classification and Labelling of Chemicals (GHS).<sup>1</sup> The book and testing protocols are revised periodically, so it is advisable to check the GHS website for the current information.

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<sup>1</sup> GHS, [http://www.unece.org/trans/danger/publi/ghs/ghs\\_welcome\\_e.html](http://www.unece.org/trans/danger/publi/ghs/ghs_welcome_e.html).

The GHS classification system has criteria for health, safety and environmental hazards. The criteria can be used to apply to minerals, chemicals, chemical mixtures and wastes.

### **Health**

- Acute toxicity—oral, dermal, inhalation
- Skin corrosion/irritation
- Serious eye damage/irritation
- Respiratory sensitisation
- Mutagenicity
- Carcinogenicity
- Reproductive toxicity
- Specific target organ toxicity (STOT)—single exposure
- Specific target organ toxicity (STOT)—repeated exposure

### **Environment**

- Aquatic acute toxicity
- Aquatic chronic toxicity
- Potential for or actual bioaccumulation
- Biodegradation (biotic or abiotic) for organic chemicals

### **Safety/physical hazards**

- Explosive solids
- Oxidising solids
- Flammable solids—readily combustible
- Flammable solids—self-reactive
- Flammable solids—pyrophoric substances
- Flammable solids—self-heating
- Flammable solids—self-heating—solids which evolve into flammable gas when wet
- Corrosive to metals.

These criteria are important in workplace transport, storage, use and handling of hazardous chemicals. In addition, they determine which chemicals require management plans to ensure the proper worker exposure controls, health surveillance, and the disposal of waste and hazardous chemicals that may cause unacceptable risk.

The GHS has now been adopted by Safe Work Australia as the basis for classification, safety data sheets and labels of chemicals and mixtures, including those that are mineral based. The GHS will be mandatory after 1 January 2017.

Mining and mineral/metal processing companies should ensure that new products such as mineral concentrates are tested and have a full report on the GHS classification hazards to meet the current legislative requirements.

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2 Safe Work Australia, <http://www.safeworkaustralia.gov.au/sites/swa/whs-information/hazardous-chemicals/pages/hazardous-chemicals-other-substances>.

## 2.1.2 Hazardous substances

Hazardous substances terminology and classification criteria were first introduced in 1994 with the NOHSC (National Occupational Health and Safety Commission) regulations to control exposure to chemicals; the NOHSC regulations were similar to the United Kingdom's COSHH (Control of Substances Hazardous to Health) regulations. The definition of hazardous substances was health based and used slightly different criteria from those in the GHS system.

## 2.1.3 Dangerous goods

Dangerous goods are substances or articles that, because of their physical, chemical (physicochemical) or acute toxicity properties, present an immediate hazard to people, assets or the environment. The classification of dangerous goods is based on the UN Economic Commission for Europe system.<sup>3</sup> Dangerous goods and transport are discussed in more detail in Section 5.

## 2.1.4 Radioactive materials and wastes

Radioactive materials such as uranium, mineral sands (containing uranium, thorium, or both) and naturally occurring radioactive materials are controlled through the various codes and publications issued by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA)<sup>4</sup> in accordance with the Australian Radiation Protection and Nuclear Safety Act and Regulations. Those documents have been developed from publications by the International Atomic Energy Agency.<sup>5</sup> ARPANSA codes are listed in Appendix 1.

The federal ARPANSA documents are incorporated into state regulations to address operational issues. More information is in Section 3.2.1 Under 'Radioactive materials' and Section 5.9

## 2.1.5 Hazardous/controlled waste material

These materials are categorised as the hazardous waste component of the waste streams which, by its characteristics, poses a threat or risk to public health, safety or the environment. It includes substances which are toxic, infectious, mutagenic, carcinogenic, teratogenic, explosive, flammable, corrosive and oxidising.

Transport of this material internationally is covered by Basel Convention, which is described in more detail in Section 5.

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<sup>3</sup> UN Economic Commission for Europe, <http://www.unece.org/trans/danger/danger.html>.

<sup>4</sup> ARPANSA, <http://www.arpansa.gov.au/>.

<sup>5</sup> IAEA, <https://www.iaea.org/>.

Transport of this material within Australia is covered by the individual state or territory environmental regulatory bodies. The state legislation is based on the National Environment Protection Council's Movement of Controlled Waste National Environment Protection Measure (NEPM).<sup>6</sup> The full listing of controlled waste categories is in Schedule A of the NEPM. Definitions to describe the classification of controlled and hazardous waste differ slightly between states, so it is advisable to refer to the relevant state regulatory body.

## 2.2 Legislation and regulations

Many pieces of legislation cover hazardous materials, such as the Acts and Regulations for workplace OHS, environmental protection, public health concerns, importing, exporting, transport and storage. This section briefly introduces the main documents.

In 1994, the NOHSC issued its first model Regulations for the Control of Workplace Hazardous Substances. The regulations were originally based on chemicals with health effects and used several criteria, including an occupational exposure standard. This was expanded to include materials classified using the European classification listing (General Classification and Labelling Requirements for Dangerous Goods and Preparations) or based on criteria in the NOHSC's Approved Criteria for Classifying Hazardous Substances.

The state governments adopted the NOHSC model regulations and standards into their occupational health and safety, dangerous goods regulations and mining-specific legislation.

In 2012, with the adoption of the new national model Work Health and Safety (WHS) Regulations, the classification system based on the GHS was introduced.

While the 'hazardous chemicals' of the GHS system used by the WHS Regulations replaces 'hazardous substances', the UN Dangerous Goods Classification System remains in place for international transport by air and sea, as well as land transport as applied in ADG Code 7.4. It also remains in place as the basis for explosives legislation. Special requirements under the Dangerous Goods Storage and Handling Regulations, controlled by state legislation, also apply to some dangerous goods.

Controlled waste transport and environmental risk are controlled by the state and federal environmental regulatory bodies.

### 2.2.1 Chemical imports

If a company plans to directly import chemicals for use at its site, it must comply with NICNAS (the National Industrial Chemicals Notification and Assessment Scheme).<sup>7</sup> If the chemical or the chemical components in the mixture are not registered in Australia, extensive toxicity data is needed for registration.

Companies that plan to directly import Class 1 explosives must obtain authorisation from the relevant state authority.

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<sup>6</sup> National Environment Protection (Movement of Controlled Waste between States and Territories) Measure, <http://www.scew.gov.au/nepms/movement-controlled-waste>.

<sup>7</sup> National Industrial Chemicals Notification and Assessment Scheme, [www.nicnas.gov.au](http://www.nicnas.gov.au).

## 2.2.2 Relevant state websites

State and territory government mining, environmental and natural resources authorities' websites list the jurisdiction's local OHS and environmental legislation:

<b>New South Wales</b>	<a href="http://www.resourcesandenergy.nsw.gov.au/">www.resourcesandenergy.nsw.gov.au/</a> <a href="http://www.epa.nsw.gov.au/">www.epa.nsw.gov.au/</a>
<b>Northern Territory</b>	<a href="http://www.nt.gov.au/d/Minerals_Energy/">www.nt.gov.au/d/Minerals_Energy/</a> <a href="http://www.worksafe.nt.gov.au">www.worksafe.nt.gov.au</a>
<b>Queensland</b>	<a href="http://www.dnrm.qld.gov.au/">www.dnrm.qld.gov.au/</a> <a href="http://www.ehp.qld.gov.au/">www.ehp.qld.gov.au/</a>
<b>South Australia</b>	<a href="http://www.safework.sa.gov.au/">www.safework.sa.gov.au/</a> <a href="http://www.minerals.dmitre.sa.gov.au/home">www.minerals.dmitre.sa.gov.au/home</a> <a href="http://www.epa.sa.gov.au/">www.epa.sa.gov.au/</a>
<b>Tasmania</b>	<a href="http://www.dpiwe.tas.gov.au">www.dpiwe.tas.gov.au</a> <a href="http://www.mrt.tas.gov.au">www.mrt.tas.gov.au</a> <a href="http://www.wst.tas.gov.au">www.wst.tas.gov.au</a>
<b>Victoria</b>	<a href="http://www.worksafe.vic.gov.au">www.worksafe.vic.gov.au</a> <a href="http://www.epa.vic.gov.au/">www.epa.vic.gov.au/</a> <a href="http://www.energyandresources.vic.gov.au">www.energyandresources.vic.gov.au</a>
<b>Western Australia</b>	<a href="http://www.dmp.wa.gov.au/">www.dmp.wa.gov.au/</a> <a href="http://www.epa.wa.gov.au/">www.epa.wa.gov.au/</a>

## 2.3 Risk management and material stewardship

The risk assessment process is inherent in all health, safety and environment legislation. The process has been comprehensively covered for the minerals industry in the leading practice handbook *Risk management*.

With increasing awareness of the potential hazards arising from the use or inappropriate disposal of hazardous materials, there is a need for risk assessments and proactive management over the life cycle of the minerals operation and the hazardous material. This can be summarised into the various stages of the operation:

- project concept
- project feasibility
- project design
- construction / acquisition
- commissioning
- operations
- maintenance

- modification
- disposal
- mine closure.

The materials stewardship value chain assists in the identification of chemical substances that are present in the ore supplied and used in mineral processing; emitted in primary mineral processing or downstream refining, smelting, and manufacturing; or emitted during disposal or recycling at the end of product life. The following questions can help to identify chemical substances that could affect human health or the environment:

- What are the chemical and mineralogical characteristics of the ore, overburden and waste at extraction, including valued substances and naturally occurring impurities?
- What chemicals are supplied and used in the mineral processing operation?
- How are the processing chemicals manufactured, transported and stored before use?
- What hazardous emissions occur in mineral or metal extraction and subsequent processing?
- How are emissions and discharges controlled?
- How are hazardous waste streams identified and managed?
- What impurities of interest are contained in the product that is sold and transported to customers?

Once this information has been collected, minerals supply chain (upstream and downstream) stakeholders who are interested in the hazardous material can be identified. Those stakeholders (community, regulators, suppliers, customers, manufacturers, transporters, plant operators) need to be provided with information on the hazardous material of interest, such as:

- the properties of chemical substances present, whether naturally occurring in the product or added
- possible exposure pathways and necessary controls to protect employees, the community and the environment
- available options for reducing, recycling, denaturing and disposing of priority substances
- emergency preparedness and response procedures
- responsibilities for correct transport, storage, handling and use procedures
- monitoring or managing requirements that will be ongoing and how they will be communicated.

Materials stewardship concepts provide a basis for defining the flow of hazardous materials related to mining and mineral processing, and this helps to identify stakeholders along the materials supply chain who may need to be involved in risk management activities.

While the initial steps of a materials stewardship approach provide useful data for risk management, the broader focus should be on managing material flows throughout the value chain in partnership with other users. This process provides powerful tools for managing overall risks to workers, the community and environmental health. The risk assessment process for hazardous materials is covered in more detail in Section 6.



## 2.4 Competency and expertise

Informed decisions throughout the risk management cycle require the input of competent people. Competence can be described as the combination of training, skills, experience and knowledge that a person has and their ability to apply them in practice.<sup>8</sup>

Depending on the hazards and risks under consideration, decision-making could involve contributions from a diverse group with technical, health, safety and environmental specialist skills, such as geologists, metallurgists, occupational hygienists, process safety engineers, environmental engineers and environmental scientists. In addition, as the operation develops, management and workers at the site will also develop competencies to ensure that the operation will remain safe in a variety of circumstances and through any changes that occur.

There have been many incidents in which decisions were made without sufficient engagement of competent people. Two of the most widely published accounts of such incidents is the *Report of the BP US refineries independent safety review panel* (frequently referred to as the Baker Report)<sup>9</sup> and the UK HSE's *BP Texas City incident: Baker review*.<sup>10</sup> The Baker Report focuses on the importance of competency to provide a safe operation.

Such incidents could have been prevented if management had engaged competent people during decision-making. There is an expectation in legislation and implied in the 'social licence to operate' principle that management will be informed about hazards, will apply appropriate risk controls and will implement an assurance process using competent people at each stage.

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<sup>8</sup> A useful reference on competence is UK Health and Safety Executive (HSE), <http://www.hse.gov.uk/competence/what-is-competence.htm>.

<sup>9</sup> Baker Report, <http://www.absa.ca/IBIndex/TheBakerPanelReport.pdf>.

<sup>10</sup> UK HSE, <http://www.hse.gov.uk/leadership/bakerreport.pdf>.

## 3.0 MATERIALS OF CONCERN

### Purpose

This section presents a brief description of hazards associated with many metals, minerals and process chemicals encountered in the mining industry.

#### Key messages

- Many minerals, chemicals and wastes encountered on mine sites are classified as hazardous using the GHS classification system.
- Consequently, many hazardous materials will be covered by legislation.
- Over their lives, mining and mineral processing operations create a number of different hazardous materials that need to be identified and controlled to protect workers, the environment and communities.

### 3.1 Introduction

Hazardous materials can occur at all stages of processing minerals, from exploration, mining and processing to transport, refining and smelting. Some materials originate from the ore body, others from chemicals used or generated during processing and degradation, and some remain in waste materials. The different types of hazards can occur at different parts of the mining and mineral processing operation's life cycle.

Section 3 has a comprehensive list of hazardous materials. Some hazardous materials occur naturally, some are by-products of production and some are used in production.

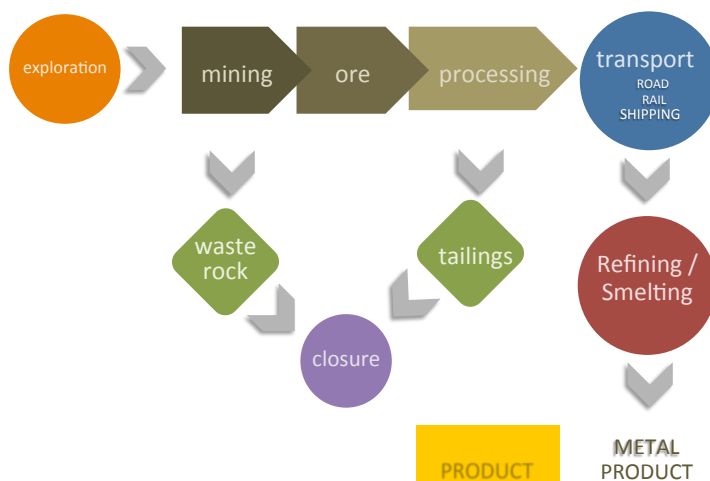
Where these materials occur, risk assessments are needed, followed by the implementation of appropriate controls and procedures. Monitoring will be needed to complete the risk management process and determine the effectiveness of the controls. Guidelines to support minerals industry risk assessments include HERAG (*Health risk assessment guidance for metals*) and MERAG (*Metals environmental risk assessment guidance*), both produced by the International Council on Mining and Metals (ICMM).<sup>11</sup> <http://www.icmm.com/>

The key stages of the mining and mineral processing life cycle are shown in Figure 1.

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<sup>11</sup> ICMM, <http://www.icmm.com/>.

Figure 1: The mining and mineral processing life cycle



### 3.1.1 Exploration

Geological survey maps, mineralogical data and discussions with site geologists should help to identify hazards and risks from naturally occurring hazardous materials and to develop procedures and systems for exploration work. For example, many areas of Western Australia are known to contain asbestiform minerals, and exploration companies in such areas should prepare an asbestos or fibrous mineral management plan. Considerations will include the need for personal air monitoring and the provision of personal protective equipment, as well as decontamination procedures and safe disposal of fibrous minerals.

### 3.1.2 Planning

Hazards from naturally occurring substances depend not only on the concentration of the substances but also on their chemical form and the surrounding environment. The water solubility of the minerals and by-products can be a critical factor in determining the hazard and risk. A risk assessment should determine whether mining can proceed without causing an adverse impact on human health or the environment.

Proper characterisation and hazard assessment will involve the use of experienced environmental geochemists and occupational hygienists. These professionals should be involved during the planning stage to prepare an appropriate management action.

### 3.1.3 Mining

Mining can produce considerable amounts of emissions unless appropriately designed control measures are applied. Airborne dust is typically controlled through ventilation and water sprays for dust suppression. Diesel-powered mobile equipment generates diesel particulate material (DPM), which is particularly hazardous during the development and operation of underground mines where ventilation is limited. HEPA (high-efficiency particulate arrestance) filtered air conditioning in mobile equipment cabins is fitted to reduce workers' respirable dust, silica and DPM exposures. When mining radioactive ores, consideration should be given to the management of possible radon accumulations in areas where there is low air movement.

Mining activities also produce waste rock, which is non- or sub-economic soil and weathered and unweathered rock that is extracted to gain access to the ore body. In many operations, especially open-cut mines, there can be significant quantities of waste rock stored in surface waste rock or overburden dumps. The materials in the dumps can be hazardous because they often contain minerals such as sulphides. Waste rock dumps have the potential to produce acid and metalliferous drainage, spontaneous combustion, dust, sediment run-off, contaminated leachate seepage and groundwater contamination.

As part of the mining activity, various materials are stored in stockpiles on site. They can be run-of-mine materials waiting to be processed, or marginally economic product waiting to be blended or for more favourable commodity prices. These stockpiles also have the potential to be hazardous, especially if they are left to weather and the mineralisation degrades, leading to similar issues to those outlined above for waste rock.

Wastewater produced during mining operations can sometimes be hazardous. It can have elevated levels of metals leached from mineralised zones and its discharge can be hazardous to ecological and sometimes human receptors.

### 3.1.4 Processing

This section describes some of the stages used in minerals processing and the hazardous materials used or created during those processes.

#### *Flotation*

Base metal, gold and other mining operations can use a flotation process to preferentially collect valuable minerals. Flotation processes generally use specific chemicals, such as xanthates or related dithiophosphates, to preferentially collect the required minerals. Potentially toxic gases such as carbon disulphide and mercaptans (organic sulphur compounds, which are odorous and can be smelt at very low levels), may be generated. Other chemicals that may be used in flotation include carbinols and lead salts, each of which requires exposure management.

The flotation process produces fine-grained waste materials (tailings) after separation of the concentrates. Tailings are typically produced in slurry form and deposited into storage facilities or dams. Tailings from metalliferous ores contain sub-economic mineralisation plus accessory minerals (for example, sulphide minerals, often in high concentrations), metal ions and process chemicals. Processing coal generates fine- and coarse-grained rejects, which may contain sulphide minerals and metal ions, including aluminosilicate that may be a source of aluminium in acidic mine drainage. Dry tailings surfaces can also produce dust hazards.

Prolonged storage of metal concentrates may result in the oxidation of sulphides (along with auto-heating) producing sulphur dioxide or the decomposition of xanthates, particularly in acidic conditions. Concentrates are also potentially hazardous due to their high metal content.

#### *Leaching*

Hazardous materials can be used and generated during heap leaching. The ore is crushed to a nominal particle size, stacked on lined pads, and irrigated with a leaching solution, such as cyanide for gold ores or sulphuric acid for copper ores. When the process is complete, the heap leach pads are decommissioned and the remnant material becomes a mine waste product. A variation on the heap leach pad is the dump leach, in which low-grade ore is placed in a stockpile and irrigated with a leaching solution in an operation similar to heap leaching.

Cyanide leaching of gold ores generally occurs in carbon-in-pulp or carbon-in-leach tanks where pH control is important to minimise the generation of hydrogen cyanide (HCN). The greater the level of dissolved solids in the process water, the more difficult it is to maintain a high slurry pH to reduce HCN generation. Fixed alarms or personal monitors are often used to warn of elevated HCN levels

Dissolved gold is then collected on activated carbon, which is screened, acid washed to remove salts, and then treated with hot caustic cyanide to leach the gold. The gold may be collected by electro-winning, which can also collect mercury if mercury is present in the ore. The regeneration of activated carbon can generate ammonia in the kiln, while HCN can be generated from the barren liquor if it is acid neutralised at tails screens.

### *Roasting*

Roasting sulphide concentrates can produce large quantities of sulphur dioxide, which can be oxidised to sulphur trioxide to then produce sulphuric acid. Uncontrolled releases of sulphur dioxide may adversely affect mine employees, communities and the environment. Some mines also burn sulphur to make sulphuric acid.

### *Calciners*

Calciners can generate a large variety of volatile compounds from organic materials. Effective scrubbers, electrostatic precipitators or other controls may be needed, as stack discharges can potentially travel long distances and affect communities. Most stack discharges from scrubbers, calciners, roasters, kilns and the like generally require some form of treatment to minimise environmental impacts. This may include water scrubbers, electrostatic precipitators, bag houses or other filters. Some toxic by-products, such as oxalate, can be destroyed by microbial action. In-line stack monitors can be designed to warn if pre-set emission or licence levels are exceeded. Common stack discharges from process plants and refineries requiring treatment include acid gases (sulphur oxides, nitrogen oxides), arsenic, heavy metals and carbon monoxide.

### *Solvent extraction*

Solvent extraction is used in several areas, including nickel-cobalt and uranium operations. Large quantities of flammable reagent carriers such as kerosene could present fire risks within process plants and refineries.

## **3.1.5 Transport**

Bulk concentrate and ores that are transported by ships have moisture content even though they may look dry and granular. Depending on the material, this will be a result of processing, in some cases rainfall, or spraying to control dust emissions. The transportable moisture limit (TML) is a critical control factor to avoid liquefaction in bulk dry cargoes, which can lead to the cargo shifting and even to the ship capsizing.

## 3.2 Hazardous materials

The following two sections refer to specific hazardous materials that often occur in the mining industry. Although this list does not include all hazardous materials, it provides an insight into health and environmental effects and lists some key information sources.

### 3.2.1 Naturally occurring hazardous materials

#### *Aluminium*

Significant occupational and environmental hazards are associated with the production of aluminium. The refining of bauxite to produce aluminium oxide (alumina) generates significant quantities of fine waste residue ('red mud') that has the potential for environmental impact due mainly to its high alkaline pH.

There is also exposure to fluorides, which have been linked to a form of airway disease known as 'pot room asthma', associated with the smelting of alumina into aluminium. The smelting of alumina includes the production of anodes formed from coal tar pitch and baked in a coal-fired furnace. There is the potential for exposure to carcinogenic polycyclic aromatic hydrocarbons during the handling of coal tar pitch, and skin contact with the pitch will lead to UV sensitivity. Because of the sulphur content of coal, the baking of the anodes can lead to sulphur dioxide exposures for overhead crane operators moving anodes in and out of furnaces and for operators tending the furnaces. There is also the potential for elevated inhalable and respirable dust exposures during anode furnace and potline maintenance.

Long-term inhalation of aluminium powder has been associated with pulmonary fibrosis. Impairment of cognitive function, motor dysfunction and peripheral neuropathy have been reported in workers exposed to aluminium in the workplace. Aluminium powder is also highly flammable. It is used in the pyrotechnic and paint industries.

The management of fluoride exposure through health surveillance is an important part of exposure control. The International Aluminium Institute provides guidance on the assessment of work-related asthma for aluminium workers.<sup>12</sup> Alumina smelting can have environmental impacts if fluoride emissions are not controlled to acceptable limits.

#### *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 and historically known as the 'king of poisons and poison of kings'. 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 compounds are less toxic.

In many regions, inorganic arsenic, as arsenopyrite (FeAsS), is the most common occupational source of arsenic. Ore can contain arsenopyrite as an impurity, and copper deposits can contain enargite (Cu<sub>3</sub>AsS<sub>4</sub>). The toxicity of arsenic minerals in dust is generally low because of low solubility and bioavailability. Bioaccessibility testing can be performed to provide information on the bioavailability of the arsenic in the mineralogy.

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<sup>12</sup> International Aluminium Institute, <http://www.world-aluminium.org/>.

However, when the ores are processed, such as at a refinery or smelter, the arsenic can be converted to arsenic trioxide ( $\text{As}_2\text{O}_3$ ), which is readily bioavailable and much more toxic. The arsenic trioxide is collected from the stack dusts, but can be inadvertently released into the atmosphere during the maintenance of scrubbing equipment and waste handling. Table 1 summarises the types of arsenic compounds and where they are found.

Table 1: Arsenic compounds

<b>TYPE OF ARSENIC COMPOUND</b>	<b>CHEMICAL COMPOSITION</b>	<b>LOCATION</b>
Arsenopyrite	$\text{FeAsS}$	An impurity in ore
Enargite	$\text{Cu}_3\text{AsS}_4$	Associated with some copper deposits
Arsenic trioxide	$\text{As}_2\text{O}_3$	Collected from stack dusts

Inorganic arsenic is mainly absorbed via the respiratory tract following inhalation. However, if workers do not wash effectively before smoking, eating or drinking, 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.

Acute arsenic poisoning affects the nervous and cardiovascular systems. Chronic exposures can result in liver damage as well as cardiovascular and central nervous system effects. Arsenic has been classified by the International Agency for Research on Cancer as a Group 1 human carcinogen.<sup>13</sup>

<sup>13</sup> IARC, <http://www.iarc.fr/>.

## Case study: Management of arsenic minerals at the Yerranderie mine site

Yerranderie is a historic abandoned silver–lead mining town south-west of Sydney near the World Heritage listed Blue Mountains National Park. The site is about 12 km upstream from Sydney’s major water supply dam, Warragamba. Mining at Yerranderie occurred between 1898 and the 1930s and recovered significant quantities of silver, lead and gold. There was minimal rehabilitation after mining ceased.

In 2003, intensive environmental studies found that small areas of the site had arsenic contamination levels that were potentially hazardous to human health and the surrounding environment, in particular Warragamba Dam. At some locations, the material contained up to 25% arsenic. Fencing and signage around those areas was a temporary solution to protect the health and safety of visitors to the historic site, but a robust longer term management solution was required.

The arsenic-contaminated material was classified as hazardous waste, and the requirements for handling, transporting and disposing of it were investigated in detail. Among a number of potential remediation options, the best was the ‘Dolocrete treatment’—a chemical fixation and immobilisation technique. The NSW Department of Environment and Climate Change provided a specific immobilisation approval that permitted the use of that technique. The aim was to immobilise the arsenic in the mineral matrix using a magnesium oxide based binder. This would allow the reclassification of the material from hazardous to industrial waste, for disposal to a licensed waste facility. The desired rehabilitation outcome was to significantly reduce the potential risks to human health and the impact on the surrounding environment.

To manage the potential OHS risks to workers during the project, full time project and OHS supervisors were engaged to ensure that all works were carried out in accordance with the approved OHS management plan.

After around 101 tonnes of the material was stabilised, laboratory analysis confirmed that the treatment effectively reduced the mobility of the arsenic (and changed the waste classification from hazardous to industrial). The material was then disposed of at a licensed waste facility. The project was completed using clean soil from the site to reshape the remediated area so that it was free-draining and landscaped in harmony with the amenity and fabric of the surrounding heritage site.

The project substantially rehabilitated the Yerranderie site, reducing risks to the surrounding environment and Sydney’s water supply and improving safety for visitors and tourists.



*Fencing and signage were not a long-term management solution.*



*Part of the mining heritage at Yerranderie.*

Source: NSW Department of Industry, Skills and Regional Development.



## Asbestos and asbestiform materials

Asbestos is the general name applied to asbestiform minerals belonging to the serpentine and amphibole mineral groups. These minerals have a particular kind of fibrosity—their fibres have a high tensile strength and flexibility (see Table 2).

**Table 2: Asbestiform and non-asbestiform minerals**

ASBESTIFORM VARIETY	CHEMICAL COMPOSITION	NON-ASBESTIFORM VARIETY
<i>Serpentine group</i> Chrysotile (white asbestos)	$Mg_3(Si_2O_5)(OH)_4$	antigorite, lizardite
<i>Amphibole group</i> Crocidolite (blue asbestos)	$Na_2Fe_3Fe_2(Si_8O_{22})(OH,F)_2$	riebeckite
Amosite (grunerite) (brown asbestos)	$(Mg,Fe)_7(Si_8O_{22})(OH)_2$	cummingtonite-grunerite
Anthophyllite	$(Mg,Fe)_7(Si_8O_{22})(OH,F)_2$	anthophyllite
Tremolite	$Ca_2Mg_5(Si_8O_{22})(OH,F)_2$	tremolite
Actinolite	$Ca_2(Mg,Fe)_5(Si_8O_{22})(OH,F)_2$	actinolite

Serpentine and amphibole minerals are found in mafic and ultramafic rocks of the 'greenstone' belts in Western Australia that host major nickel and gold deposits, as well as other mafic and ultramafic rocks elsewhere in Australia. Rarely, these minerals are asbestiform and, if they are present, they usually occur in veins or small veinlets. Such occurrences are usually small and isolated and are therefore not often noticed. The most well-known asbestos deposits are near Wittenoom in the Pilbara region of Western Australia and at Woodsreef near Tamworth in New South Wales.

Where asbestiform minerals are encountered, airborne asbestos fibres may appear as a minor/trace contaminant in the dust produced during blasting, crushing and subsequent handling and processing. Concern about the effect on health from long-term, low-level exposure to asbestos requires that appropriate procedures be applied wherever asbestiform minerals are encountered to ensure that exposures are as low as is reasonably practicable. It is the responsibility of the mine operator to ensure that mining operations provide a safe and healthy work environment.

Imports of asbestos into Australia are banned; however, the use of this hazardous material is not always banned in other countries. Hence, asbestos can occasionally be encountered as a component of gaskets, seals and insulation material in equipment imported from overseas. Purchase specifications for new equipment should include a clause saying that no asbestos or asbestiform products are to be used in the assembly of the equipment. Export from Australia of asbestos and goods containing asbestos is prohibited, except where the asbestos exists as a naturally occurring trace element in a raw material.

Asbestos may be on site from old plant equipment, including asbestos cement sheets in old buildings on the leasehold, as backing on vinyl floor coverings and in buried pipework. Asbestos lagging is seldom employed on pipework these days, but some old plants may still contain it. Similarly, friable asbestos may be found in old switchboard backings. Asbestos regulations have been gazetted in all states based on recognition, evaluation and control. In addition, they place restrictions on its removal and disposal of asbestos-containing materials. Where asbestos and asbestiform materials have been identified, all operations should have an asbestos register and an asbestos management plan.

Safe Work Australia defines a respirable asbestos fibre as one with a diameter of less than three microns (1 micron = 1/1000 millimetre), a length greater than five microns and a length-to-width ratio greater than 3:1. For comparison, a human hair is approximately 20 to 100 microns wide. With asbestos, the size of the particle is critical in determining whether there will be a risk to health from inhaling the fibres. Fibres around 10 microns or less long and 3 microns or less wide are most likely to remain in the lungs. Fibres larger than that tend to be removed by the normal clearing mechanism of the lungs.

People occupationally exposed to asbestos have developed several types of life-threatening diseases, including asbestosis (fibrosis of lung tissue), lung cancer and mesothelioma (an aggressive cancer affecting the membrane lining of the lungs and abdomen).

## Case study: Asbestiform materials in minerals

Expert guidance and a robust management program are needed wherever asbestiform minerals are encountered, to ensure that exposures are as low as is reasonably practicable. Asbestos is a known carcinogen and is regarded with zero tolerance by workers, regulators and the community. It is a banned substance in many countries.

To minimise the potential risks from asbestiform material, a competent person (such as a geologist or mineralogist) should analyse exposed rock during the initial studies into the ore body to determine the presence and extent of asbestos.

An asbestos management plan can then be developed for the risk areas determined through asbestos exposure monitoring. The plan should include the following:

- provision of information, instruction, training and supervision to all employees
- development of written procedures
- arrangements for the monitoring of airborne fibre levels
- arrangements for the regular surveillance of all mined rock to ensure minimal disturbance of fibrous material
- arrangements for access to all areas containing fibres to be strictly controlled and monitored
- to the extent that is reasonably practicable, arrangements for the suppression of dust at source and the isolation of workers from dust by the provision of appropriate equipment and facilities, plus the introduction of dust containment, collection and handling facilities to minimise airborne fibre levels
- arrangements for the implantation of approved disposal procedures for fibrous waste.

The Western Australian Department of Mines and Petroleum has developed comprehensive reference sources on asbestiform materials.<sup>1</sup> In addition, Safe Work Australia has published the model code of practice *How to manage and control asbestos in the workplace*.<sup>2</sup>

Sources: WA Department of Mines and Petroleum and Mr A Roger, OH&S Pty Ltd.

1 WA Department of Mines and Petroleum, reference sources for asbestiform materials, <http://www.dmp.wa.gov.au/Safety/Guidance-about-fibrous-mineral-6877.aspx>.

2 Safe Work Australia, *How to manage and control asbestos in the workplace*, <http://www.safeworkaustralia.gov.au/sites/swa/about/publications/pages/manage-control-asbestos-cop>.

## *Cadmium*

Cadmium is found naturally as cadmium sulphide in greenockite. It is produced commercially as a by-product of the smelting of the sulphide ores of zinc, lead and copper ores. Occupational exposure occurs in processes involving the handling of cadmium metal or its salts, or when thermally generated cadmium fumes occur in the workplace, such as in smelting. A potential source of substantial exposure is welding and thermal cutting of cadmium-plated metal products.

Cadmium is very toxic. Although absorption of ingested cadmium is poor (about 5%), up to 50% of inhaled cadmium is absorbed. Cadmium is concentrated in the liver and kidneys. Following inhalational exposure to cadmium, the principal toxic effects are on the lungs. Toxicity is initially characterised by dyspnoea (shortness of breath), cough and chest tightness; pulmonary oedema (build-up of fluid in the lungs), which may develop within 24 hours of exposure; and proliferative interstitial pneumonitis, which may occur 3–10 days following exposure. Cadmium is a cumulative toxicant and affects the kidneys. The half-life of cadmium in human kidneys is probably 10–20 years. Signs of renal dysfunction are the first indications of chronic cadmium toxicity. Cadmium has been classified by the IARC as a Group 1 human carcinogen.

More information is on the International Cadmium Association website.<sup>14</sup>

## *Coal, Also see Silica - Respirable Crystalline Silica section*

Coal mining can result in exposure to hazardous levels of coal dust and respirable crystalline silica (RCS).<sup>15</sup>

Most coal seams contain low levels of RCS (less than 5%), and generally exposures to RCS while mining the coal seam are below current occupational exposure limits. However, significant exposures to RCS can occur due to the need to mine through stone (non-coal) faults, roof or floor material, in which the percentage of RCS can be considerably higher. Even when not mining through stone, there is a risk of RCS exposure for roof bolters when installing roof and rib (wall) supporting mesh and bolts. Elevated exposure to RCS can lead to silicosis and lung cancer see Section: Silica- Respirable Crystalline Silica.

Elevated exposure to coal dust can lead to coal worker's pneumoconiosis, (CWP), (see Case study: The control of pneumoconiosis in the New South Wales coal industry, Section 6), and to chronic obstructive pulmonary disease, a serious, progressive and disabling condition that limits airflow in the lungs.

The risk of elevated exposure to coal dust and RCS is particularly high in underground mining (such as longwall and development panels), but surface operations such as drilling and blasting, geological sampling and some maintenance activities can result in elevated dust exposures.

Coal dust exposures and RCS exposures are assessed by measuring the respirable fraction of dust (in Australia using the methodology defined in AS2985-2009).

Coal mining can also entail elevated exposure to inhalable dust for workers involved in ancillary activities underground, such as building ventilation stoppings, installing support services such as pipework and installing additional roof support. In addition, elevated exposures to inhalable dust can occur in production activities such as long wall and development.

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<sup>14</sup> International Cadmium Association, <http://www.cadmium.org/>.

<sup>15</sup> See also 'Silica respirable crystalline silica'.

The Queensland Mines Department website has a comprehensive resource on preventing dust-related diseases.<sup>16A</sup> The website will include new documents developed in 2016 titled “Dust Control in Underground Coal Mines” and “Monitoring Respirable Dust in Coal Mines”. In addition, information addressing Coal Workers Pneumoconiosis can be found on the Queensland Government website.<sup>16B</sup>

Coal is an organic material and prone to spontaneous combustion. The most significant risk from combustion is that it may provide a spark for a methane gas explosion if gas levels enter the explosive range, leading to a coal dust explosion and possible loss of lives. The spontaneous combustion of coal emits a range of organic and hydrocarbon compounds, of which polycyclic aromatic hydrocarbons (PAHs) are of particular concern. While the risk of elevated exposure is low due to dilution by air on the surface or underground, contact with surfaces by rescue workers after a major coal mine fire or explosion can lead to ultraviolet skin sensitivity due to the PAHs on those surfaces.

In addition, spontaneous heating or combustion of coal can be a critical hazard in large coal stockpiles and waste rock dumps. When coal is exposed to oxygen, its temperature rises and it generates heat, promoting further oxidation, which can cause it to ignite suddenly. During the oxidation process, a number of toxic gases can be liberated in significant concentrations. There is a risk that personnel working in and around such areas may be exposed to toxic gases, particularly carbon monoxide and to a lesser extent sulphur dioxide. In 2012, several surface coal mines in Queensland experienced the release of toxic gases associated with spontaneous combustion. More information is on the *Mines Safety Bulletin* website.<sup>17</sup>

## Copper

Australia has about 13% of the world’s economic copper reserves and is ranked second after Chile (27%) and just ahead of Peru (10%). The main sulphide ore minerals of copper in Australia are chalcopyrite ( $\text{CuFeS}_2$ ), bornite ( $\text{Cu}_5\text{FeS}_4$ ), covellite ( $\text{CuS}$ ) and chalcocite ( $\text{Cu}_2\text{S}$ ). Copper concentrate is produced from the ore, processed in a smelter and then refined, normally by electrochemical means. The major source of copper exposures at copper smelters is the fumes.

Copper ores are associated with high silica content, and there is potential for elevated exposure to respirable crystalline silica during copper mining, particularly in crushing and hauling underground and in the crushing and grinding circuit of the concentrator stage of processing. Other elements that may be associated with copper, such as uranium or arsenic, are often hazardous materials that need to be managed in the waste stream.

In copper smelting, there is potential for exposure to sulphur dioxide during the roasting stage and for arsenic exposure during smelting. The final stages of copper cathode production, in which copper matte is converted to copper metal, can result in emissions of sulphur dioxide if controls are not adequate.

Copper is also produced through heap leaching followed by solvent extraction and electro-winning. There is the potential for exposure to sulphuric acid mist, a human carcinogen, for workers tending the electro-winning cells. In 1992, IARC classified strong acid mists containing sulphuric acid as a Group 1 human carcinogen. In 2012, it reaffirmed that classification for ‘mists from strong inorganic acids’, noting that such mists cause cancer of the larynx.

Copper is an essential trace element that is required for plant, animal, and human health. It is incorporated into a variety of proteins and metallo-enzymes that perform essential metabolic functions. Exposure to elevated levels of copper may result in nausea, vomiting, abdominal pain and diarrhoea. High levels may damage the liver and may also cause the destruction of red blood cells, possibly resulting in anaemia.

<sup>16A</sup> Queensland Mines Department, Preventing dust-related lung diseases, <https://www.dnrm.qld.gov.au/mining/safety-and-health/alerts-bulletins-search-tool/alerts-bulletins-search/alerts-bulletins/mines-safety/preventing-dust-related-lung-diseases>.

<sup>16B</sup> Queensland Business and Industry Portal, Coal Workers Pneumoconiosis, <https://www.business.qld.gov.au/industry/mining/safety-health/mining-safety-health/medical/pneumoconiosis>

<sup>17</sup> *Mines Safety Bulletin*, no. 120, 2012, <https://www.dnrm.qld.gov.au/mining/safety-and-health/alerts-bulletins-search-tool/alerts-bulletins-search>.

The adverse effects of copper are usually environmental, as it is considered to be among the most toxic of the heavy metals to freshwater and marine biota. It is a key metal to analyse when performing tests for aquatic toxicity required as part of product stewardship, for example the transport of new copper concentrates. More information is available from the European Copper Institute website.<sup>18</sup>

### *Iron ore*

Iron ore consists mainly of iron oxides, and the main forms mined are magnetite ( $\text{Fe}_3\text{O}_4$ ) and hematite ( $\text{Fe}_2\text{O}_3$ ). The major constituent impurities are quartz, phosphorus, alumina and sulphur. Other minor constituents often found in iron ore include riebeckite (blue asbestos), titanium, vanadium, zinc, copper and more rarely chromium, nickel, arsenic, lead, tin and cadmium. Amounts of those substances vary considerably from one ore to another. Iron's physical properties are that it is a reddish-brown solid, is not combustible and is insoluble in water.

Health hazards that arise due to exposures to the ore dust vary considerably because of its variable composition in different mines. Iron oxide and silica predominantly contribute to its toxicological properties. Animal experiments involving intratracheal instillation found that iron oxide exhibited low toxicity and caused much less inflammation and damage compared to crystalline silica. Iron ore has not been classified as a carcinogen.

### *Lead*

Lead mineralisation in ore bodies generally occurs as lead sulphide (galena,  $\text{PbS}$ ), but can also be present as lead carbonate (cerussite,  $\text{PbCO}_3$ ). Lead carbonate is soluble in water and inherently bioavailable and more toxic than lead sulphide, which has low water solubility. There are risks of lead exposure during mining, particularly underground mining, concentrate storage facilities, and smelting and refining operations.

Lead is also used as a reagent in the form of lead nitrate in float operations and litharge ( $\text{PbO}$ ) at gold fire assay laboratories. Fume extraction systems are needed to remove lead fumes from the muffle furnaces, as well as cleanliness in the gold fire assay laboratories to reduce lead exposures.

Lead exposures can occur from inhalation of dust or fumes, as well as ingestion resulting from a lack of poor personal hygiene, such as smoking or eating with contaminated hands.

State lead regulations apply to lead mining and processing. Regulations specify monitoring both occupational exposure to airborne levels and workers' blood lead levels to prevent adverse health effects. Where lead is a risk in the workplace, the site is expected to have a procedure that details the hazards and locations of the lead, monitoring requirements for both air and blood lead levels, and control requirements. Decontamination facilities and the company laundering work clothes are important aspects for cleanliness and preventing lead contaminants being taken home by workers.

Lead exposures may cause worker, environmental and community health issues. Particularly susceptible populations are pregnant women and children because of the effects of lead on the nervous system and on mental development in children.

Lead is classified as a teratogenic chemical because of effects on the unborn foetus. It can cross the placental barrier, which means that pregnant women who are exposed to lead also expose their unborn children. Lead can damage the developing baby's nervous system. Even low-level lead exposures in

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<sup>18</sup> European Copper Institute, <http://www.copperalliance.eu/>.

developing babies have been found to affect behaviour and intelligence. Lead exposure may cause miscarriages, stillbirths, and infertility.

Lead poisoning can happen if a person is exposed to elevated levels of lead over a short or long period. Symptoms include abdominal pain, constipation, fatigue, headache, irritability, loss of appetite, memory loss, and pain or tingling in the hands and/or feet. Because the symptoms can occur slowly or be caused by other things, lead poisoning can be easily overlooked. Exposure to high levels of lead can cause anaemia, weakness and kidney and brain damage.

Lead affects the central nervous system of animals and inhibits their ability to synthesise red blood cells. Lead can also be absorbed by plants from the soil, with most of the lead retained in their roots; there is evidence that plant foliage can also take up lead.

Lead has been classified by the IARC as a Group 2A carcinogen (a probable human carcinogen).

More information is on the International Lead Association website.<sup>19</sup>

## *Manganese*

The main manganese minerals are pyrolusite ( $MnO_2$ ), manganite ( $MnO(OH)$ ), and rhodochrosite ( $MnCO_3$ ). Manganese is the fourth most used metal after iron, aluminium and copper, by tonnage. Approximately 90% is used as an alloying agent in steel production; most of the rest is used in foundry and welding applications.

Workplace exposure to manganese occurs during mining, in the production of alloys, from welding activities and in other sectors such as battery production. Exposure is primarily due to inhalation of particulate matter containing variable concentrations of manganese.

Ferromanganese and silicomanganese are typically produced by smelting in an electric induction furnace, where the higher manganese oxides are reduced to manganese oxide by carbon monoxide, so there is potential for exposure to elevated levels of carbon monoxide.

Long-term exposure to high levels of manganese is known to result in severe neurotoxic symptoms, some of which resemble idiopathic Parkinson's disease; this condition, known as 'manganism', seems to be of a historical nature as physiological changes associated with it are no longer seen because workplace exposure has significantly decreased since the 1970s. More information is on the International Manganese Institute website.<sup>20</sup>

## *Mercury*

Historically, mercury amalgamation was the main method of extracting gold (and silver) from quartz reef and lode deposits. Mercury was also used to catch very fine gold during alluvial mining. Although other methods of gold recovery have been developed such as the cyanide process, mercury can still be found in small or artisanal operations. Workplace concentrations of mercury should be monitored routinely where exposure is possible such as through direct reading instruments and biological monitoring of workers. Mercury exposure may occur when ores contain trace amounts of mercury, for example (1) when some zinc concentrates are roasted, (2) when old gold tailings are retreated and (3) because some types of gold deposits, particularly epithermal gold deposits, can have high naturally occurring mercury.

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<sup>19</sup> International Lead Association, <http://www.ila-lead.org/>.

<sup>20</sup> International Manganese Institute, <http://www.manganese.org/>.

Symptoms of high exposures to inorganic mercury include: skin rashes and dermatitis; mood swings; memory loss; mental disturbances; and muscle weakness. High exposures to mercury vapour can also include kidney effects, respiratory failure and death.

Environmental effects of mercury include toxicity to, and bio-accumulation in, fauna.

A review by the IARC found that metallic mercury and inorganic mercury compounds are not classifiable as to their carcinogenicity to humans, Group 3.

## *Methane*

Methane is a colourless, flammable, non-toxic gas that has no odour in its pure state. Methane is the major component of natural gas and is found in varying levels in most coal and shale deposits. It is a simple asphyxiant due to its ability to displace oxygen from air where sufficient quantities exist. It is commonly encountered in coal seams and is a well-known explosive hazard. Adequate ventilation can minimise the risk. In some cases, the coal seam methane is collected for use as fuel.

Methane and other flammable gases can occasionally be encountered when drilling in underground metalliferous mines. Methane can be monitored using a wide range of portable gas detectors.

## *Mineral sands*

Australia has extensive deposits of mineral sands, which consist of:

- titanium minerals: rutile ( $\text{TiO}_2$  with up to 10% iron); ilmenite ( $\text{FeTiO}_3$  with some manganese and magnesium); and leucoxene (hydrothermally altered ilmenite)
- zircon (zirconium silicate,  $\text{ZrSiO}_4$ ), which may have traces of uranium and thorium (up to 1%) in the crystal structure, along with hafnium
- monazite: a rare earth phosphate containing a variety of rare earth minerals (particularly cerium and lanthanum) and 5–12% (typically about 7%) thorium
- xenotime: yttrium phosphate with traces of uranium and thorium.

An important occupational health issue of specific relevance to the mineral sands industry is radiation (see also 'Radioactive materials'). In ore or general heavy mineral concentrate the radiation levels are too low for radioactive classifications. However, when the radioactive material is concentrated during the separation and production of monazite, the radiation levels are increased, creating the need for special controls to protect some designated employees in dry separation plants.

The most significant potential radiation problem is alpha radiation arising from thorium in airborne dust, which may be inhaled. Dust control is therefore the most important objective in radiation safety for the titanium minerals industry. This contrasts with other industries, where the focus for radiation protection has been direct gamma radiation from materials in rock. Exposure to gamma radiation still needs to be controlled in the mineral sands industry, due mainly to uranium and thorium in zircon and monazite.

References include the World Nuclear Association, UK, Code of Practice and Safety Guide for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing, Code of Practice and Safety Guide for Radiation Protection, Radioactive Waste Management in Mining and Mineral Processing (2005)<sup>21</sup>, Radiation Protection Series No. 9, Australian Radiation Protection and Nuclear Safety Agency (August 2005)<sup>22</sup>.

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<sup>21</sup> World Nuclear Association, *Occupational safety in uranium mining*, 2014, <http://www.world-nuclear.org/information-library/safety-and-security/radiation-and-health/occupational-safety-in-uranium-mining.aspx>.

<sup>22</sup> ARPANSA, Radiation Protection Series Number 9, <http://www.arpansa.gov.au/pubs/rps/rps9.pdf>

Other issues associated with mineral sands mining include dust generation (see Section 3.2.2, 'Air particulates') and RCS (see 'Silica').

## *Nickel*

Australia is a major nickel producer. More than 80% of nickel production is used in alloys, and about 65% of world nickel output is consumed in the manufacture of stainless steel. The types of hazardous materials associated with nickel mining and processing depend on the ore body and processing technology used.

Sulphur dioxide (SO<sub>2</sub>) is a major air pollutant emitted in the roasting, smelting and converting of sulphide ores. Nickel sulphide concentrates contain 6–20% nickel and up to 30% sulphur. Ammonia and hydrogen sulphide are pollutants associated with the ammonia leach process; hydrogen sulphide emissions are associated with acid leaching processes. Highly toxic nickel carbonyl is a contaminant of concern in carbonyl refining.

Workers engaged in nickel production (which may include mining, milling, concentrating, smelting, converting, hydrometallurgical processes, refining and other operations) are exposed to a variety of nickel minerals and compounds, depending upon the type of ore mined and the processes used to produce intermediate and primary nickel products. Generally, exposures in the producing industry are to the moderately soluble and insoluble forms of nickel.

Soluble nickel compounds have been classified as human inhalation carcinogens. However, the precise role of soluble nickel in human carcinogenicity is still uncertain. Epidemiological information suggests that an increased risk of respiratory cancer associated with refinery process exposure to soluble nickel compounds primarily occurs at levels more than 10 times the occupational exposure standard.

Historically, workplaces where contact with soluble nickel has been prolonged have shown high risks for allergic contact nickel dermatitis. Unlike for metallic nickel, which does not appear to be carcinogenic in humans or animals, the evidence for the carcinogenicity of certain oxidic nickel compounds is more compelling. Excess respiratory cancers have been observed only in refining operations in which nickel oxides were produced during the refining of sulphidic ores and where exposures were relatively high. A causal relationship for respiratory cancer can at best be established for nickel sub-sulphide. The human data suggests that respiratory cancers have been mainly associated with exposures to less soluble forms of nickel (including sulphidic nickel) at high concentrations. The IARC has classified nickel compounds as Group 1 human carcinogens.

More comprehensive information about the health and environmental impact of nickel is on the Nickel Institute website, including the guideline titled *Safe use of nickel in the workplace*.<sup>23</sup>

## *Pyrite and pyrrhotite*

The name 'pyrite' is derived from the Greek 'pyr' meaning 'fire.' This name was given because pyrite can be used to create the sparks needed for starting a fire if it is struck against metal or another hard material. The presence of pyrite in coal has been recognised as a contributing factor to self-heating for many years. The fundamental reaction for pyrite self-heating is the reaction of pyrite producing sulphur dioxide and iron sulphate, which is strongly exothermic.

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<sup>23</sup> Nickel Institute, <http://www.nickelinstitute.org/NIPERA>.



In addition, copper, gold, lead, silver, zinc and other desirable metals are often found in ores rich in iron sulphide. When iron sulphide is exposed to air or dissolved oxygen in water, the sulphide oxidises to sulphate, which then turns to sulphuric acid ( $H_2SO_4$ ). Sulphuric acid is a highly corrosive chemical. It is also one of the primary constituents in acid rain and is toxic to most living organisms. The sulphuric acid produced in sulphide mine tailings makes the surrounding water more acidic. In addition to the direct effects of that acidity, acid water leaches toxic heavy metals from the tailings into receiving water bodies.

The mining process allows these acid and heavy metal generating reactions to occur at much higher rates than occur in nature. Metals mining produces waste rock and mine tailings with a surface area that is vastly greater than that of the undisturbed rock (by a factor of 100,000 or more), which proportionally increases the rate of acid formation.

Sulphide minerals can spontaneously heat or self-heat (that is, heat without external heat input) under certain conditions. Self-heating occurs due to exothermic oxidation reactions. One sulphide in particular, pyrrhotite  $Fe_{1-x}S$  ( $x = 0-0.2$ ) is known to undergo self-heating readily. Samples containing more than 10% pyrrhotite are especially prone to self-heating. Under extreme conditions self-heating can lead to ignition.

Several factors affect sulphide self-heating; some key parameters are the pyrrhotite content in the sample, the moisture content of the sample, the oxygen content of air, temperature, particle size, galvanic interactions, the presence of bacteria, pH and moisture.

Corrosivity and self-heating testing are a requirement before transporting metal sulphide concentrates to comply with the ADR Code 7.4.

See also 'Sulphidic ore bodies'.

## *Radioactive materials*

Radioactive materials in the mining sector may be encountered in the following scenarios:

- by exposure to naturally occurring radioactive material (NORM)
- in mining, processing and waste management of naturally occurring radioactive ore bodies
- in the operation and management of devices and equipment with a sealed radioactive source, such as those used for process control, analysis or investigation.

In Australia, the management of uranium, mineral sands and NORM is regulated by ARPANSA in accordance with the Australian Radiation Protection and Nuclear Safety Act and Regulations. The management of radioactive waste generated by the mining industry is regulated by appropriate state and territory bodies.

In its Radiation Protection series publication (RPS no. 15), ARPANSA defines NORM as material containing radionuclides that exist in the natural environment. Those materials include uranium 238, uranium 235 and thorium 232, as well as radioactive decay products. They occur in a range of rock types and geological settings. The parent radionuclides have half-lives similar to or greater than the age of the Earth and so occur widely in the planet's crust. Igneous and certain metamorphic rocks are more radioactive than most sedimentary rocks.

Typically the NORM levels in most natural substances are low, but any operation that extracts and processes materials from the ground has the potential to concentrate NORM in products and waste streams. This potential also exists in downstream processing operations.

Exposure to elevated radioactivity levels can occur in the following industries: rare earths; oil and gas; bauxite/alumina/aluminium; phosphates/fertilisers; copper; tin/tantalum; coal; iron/steel; and mineral sands mining. Examples include:

- alumina production, particularly where red mud residue can have a two- to threefold increase in the radionuclide content of the original bauxite ore
- phosphate production, where most natural phosphates contain elevated levels of uranium and radium, which can become concentrated in the products and by-products
- some copper sulphide ore-bodies are associated with uranium radionuclides, with the subsequent extraction, milling and smelting processes leading to concentration of radionuclides.
- potassium has naturally occurring radioactivity which can be found in quarrying activities. K-40 can be a gamma contributor in mining and quarrying.

The level of radioactivity obviously increases in uranium orebodies, but can also be elevated in mineral sands, rock phosphates and other ores. Substantial quantities of radioactive waste are also produced during mining and processing, notably uranium mill tailings and monazite wastes from mineral sand mining. The ARPANSA Mining Code (RPS no. 9) applies to the mining and processing of ores for the production of uranium and thorium concentrates, as well as the separation of heavy minerals in mineral sands operations. It relates to occupational and public radiation exposure and the management of radioactive wastes. Key components of the code (and accompanying safety guide) are the development of a radiation management plan and a radioactive waste management plan that apply to operational, temporary cessation and permanent closure phases of operations. The code also includes recommended dose limits for limiting radiation exposure.

Devices and equipment with sealed radioactive sources are used for a variety of purposes, including measurement and control of thickness, level, density, weight, composition and moisture. Their operation and management comes under various codes and licensing regimes that cover their use, transport, security, maintenance and disposal. In addition to specific state and territory legislation and licensing, ARPANSA codes and guides cover transport (RPS C-2, RPS no. 5 and no. 13), operation (RPS no. 5 and no. 13), monitoring (RPS no. 5 and no. 13), incident management (RPS no. 7 and no. 13) and security (RPS no. 11).

The level of potential hazard from radioactive minerals depends on the type of radioactivity and its half-life. Organs potentially at risk from radionuclides of the uranium and thorium decay chain include the lung, kidney, skeleton, liver and colon. Radiation exposure during mining and mineral processing occurs through three principle pathways: external gamma radiation from ores and concentrates; inhalation of long-lived alpha-emitting radionuclide dusts; and inhalation of short-lived decay products of radon, which is produced by the radioactive decay of radium and has previously been a major problem in poorly ventilated underground mines.

A number of laws cover radiation. The radiation liaison officer in the relevant state authority can provide support or refer to the *Code of practice and safety guide for radiation protection and radioactive waste management in mining and mineral processing*. The most relevant codes and guides, including the one on mining and mineral processing, are published by ARPANSA.<sup>24</sup>

Radiation Protection Series publications are listed in Appendix 1.

The transport of radioactive materials is covered in Section 5.

### ***Silica (Silicon Dioxide)—respirable crystalline silica (RCS)***

Silica is one of the most abundant minerals on Earth. It occurs in non-crystalline and in crystalline forms. Crystalline forms include quartz, cristobalite and tridymite. The most prevalent form is quartz, a common gangue mineral and a constituent in many igneous and metamorphic rocks. Silica is non-hazardous until ground or blasted into a dust. Key operational areas that could lead to elevated exposure include drilling, particularly overburden and underground; blast hole charging; underground haulage; crushing, grinding and conveying both surface and underground; coal and metalliferous mining support activities; and mining. Silica exposure during cleaning and maintenance activities can often be significant, particularly when compressed air or dry sweeping is used to remove gathered dust. Those practices should always be avoided and replaced by vacuuming or wet cleaning methods.

All mining states have regulations controlling worker silica exposures. Silica sand blasting is banned in Australia due to the risk of RCS exposure. Control of exposure to RCS is by minimising the creation of fine dust through water suppression (fine misting sprays), road watering, water additives for enhanced dust suppression, ventilation, rubber curtains, air curtains, enclosed cabins and good housekeeping and preparation (cleaning) of equipment and plant before maintenance.

Respirable sized crystalline silica particles (less than 10 micron aerodynamic diameter) can reach the deep parts of the lung, the alveoli, and are associated with health effects. Repeated exposures can cause particles to remain in the lungs and result in fibrosis of the lung tissue, called silicosis. Progression of the disease leads to fatigue, extreme shortness of breath, loss of appetite and pain in the chest, all of which may lead eventually to death. Crystalline silica dust is classified as a Group 1 carcinogen (lung cancer) by the IARC.

A website created by the European Industrial Minerals Association on respirable silica is very informative,<sup>25</sup> as is the UK HSE Commission.<sup>26</sup>

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<sup>24</sup> ARPANSA, *Code of practice and safety guide for radiation protection and radioactive waste management in mining and mineral processing*, Radiation Protection series no. 9, 2005, <http://www.arpansa.gov.au/pubs/rps/rps9.pdf>.

<sup>25</sup> European Industrial Minerals Association, <http://www.crystallinesilica.eu/content/welcome>.

<sup>26</sup> UK HSE, <http://www.hse.gov.uk/pubns/indg463.htm>.

## Case study: Incidence of silicosis in Western Australian mines

In the 1930s 10% of all underground miners in Western Australia suffered from silicosis, due to the very dusty conditions in the underground, mainly quartz-based, goldmines.

The combination of an enhanced mines inspectorate, new methods to measure silica dust in the air, new drilling equipment with water suppression and improved ventilation saw dust exposures drop significantly after World War II. It is believed that exposure levels dropped by at least 10 times between the end of the war and the 1970s. Exposure levels have since dropped further, and respirable silica exposures in Western Australian mines now average about one-tenth of the current exposure standard.

An occasional new employee from interstate or overseas may still be found to have silicosis before employment in Western Australian mines. However, the low levels of exposure have resulted in no cases of silicosis being detected in employees who have worked in only the state's mines and started their careers after 1974.

## *Sulphidic ore bodies—acid and metalliferous drainage*

Acid and metalliferous drainage (AMD) can occur naturally when rocks containing metal sulphide minerals are exposed to oxygen and water, or when sulphidic rock material is disturbed and exposed to oxidation as a result of mining, highway construction or coastal land development (acid sulphate soils). The predominant acid-generating sulphide mineral is pyrite ( $\text{FeS}_2$ ); others include pyrrhotite ( $\text{FeS}$ ), marcasite ( $\text{FeS}_2$ ), chalcopyrite ( $\text{CuFeS}_2$ ) and arsenopyrite ( $\text{FeAsS}$ ). The reaction of pyrite with oxygen and water produces a solution of ferrous sulphate and sulphuric acid. Ferrous iron can be oxidised, producing additional acidity.

While the main impact of AMD is on environmental values, in extreme cases it can potentially affect human health through the contamination of water supplies and heavy metal take-up in aquatic organisms used as food. The *Preventing acid and metalliferous drainage* leading practice handbook details the underlying geochemistry and the impacts of poorly managed drainage, and includes case studies of best practice management.



*Acid drainage affected King River, Tasmania, downstream from Mount Lyall Copper Mine.*

Source: Professor David J Williams.



*Marcopper Marinduque copper mine accident: tailings discharge into the Makulapnit-Boac River, Philippines.*

Source: Tom Farrell.

## Zinc

The main zinc mineral is sphalerite ((Zn,Fe)S), which contains up to 67% zinc. Iron and lead sulphides, in the form of the minerals pyrite and galena, are always associated in significant quantities with sphalerite, while smaller quantities of other metals are commonly found.

Zinc is an essential element for human health. Most health issues have been associated with metal fume fever, such as during smelting or when welding galvanised items has produced zinc oxide fumes. During mining or smelting, the health issues are generally associated with the heavy metals present, such as lead. Electrolytic processing of zinc involves the potential for exposure to sulphuric acid mist, a human carcinogen, for personnel tending the electrolytic process.

Inhaling large amounts of zinc (as zinc dust or fumes from smelting or welding) can metal fume fever, which is a short-term disease that is generally reversible once the exposure to zinc is removed.

Dissolved zinc compounds are known to be toxic to the aquatic environment.

More information on zinc is at the International Zinc Association website.<sup>27</sup>

### 3.2.2 Airborne by-products hazardous materials

#### *Air particulates, PM<sub>10</sub> and PM<sub>2.5</sub>*

Air particulates are commonly described by two forms, PM<sub>10</sub> and PM<sub>2.5</sub>. The National Environment Protection (Ambient Air Quality) Measure defines PM<sub>10</sub> as particulate matter with an equivalent aerodynamic diameter of 10 microns or less, and PM<sub>2.5</sub> as being particulate matter with an equivalent aerodynamic diameter of 2.5 microns or less.

The generation of air particulates is common in the mining industry due to the substantial ground disturbance associated with operations, especially surface mining.

Health impacts can be significant. The federal Department of the Environment lists the following:

- toxic effects by absorption of toxic material into the blood (e.g. lead, cadmium, zinc)
- bacterial and fungal infections (from live organisms)
- fibrosis (such as from asbestos, respirable crystalline silica)
- cancer (such as from asbestos, chromates)
- irritation of mucous membranes (for example, by acid and alkalis)
- increased respiratory symptoms, aggravation of asthma and premature death (the risks are highest for sensitive groups, such as the elderly and children).

These impacts are influenced by a range of factors, including particulate chemical and physical properties, concentrations, particle size and exposure duration.

Particulates also have environmental impacts. PM<sub>10</sub> and PM<sub>2.5</sub> are very fine and light and are therefore easily entrained into the air by wind or disturbances. Once in the air, particulate matter usually takes a long time to settle out again, particularly the fine particles. When they settle on land, they may settle permanently or be re-entrained. In water, particulates may settle, dissolve, or both. Particulate material may affect fauna in

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<sup>27</sup> International Zinc Association, <http://www.zinc.org/>.

the same way that it affects humans. Other environmental impacts include pollution by metals and chemicals, depending on the nature of the emissions, as well as aesthetics and impacts on the utility of areas.

Under the Ambient Air NEPM<sup>28</sup>, the federal and state and territory governments have set a national ambient air quality standard for PM<sub>10</sub> and a target to gather more data on PM<sub>2.5</sub> emissions for the National Pollutant Inventory.<sup>29</sup>

Particulate matter (PM<sub>2.5</sub> and PM<sub>10</sub>) has recently attracted attention, particularly near coal mines in New South Wales and Queensland, because of concerns about public respiratory health.

References, with information about good practice, are in the NSW Government report *Management of dust from coal mines*.<sup>30</sup>

More information is in Section 5, Transportation of hazardous materials.

## Ammonia

Significant quantities of ammonia are used in certain processes, such as the uranium alkaline leach process, and during treatment of some copper and nickel ores. Large quantities of ammonia can be stored and managed on site. Ammonia can also be generated in gold rooms during electroplating with gold solutions. Another source of ammonia arises where ammonium nitrate, usually from ammonium nitrate – fuel oil (ANFO) spillages comes into contact with alkaline materials, such as shotcrete, that has been used to cover or stabilise mine wall surfaces. Ammonia is one of the gases usually checked before re-entry underground. It is normal practice to wait for ventilation to remove gases to acceptable limits and then to perform checks using a gas meter to determine it is safe for the shift crew to enter.

At room temperature, ammonia is a colourless, highly irritating gas with a pungent, suffocating odour. It interacts immediately upon contact with available moisture in the skin, eyes, oral cavity, respiratory tract, and particularly mucous surfaces to form very caustic ammonium hydroxide. Ammonium hydroxide causes the necrosis of tissues by disrupting cell membrane lipids (saponification), leading to cellular destruction. As cell proteins break down, water is extracted, resulting in an inflammatory response that causes further damage. Hence, exposure to high concentrations of ammonia in air causes immediate burning of the nose, throat and respiratory tract. This can cause bronchiolar and alveolar oedema and airway destruction, resulting in respiratory distress or failure. Inhalation of lower concentrations can cause coughing and nose and throat irritation. Ammonia's odour provides adequate early warning of its presence, but ammonia also causes olfactory fatigue or adaptation, reducing awareness of one's prolonged exposure at low concentrations. Consequently, it is recommended that a risk assessment be performed using an appropriate gas detector, given ammonia's potential to be extremely corrosive. It is possible to be overcome immediately on contact with a concentrated ammonia plume.

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28 NEPC, National Environment Protection (Ambient Air Quality) Measure, 1998, <https://www.legislation.gov.au/Details/C2004H03935>.

29 National Pollutant Inventory (NPI), *Particulate matter* (PM10 and PM2.5), 2013, <http://www.npi.gov.au/resource/particulate-matter-pm10-and-pm25>.

30 Department of Environment and Climate Change, Water NSW, Department of Planning and Industry and Investment NSW, Environmental compliance and performance audits: management of dust from coal mines, 2010, <http://www.epa.nsw.gov.au/resources/licensing/10994coalminedust.pdf>.

## *Carbon dioxide*

Carbon dioxide can be found in some mines as a seam gas and also in diesel engine exhaust, mine fires, explosions and blasting operations. It can be measured using a portable gas detector fitted with an electrochemical cell, or by using indicator stain tubes.

It is a colourless and odourless gas. It has a density relative to normal air of 1.53 and can accumulate in low-lying areas if the air is very still. Carbon dioxide plays a major role in the body's respiration and cerebral circulation systems. At low concentrations, it acts as a respiratory and central nervous system stimulant. At high concentrations, it acts as a simple asphyxiant and depresses the central nervous system, causing unconsciousness and narcosis. Other effects known to occur in humans at high exposures include changes in sensory perceptions, disturbed judgement and mood changes.

## *Carbon monoxide*

Carbon monoxide can occur during blasting in an oxygen-poor environment, roasting and smelting, and diesel exhaust. It is a colourless, odourless, tasteless gas with a density relative to normal air of 0.97. Due to its general association with heat, it is usually found in spaces tending towards roof level even though it has a specific gravity similar to air. Carbon monoxide is flammable and can form explosive atmospheres when mixed with air at concentrations between 12.5% and 74%.

Carbon monoxide poisons the body by being absorbed into the bloodstream and preventing the blood from taking up and transporting oxygen (haemoglobin attaches to the carbon monoxide, forming carboxyhaemoglobin and blocking the formation of oxyhaemoglobin). If exposure is continued, the blood becomes saturated with carbon monoxide and can no longer absorb oxygen.

Carbon monoxide poisoning is cumulative. A person can be exposed for a number of short periods with no apparent ill effect. However, on each occasion, the blood has absorbed some of the gas and the victim becomes more and more susceptible to poisoning. This occurs because the half-life of carboxyhaemoglobin is between four and five hours.

Acute carbon monoxide poisoning is a reversible process. In fresh air or with oxygen, the blood gradually rids itself of the carbon monoxide and regains its normal oxyhaemoglobin level. The patient recovers fully, without adverse effects to the blood, lungs and air passages.

## *Diesel particulate matter*

Diesel particulate matter (DPM) is a by-product of diesel fuel combustion and can be an exposure risk in underground coal and metalliferous mines and possibly in vehicle workshops. It is an odorous material causing irritant effects that may give rise to eye, throat and bronchial irritation, as well as light-headedness, nausea, cough and phlegm.

Diesel exhaust has been classified by the IARC as a Group 1 carcinogen because of the increased risk of lung cancer in workers. Low-sulphur diesel fuel (10 ppm sulphur) is supplied in Australia to reduce DPM in exhaust emissions.

State mines authorities have published guidance documents and requirements to reduce personal exposures below an occupational exposure limit. This is an important issue in underground mines, particularly during the development phase when the mine ventilation system is not fully functional or during times of high-intensity diesel vehicle use, such as longwall moves. Control methods include maintenance and tuning of engines, enclosed cabins, remote operation, catalytic converters, filters on vehicle exhaust systems, reduction of vehicles underground, and improved ventilation in enclosed areas, such as vehicle workshops and headings where shotcreters are working.

State authorities offer guidance:

- New South Wales: *Safety bulletin: diesel emissions in mines*, June 2013.<sup>31</sup>
- Queensland: *QGN 21: Guidance note for management of diesel engine exhaust in metalliferous mines*, January 2014.<sup>32</sup>
- Western Australia: *Guideline: management of diesel emissions in Western Australian mining operations*, 2013.<sup>33</sup>

## Hydrogen sulphide

Hydrogen sulphide is a seam gas commonly encountered in some of Queensland's underground and open-cut coal mines. It is a colourless gas that has a sweet taste and a pungent odour resembling that of rotten eggs. Hydrogen sulphide is produced from the decay of organic materials and is a naturally occurring seam gas in some coal and shale deposits. It can be detected by smell at low concentrations, but this is an unreliable warning characteristic because nasal sensitivity decreases with exposure and increases in gas concentration.

Hydrogen sulphide is a highly toxic gas that irritates the mucous membranes and eyes and has a narcotic effect on the nervous system. The gas acts on the nervous system, causing headache, dizziness, excitement and a staggering gait. Exposures to concentrations greater than 500 ppm can result in anoxia (absence of oxygen in arterial blood and tissues), resulting in death.

Hydrogen sulphide forms flammable mixtures in air in the range of approximately 4.5% to 45%.

## Nitrogen oxides

Nitrogen oxides (NOx), along with carbon monoxide and carbon dioxide, are the main toxic gases generated during blasting operations. In underground mines, it is normal practice to wait for ventilation to remove the gases to acceptable limits, and then check using a gas meter to determine when the shift crew can re-enter safely. In open-cut mines, the blast gases are dissipated by wind.

The amount of blast gas generated depends on many factors, such as blast design, ground confinement, water contamination and product selection. Guidance on reducing blast gases is available.<sup>34</sup>

Combustion products of diesel exhaust can also generate significant quantities of nitrogen dioxide in underground mines. Tailpipe emissions should be regularly tested for gas to identify dirty engines. In addition, air at the working face should be tested to ensure that NOx concentrations are maintained below acceptable levels.

NOx are strong irritants. Depending on the concentration, inhalation can cause coughing, wheezing and breathing difficulties during strenuous activities. It may also aggravate asthma and increase susceptibility to respiratory illnesses such as pneumonia and bronchitis. Repeated exposures can cause permanent lung damage.

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31 [http://www.resourcesandenergy.nsw.gov.au/\\_\\_data/assets/pdf\\_file/0005/469454/SB13-03-Diesel-emissions-in-mines.pdf](http://www.resourcesandenergy.nsw.gov.au/__data/assets/pdf_file/0005/469454/SB13-03-Diesel-emissions-in-mines.pdf).

32 [https://www.dnrm.qld.gov.au/\\_\\_data/assets/pdf\\_file/0019/240364/qld-guidance-note-21.pdf](https://www.dnrm.qld.gov.au/__data/assets/pdf_file/0019/240364/qld-guidance-note-21.pdf).

33 [http://www.dmp.wa.gov.au/Documents/Safety/MSH\\_G\\_DieselEmissions.pdf](http://www.dmp.wa.gov.au/Documents/Safety/MSH_G_DieselEmissions.pdf).

34 Queensland Government, *Managing blast fumes*, 2016, <https://www.business.qld.gov.au/industry/explosives-fireworks/licensing-other-requirements/blasting-shotfiring/managing-blast-fumes>.



## *Sulphur dioxide*

Sulphur dioxide (SO<sub>2</sub>) is formed by the oxidation of sulphur, particularly in metal sulphide ore bodies and when smelting sulphidic ores.

It is a colourless gas with a characteristic irritating, pungent odour at low concentrations. Exposure routes to the human body are mainly through inhalation and skin and/or eye contact. Symptoms of exposure to SO<sub>2</sub> can include irritation of the eyes, nose, and throat; choking; cough; and reflex bronchoconstriction.

Under the Ambient Air NEPM, the Australian and state and territory governments have set national ambient air quality standards for nitrogen dioxide, sulphur dioxide and carbon monoxide.<sup>35</sup>

### **3.2.3 Process and general-use hazardous materials**

#### *Cleaning agents*

Cleaning agents are made up of a variety of chemicals, many of which may be classified as hazardous materials. They vary from organic compounds for general cleaning and chlorine-based cleaners through to hydrofluoric acid to clean aluminium metalwork. Care needs to be taken in the selection and handling by staff. Serious injuries have occurred through misuse, poor supply of personal protective equipment, and staff mixing their own cleaning mixtures from existing products.

A poisons permit may be needed from the state health department to use hydrofluoric acid products. Specialist treatments should be available wherever fluoride-based cleaners are used.

#### *Cyanide*

Sodium cyanide is used for gold recovery in large operations. The *Cyanide management* leading practice handbook provides extensive information about sodium and calcium cyanides, paying particular attention to toxicity in mammals and environmental impacts.

Environmental best practice, and the major goldminers, adhere to the International Cyanide Management Code for the Gold Mining Industry.<sup>36</sup> The code covers the production, transport, use and disposal of cyanides.

The risk of cyanide poisoning arises from ingestion and exposure to workplace vapours, mists and solutions. Small quantities of hydrogen cyanide are generated when sodium cyanide is exposed to moist air or acids. Current controls include the management of the pH of process streams, coupled with the use of personal and area hydrogen cyanide gas monitoring devices.

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<sup>35</sup> Department of the Environment, *Air quality standards*, no date, <http://www.environment.gov.au/protection/air-quality/air-quality-standards>.

<sup>36</sup> <http://www.cyanidecode.org/>

## *Fumigants*

When items from overseas are received in shipping containers, care should be taken because the containers may have been fumigated. Containers are typically fumigated with a methyl bromide and chloropicrin mixture. There have been cases of worker exposure in Australia when containers have been inspected at the port or unloaded at explosives stores.<sup>37</sup>

## *Polymeric compounds*

Polymeric compounds are chemicals used as resins throughout the mining industry in strata binding, drilling and void filling. Most use occurs in underground coal mines. Three types of resins are currently approved for use in underground coal mines and they are broadly classified as polyurethane (PUR), urea silicate and phenolic resins.

The PUR and urea silicate resins contain methylene diphenyl diisocyanate (MDI) in the catalyst component. Exposures to isocyanates are known to cause health effects ranging from acute irritation to permanently debilitating respiratory conditions. The most significant of the conditions is occupational asthma resulting in respiratory sensitisation. There is a growing body of epidemiological evidence to link skin absorption of diisocyanates and polyisocyanates to respiratory sensitisation.

Phenolic resins are formed by cross-linking phenol and formaldehyde in the presence of an acid to form a polymer. Phenol is a highly corrosive and toxic substance that can enter the body through inhalation, ingestion and skin absorption. Exposure to phenol can result in acute irritant effects and systemic toxic effects. Systemic toxic effects due to high exposure include central nervous system impairment and liver and kidney damage. Formaldehyde is highly irritating to the eyes, nose and throat. It is a known respiratory and skin sensitising agent and is classified as by the IARC as a Group 1, human carcinogen.

The use of strong acids to make the polymer is also a significant hazard. The acid mixture usually comprises a mixture of one or more of acetic, sulphuric, phenolsulphonic and phosphoric acids, all of which are highly irritating to the skin, eyes, mucous membranes and respiratory system.

The chemical properties of these polymeric compounds and the processes by which they are applied suggest that skin absorption represents the greatest risk of exposure for mine workers. For that reason, biological monitoring is the preferred method for assessing exposure.

The chemical reaction that creates polyurethane foam is exothermic. This means that heat is released to the surroundings during the reaction. Depending on the mixing ratio and the presence of contamination, the temperature reached during the setting can vary from 133°C to 198°C. There have been a number of fires in underground mines and tunnels in which PUR was a causal factor or where its combustion resulted in the production of large quantities of toxic smoke and gases.

More information is available through the New South Wales and Queensland mines departments.

## *Explosives*

Explosives are a special category of hazardous materials with specific implications for workplace health and safety and civil and national security. Section 4 of this handbook covers explosives in detail, including recent changes to regulations.

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<sup>37</sup> Comcare, Alert 9: Methyl bromide—toxic fumigant in cargo containers, November 2013, [http://www.comcare.gov.au/news\\_and\\_media/safety\\_alerts/safety\\_alerts\\_-\\_current/methyl\\_bromide-toxic\\_fumigant\\_in\\_cargo\\_containers](http://www.comcare.gov.au/news_and_media/safety_alerts/safety_alerts_-_current/methyl_bromide-toxic_fumigant_in_cargo_containers).

## *Oil and fuel*

The Australian Government regulates fuel quality through the National Fuel Quality Standards.<sup>38</sup>

Low-sulphur diesel fuel (10 ppm max) is the only diesel quality supplied throughout Australia to sites for mobile equipment and power plants. Low-sulphur diesel has the benefit of reduced emissions and in particular reduced DPM.

The main hazard is fire, as it is classified as a combustible fuel. Repeated skin contact may cause drying of the skin and dermatitis. Since considerable quantities of hydrocarbons may be stored on a mine site, their presence also constitutes a security hazard because they could be targeted in an attack. There are also potential impacts on the environment from spills, storage tank leaks and accidental discharges.

Lubricating oils for mobile equipment and fixed plant are generally not classified as hazardous. However, it is recommended that the safety data sheet be checked before the product is allowed on site, as some may have speciality performance chemicals added for lubrication performance.

## *Paints, pesticides and laboratory chemicals*

Stored oil-based paints are fire hazards, while pesticides and laboratory chemicals may have human health impacts, environmental impacts, or both.

Old and new containers may contain residual chemicals that pose risks to human health and the environment. They should be disposed of safely. Cleaned containers might not be hazardous, and collection and recycling options may be available under the drumMUSTER program for plastic and metal containers in which pesticides have been supplied.<sup>39</sup>

## *Polychlorinated biphenyls (PCBs) from transformers*

Australia's 2003 Polychlorinated Biphenyls Management Plan has been taken up in state and territory regulations.<sup>40</sup> As a result of earlier efforts to remove PCBs from service, many transformer oils are dilute solutions of PCB in paraffin. Where the PCB content is 50 mg/kg (50 ppm) or greater, the material must be treated to destroy PCBs and reduce the level to 2 ppm or less. Although complete phase-out may still be some years away, most PCB-containing oil has been removed from service and treated as required.

## *Quicklime*

Quicklime (calcium oxide, CaO) and slaked lime (calcium hydroxide, Ca(OH)<sub>2</sub>) are widely used in the mining industry for pH control in processing gold and base metals, as well for neutralising waste streams before deposition in tailings storage facilities. Quicklime can either be slaked on site or sometimes directly added to crushed ore before further processing. It reacts vigorously with water and can cause damage to the eyes and respiratory system.

## *Solvents used in extraction plants*

Hydrocarbon solvents, such as kerosene, are used in solvent extraction plants for separating complex metal ions. As for petroleum products, there are flammability hazards and security risks. Key considerations for the safe use of hydrocarbon solvents have been captured in the following case study.

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<sup>38</sup> National Fuel Quality Standards, <http://www.environment.gov.au/topics/environment-protection/fuel-quality/standards>.

<sup>39</sup> drumMUSTER, <http://www.drummuster.com.au/>.

<sup>40</sup> Environment Protection and Heritage Council, *Polychlorinated Biphenyls Management Plan*, April 2003, <http://www.nepc.gov.au/system/files/resources/378b7018-8f2a-8174-3928-2056b44bf9b0/files/anzecc-gl-polychlorinated-biphenyls-management-plan-revised-200304.pdf>.

## Case study: Copper solvent extraction fires

The first two commercial copper solvent extraction (CuSX) plants were small-scale plants built in Arizona in the late 1960s. The plants were built to treat heap leach and dump leach solutions, respectively, and to produce 5,500–6,500 short tons per annum (STPA) of cathode copper. They were followed soon after by a much larger CuSX plant in Zambia, which treated tailings leach solution and produced approximately 100,000 TPA of cathode copper. Since then, CuSX plants have proliferated worldwide. Continued improvements in design and lower unit capital and operating costs have led to the production of up to 168,000 TPA (185,000 STPA) at the world's largest electro-winning plant, at Morenci, Arizona. An even larger 200,000 TPA capacity plant is to be built in Chile.

In CuSX plants designed within the past two or three years, fire safety has been closely examined and incorporated into appropriate low-risk designs. However, it seems highly likely that fire risks and controls were not adequately addressed in plants designed before 2002.

Small but serious CuSX fires occurred at copper heap leach operations in Arizona in 2003 and in Mexico in 2004. The fires demonstrated the need for a serious and immediate review of CuSX design policies for fire control. Both were examined in detailed reviews of fire safety, but there has been only limited public reporting of the findings. The results of these and other reviews are being applied to the design of some new plants and possibly to the retrofit of some existing plants to minimise the risk of fire. Little is known about refits of the older CuSX plants, which might still face significant fire risk.

Causes of fires in CuSX plants include static electricity, inadequate piping design (allowing the formation of flammable vapours and mists inside organic drain lines), and human error during maintenance work. There have been four fires since 1969, all in relatively new plants. There appears to be no connection between the size of the mining companies or constructing engineering companies and the risk of fires. The fires were more likely to occur in a culture that has been insensitive to the real risks of fire in CuSX plant design, operation and maintenance.

Solvent extraction is practised at the Australian uranium mines—Ranger and Olympic Dam. No solvent fires have been reported at Ranger, but BHP Billiton's 2003 Environment, Health, Safety and Community Report said of the Olympic Dam site:

In October 2001, a fire caused substantial damage to the solvent extraction unit at Olympic dam. There had been a fire in a similar area of the plant in December 1999. The 2001 fire was most likely caused by ignition of solvent-soaked crud (an impurity from the solvent extraction process) inside a solvent transfer pipe. The hazard of an internal fire was not identified at any time during the design, construction and operation of the solvent extraction plant, and had not previously been experienced in the solvent extraction industry.

In rebuilding the solvent extraction plants, new standards for fire prevention and fire protection as identified in the investigation of the 2001 fire were incorporated. They include:

- changing pipe work material from high-density polyethylene to conductive, fibre-reinforced plastic to reduce static build-up in the pipe work
- installing an automatic system to scuttle solvent from the tanks in the event of a fire
- increasing the bunding and drainage sumps to contain and remove any solvent spillage.

No further fires have been reported at the Olympic Dam facility.

Source (Olympic Dam): Including material from [hsecreport.bhpbilliton.com/wmc/2003/sitedata/crp\\_ehsprf\\_ftly.htm](http://hsecreport.bhpbilliton.com/wmc/2003/sitedata/crp_ehsprf_ftly.htm)

## *Sulphuric acid*

Large amounts of sulphuric acid can be used to leach ores containing metals such as copper and nickel. Some mines produce the sulphuric acid required by burning imported sulphur, while sulphur dioxide can also be recovered from smelter off-gases to produce sulphuric acid.

Sulphuric acid is a corrosive chemical and can severely burn the skin and eyes. It may cause third degree burns and blindness on contact. Exposure to sulphuric acid mist can irritate the eyes, nose, throat and lungs, and at higher levels can cause a build-up of fluid in the lungs (pulmonary oedema). Asthmatics are particularly sensitive to the pulmonary irritation. Repeated exposures may cause permanent damage to the lungs and teeth. The IARC has classified 'occupational exposures to strong-inorganic-acid mists containing sulphuric acid' as carcinogenic to humans.

Sulphuric acid will also severely burn plants, birds or land animals exposed to it. It has moderate chronic (long-term) toxicity to aquatic life.

## *Xanthates*

Xanthates are a group of chemicals typically used in sulphide flotation in mineral processing applications. Common xanthate products are sodium ethyl xanthate (SEX), sodium isopropyl xanthate (SIPX), sodium isobutyl xanthate (SIBX) and potassium amyl xanthate (PAX).

Xanthates are classified into Division 4.2 dangerous goods (substances liable to spontaneous combustion) in the Australian Dangerous Goods (ADG) Code. High levels of moisture and high temperatures during transport and storage increase decomposition, producing toxic and flammable decomposition products such as carbon disulphide (CS<sub>2</sub>) and mercaptans. Ultimately, solid xanthates can spontaneously combust, producing sulphur dioxide, carbon monoxide and carbon dioxide.

Low-level exposure to CS<sub>2</sub> and mercaptans causes nausea and irritation of the eyes, skin and respiratory tract. Symptoms of higher exposures include tremors, dyspnoea, vascular collapse and increased susceptibility to heart disease.

When disposing of solid xanthates, they should be dissolved in water before transfer to the disposal site, such as a tailings storage facility (TSF), if permitted under the site licence. Bags of xanthates that have been thrown intact into a TSF have survived decades before causing health concerns when uncovered during retreatment of the tailings.

Two useful references on xanthates are:

- Queensland Department of Natural Resources and Mines: *Xanthates in mining*<sup>41</sup>
- NICNAS: *Sodium ethyl xanthate assessment report*.<sup>42</sup>

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<sup>41</sup> Queensland Department of Natural Resources and Mines, *Xanthates in mining*, Mines Safety Bulletin, no. 132, 27 March 2013, <https://www.dnrm.qld.gov.au/mining/safety-and-health/alerts-bulletins-search-tool/alerts-bulletins-search/alerts-bulletins/mines-safety/xanthates-in-mining>.

<sup>42</sup> NICNAS, *Sodium ethyl xanthate assessment report*, May 1995, [www.nicnas.gov.au/publications/car/PEC/PEC5.asp](http://www.nicnas.gov.au/publications/car/PEC/PEC5.asp).

# 4.0 EXPLOSIVES AND AMMONIUM NITRATE-CONTAINING PRECURSORS

## Purpose

This section provides an overview of explosives regulations.

### Key messages

- Explosives legislation minimises the safety and security risks by licensing the transport, storage, manufacture, import, export and use of explosives and precursors containing ammonium nitrate.
- Unsupervised access to explosives and precursors containing ammonium nitrate requires a security clearance and a security plan.
- Transport, storage and handling require compliance with prescriptive codes.

## 4.1 Introduction

Class 1 explosives are subject to safety and security controls under each set of state or territory explosives legislation. This legislation is characterised by restricting access to explosives to licensed companies and their authorised employees and nominees. The company licences require the preparation of a security plan to exclude unauthorised people from accessing the explosives in order to prevent theft and sabotage of the explosives. Company licences cover one or more of import/export, transport, storage, manufacture, sale, use and disposal. Competency-based licences for individual shotfirers and drivers of explosives complement the company licences.

Unsupervised access to explosives by any individual requires a security clearance by the jurisdiction's police commissioner, which includes a criminal history check and a check to exclude potential terrorists. Most commonly, a plastic dangerous goods security card with colour photo ID identifies employees and nominees authorised by mine management under a company explosives licence to have 'unsupervised access to explosives'. Those individuals without a security clearance can have only 'supervised access to explosives'.

As agreed by the Council of Australian Governments (COAG) on 25 June 2004, all jurisdictions now apply this licensing system not only to explosives, but also to security-sensitive ammonium nitrate (SSAN) as an anti-terrorism measure. SSAN is mainly ammonium nitrate-containing precursors for making Class 1 bulk explosives (as well as ammonium nitrate fertilisers). These precursors are Division 5.1 oxidising substances and include ammonium nitrate classified as UN 1942 and 2067 and ammonium nitrate emulsions, suspensions and gels classified as UN 3375 and usually referred to as ammonium nitrate emulsions or ANEs.

For instance, the prime contractor transporting SSAN requires an SSAN transport licence that is associated with a transport security plan. The national *Ammonium nitrate guidance note no. 1—Transport* can be consulted when developing the security plan.<sup>43</sup>

The SSAN must be transported in locked or sealed containers from a secure location to another secure location and cannot be supplied to anyone not authorised in writing to receive it.

All explosives containing nitroglycerine and most of the packaged explosives of the past have been replaced by ammonium nitrate-containing bulk explosives, greatly increasing the efficiency of blasting operations by eliminating the slow manual handling of packaged explosives.

Class 1 bulk explosives are of two types:

- ANFO: ammonium nitrate – fuel oil mixtures, which are dry, prill-based (pelletised) and can be blow-loaded into the blast hole
- sensitised ANE: ammonium nitrate emulsions, which have been replacing ANFO for most blasting situations because they are waterproof, more versatile and more effective.

Mine site manufacture has all but replaced the transport of hazardous Class 1 explosives on public roads with the transport of low-hazard Division 5.1 oxidising agents, thereby greatly reducing explosion risks to the public.

Most Class 1 explosives still being transported on public roads are initiating explosives (boosters, detonator cord and detonators) needed to initiate the bulk explosives. Small amounts of packaged ANFO and packaged emulsion-based explosives are also transported and used by small business shotfirers and prospectors. Transported Class 1 volumes make up a small fraction of the total Class 1 explosives used at today's mine sites.

In recent years, Queensland and New South Wales miners have suffered partial, inefficient blasts accompanied by emissions of orange, toxic nitrogen dioxide, mainly as a result of water-degraded ANFO. ANFO is very water sensitive—either water in the blast hole or prolonged storage at high humidity will degrade it. These problems can largely be solved by switching to waterproof ANEs. The Australian Explosives Industry Safety Group's *Code of practice: prevention and management of blast generated NOx gases in surface blasting* should be consulted for more information (see list of codes below).

The membership of the Australian Explosives Industry Safety Group (AEISG) comprises the larger Australian manufacturers of explosives and bulk precursor chemicals. The AEISG strives to improve the safe transport, storage, handling and use of explosives and their precursors and continually updates a suite of industry codes of practice. The codes are widely used by industry and have found acceptance among regulatory authorities as a benchmark for minimising the risks from explosives as far as is reasonably practicable. The following codes are available at the AEISB website:<sup>44</sup>

- Storage and handling of UN 3375
- Elevated temperature and reactive ground
- Prevention and management of blast generated NOx gases in surface blasting
- Blast guarding in an open cut mining environment.

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43 *Ammonium nitrate guidance note no. 1—Transport*, [http://www.dmp.wa.gov.au/Documents/Dangerous-Goods/DGS\\_SRS\\_AmmoniumNitrateGuidanceNoteTransport.pdf](http://www.dmp.wa.gov.au/Documents/Dangerous-Goods/DGS_SRS_AmmoniumNitrateGuidanceNoteTransport.pdf).

44 AEISG, <http://www.aeisc.org.au/index.php/cop.html>.



- Segregation barriers for transporting mixed loads of detonators and high explosives
- Mobile processing units.

## 4.2 Manufacture of bulk explosives

Unsensitised ANEs are transported by road tank vehicle from the manufacturing plant on public roads to the mine site and are pumped into large storage tanks. As required, the ANEs are transferred from the tanks into mobile processing units (MPUs) specially designed to blend various sensitisers into UN 3375 mixtures to convert them at the bench into Class 1 explosives, which are sensitive to booster charges ready for blasting. The MPUs contain various delivery systems, including pumps and augurs, to transfer the mixtures into the blast hole.

MPUs carry ammonium nitrate, which can be converted to ANFO. The ANFO can also be mixed with ANEs to form heavy ANFO.

MPUs are licensed for the transport and manufacture of explosives under the jurisdiction's explosives legislation. Their design, construction, placarding and safety equipment are required to comply with the AEISG's code of practice for MPUs.

Depending on the blasting requirements, typical sensitisers that can be added to ANEs include glass micro-balloons, polystyrene beads and, most commonly, a small volume of dilute sodium nitrite solution. These sensitisers introduce tiny 1-mm diameter air-nitrogen voids necessary for the propagation of the detonation and lower the density of the mixtures to a critical density when they become booster-sensitive Class 1 explosives.

There are two types of ANE:

- **Ammonium nitrate emulsions** were introduced in the mid-1980s and have now largely replaced the suspensions and gels described later in this handbook. They are unique, extremely viscous, porridge-like water-in-oil emulsions typically around 70% ammonium nitrate, 15% water and the balance hydrocarbon-based materials. The emulsion contains countless submicroscopic droplets of supersaturated ammonium nitrate dispersed evenly in an emulsifier-stabilised oil matrix without any solid particles.

The emulsions are a miracle of nanotechnology and achieve the most intimate possible mixing of an aqueous solution of oxidiser with a hydrocarbon-based fuel because of the very large surface area of the tiny oxidiser droplets, which have an average diameter of only about 300 nanometres. This intimacy of contact between oxidiser and fuel allows for power and versatility. Mixtures range from less than half to almost triple the relative bulk strength of ANFO and a wide range of velocities of detonation.

Emulsions represent the achievement of 150 years of relentless work in explosives technology to improve safety, cost-effectiveness, water resistance and flexibility to be tailor-made to suit any possible blasting condition and rock type.

- **Ammonium nitrate suspensions and gels** were introduced in the mid-1960s. They are made of solids suspended in a thickened aqueous solution of ammonium nitrate and other oxidisers. Some dissolved or liquid fuels may be present. The thickener is usually a naturally occurring starch. At the blast hole, these string-like starch molecules are chemically cross-linked to form well-structured water-resistant Class 1 explosives.

## 4.2.1 Storage and handling of ANEs

The best code of practice to consult on the storage and handling of UN 3375 mixtures is the AEISG's *Code of practice: storage and handling of UN 3375*. This code covers safety, security, emergency response management and regulatory/licensing requirements. It also covers the requirement to locate ANE storage tanks so that they are sufficiently separated from protected works (occupied buildings and areas where people congregate on a regular basis). Adequate separation distances from explosives magazines and storages of fuel and ammonium nitrate are also required.

The hazard potential associated with pumps transferring ANEs is well known, and it is important to prevent pumps operating under no-flow conditions. Such conditions can cause the overheating and decomposition of ANEs under confinement and lead to an explosion. The AEISG code devotes a comprehensive chapter to safe pump management.

## 4.2.2 Storage and handling of ammonium nitrate

The most comprehensive code of practice in Australia covering the storage and handling of ammonium nitrate is the Western Australian Department of Mines and Petroleum's code.<sup>45</sup> It deals with the explosion risk of ammonium nitrate (AN) of Division 5.1 oxidising substances (pure AN of UN 1942 and AN containing fertiliser mixtures of UN 2067) during storage. The code explains the hazards of AN and how to implement the three explosion prevention strategies:

- Prevent external fires from reaching the AN by removing all combustible materials from the vicinity.
- Prevent incompatible materials from mixing with AN.
- Prevent the setting of explosives charges (which is a security measure).

Under ambient conditions, AN will not detonate from heat, flame, impact or friction. However, an external, high-intensity fire can melt the solid. The melt is explosion sensitive, especially if contaminated with dirt or fuel, confined, or both.

While AN does not burn, it must be rigorously segregated from any sources of fire to avoid it melting and subsequently exploding under certain circumstances. In practice, this means isolating the AN from other substances, fuels and dangerous goods in a dedicated storage: a building, open-air area, freight container, silo or bin storage. The code recommends separation distances from various offsite premises; the distances are in harmony with the risk criteria recommendations in the NSW Department of Planning and Environment's hazardous industry planning advisory paper on risk criteria for land-use safety.<sup>46</sup> The code also recommends separation distances between individual stacks of ammonium nitrate in intermediate bulk containers to prevent sympathetic detonation between stacks.

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<sup>45</sup> *Code of practice: safe storage of solid ammonium nitrate*, WA Department of Mines and Petroleum, [http://www.dmp.wa.gov.au/Documents/Dangerous-Goods/DGS\\_COP\\_StorageSolidAmmoniumNitrate.pdf](http://www.dmp.wa.gov.au/Documents/Dangerous-Goods/DGS_COP_StorageSolidAmmoniumNitrate.pdf).

<sup>46</sup> NSW Department of Planning and Environment, Hazardous industry planning advisory paper no. 4: Risk criteria for land use safety planning, January 2011, <http://www.planning.nsw.gov.au/-/media/Files/DPE/Other/hazardous-industry-planning-advisory-paper-no-4-risk-criteria-for-land-use-safety-planning-2011-01.ashx>.

## 4.3 Storage of class 1 explosives

All states and territories mandate Australian Standard AS 2187.1 (1998) for the storage of explosives. In 2015, Safe Work Australia oversaw the replacement of this standard with a more flexible, updated code of practice.

An explosives storage licence is necessary to store Class 1 mining explosives. All licence holders are required to develop an explosives management plan (for security and safety) and an emergency response plan.

Licence holders need to restrict magazine access to authorised people and keep an accurate stock record of explosives. Good inventory control allows the detection of theft and optimal management of the use of explosives.

All packaging of explosives must be in good condition and comply with the packaging approved by the *Australian Code for the Transport of Explosives by Road and Rail*.

An explosives storage facility must be designed and located so that in the event of a detonation of the maximum quantity of explosives in the largest capacity magazine:

- the detonation will not sympathetically propagate to an adjacent magazine
- debris from the detonation will not carry to a place offsite, where it could injure a person or damage property
- the air-blast overpressure of the detonation will not exceed approximately 5.5 kPa at an offsite occupied building.

These objectives can normally be achieved by adopting the separation distances to protected works Class B and the intermagazine distances and distances between magazines and storages of ammonium nitrate in Table 3.2.3.2 of AS 2187.1.

Much of AS 2187.1 describes the construction and design of magazines. By far the largest driver of magazine design is security using heavy steel doors and lock construction in order to make the theft of explosives as difficult as possible. Other design considerations are:

- preventing fires, which dictates the use of non-combustible construction materials
- keeping explosives cool using natural ventilation and sun roofs to reflect the sun
- preventing water ingress from rain and floods.

Theoretically, one could dispense with heavy/high-security magazine construction in circumstances in which security is provided by other means, perhaps by a combination of security guards, high-security double razor wire perimeter fencing and CCTV. However, heavily constructed high-security magazines complying with AS 2187.1 have a number of distinct advantages and tend to provide the most cost-effective and appropriate security control for mine sites and other remote locations:

- They do not rely on additional non-magazine security measures, except a security perimeter fence complying with AS 2187.1.
- They rely on engineering design for security and not on less reliable administrative security controls.
- They have the ability to prevent theft, rather than merely reveal theft after the event.

The UN Dangerous Goods Classification System recognises 35 classification codes and 13 different compatibility groups (A to S) for Class 1 explosives, as shown in Table 3, Table 3.1.2, from AS 2187.1.

Table 3: Classification codes for Class 1 explosives

DIVISION	COMPATIBILITY GROUP												
	A	B	C	D	E	F	G	H	J	K	L	N	S
1.1	1.1A	1.1B	1.1C	1.1D	1.1E	1.1F	1.1G	*	1.1J	*	1.1L	*	*
1.2	*	1.2B	1.2C	1.2D	1.2E	1.2F	1.2G	1.2H	1.2J	1.2K	1.2L	*	*
1.3	*	*	1.3C	*	*	1.3F	1.3G	1.3H	1.3J	1.3K	1.3L	*	*
1.4	*	1.4B	1.4C	1.4D	1.4E	1.4F	1.4G	*	*	*	*	*	1.4S
1.5	*	*	*	1.5D	*	*	*	*	*	*	*	*	*
1.6	*	*	*	*	*	*	*	*	*	*	*	1.6N	*

\* Denotes impossible classification code.

Table 3 shows the 13 compatibility groups that are permitted to be stored in the same magazine. The rules are simple for mining explosives, which mainly fall into the same 'D' compatibility group, being of classification codes 1.1D and 1.5D. They must be stored separately from detonators of 1.4B or 1.1B.

## 4.4 Use of explosives

The standard for the use of mining explosives is AS 2187.2 (2006)—*Use of explosives*, which is mandated by nearly all jurisdictions. It takes a risk management approach to blasting operations and requires, together with most jurisdictions, the preparation of a blast plan and a written blast record to direct the blasting operations. The blast plan identifies:

- hazards and the safety controls
- identifies site-specific requirements
- controls the blast process from design to initiation
- evaluation and misfire treatment
- ensures that blasting is done safely for site personnel, the public and surrounding premises.

The standard includes guidance on charging, methods of initiation, post-blast procedures, the treatment of misfires and the disposal of explosives.

Individual shotfirers require a dangerous goods security card/clearance and a shotfiring licence. A prerequisite for the shotfiring licence is a training certificate demonstrating the completion of the suite of national units of competency applicable to the blasting application, either for surface, underground or underground coal operations, from the Resources and Infrastructure Industry Training Package.<sup>47</sup> Another prerequisite is a medical certificate.

<sup>47</sup> 'Training package details: RII09: Resources and Infrastructure Industry Training Package', *training.gov.au*, <https://training.gov.au/Training/Details/RII09>.

# 5.0 TRANSPORTATION OF HAZARDOUS MATERIALS

## Purpose

This section summarises the road, rail and marine transport codes that affect the transport of hazardous materials.

### Key messages

- The correct classification of the hazardous material is important in order to achieve the correct hazard reduction and compliance with prescribed codes. Classification may require laboratory testing prior to transporting.
- Transporting dangerous goods requires compliance with prescribed codes for land, sea and air transport.
- Criteria used for classifications of metal concentrates have changed in recent years, affecting international shipping requirements.

The focus of this section is on hazardous materials that are classified as dangerous goods and hazardous waste.

## 5.1 UN dangerous goods classification system

Dangerous goods are substances or articles that, because of their physical, chemical (physicochemical) or acute toxicity properties, present an immediate hazard to people, property or the environment.

Guidelines for the classification and transport of dangerous goods are published by the United Nations as *Recommendations on the transport of dangerous goods*.<sup>48</sup> They are then incorporated into:

- national road and rail codes, such as the Australian Dangerous Goods Code<sup>49</sup>
- International Maritime Organization (IMO) codes for the marine transport of dangerous goods<sup>50</sup>
- the International Air Transport Association (IATA) Dangerous goods code.<sup>51</sup>

48 UNECE, *Recommendations on the transport of dangerous goods*, <http://www.unece.org/trans/danger/danger.html>.

49 National Transport Commission, *Australian Dangerous Goods Code: model law*, <http://www.ntc.gov.au/heavy-vehicles/safety/australian-dangerous-goods-code/adgc-model-law/>.

50 IMO, *IMDG Code*, codes for the marine transport of dangerous goods, <http://www.imo.org/Publications/IMDGCode/Pages/Default.aspx>.

51 IATA, *Dangerous goods*, <http://www.iata.org/whatwedo/cargo/dgr/Pages/index.aspx>.

The classification of dangerous goods is outlined in the Australian Code for the Transport of Dangerous Goods by Road and Rail, 7th Edition, published in 2007 (ADG Code 7) and updated to ADG Code 7.4 in 2016 by the National Transport Commission.<sup>52</sup>

The administration of the ADG Code and the associated road and rail transport legislation is the responsibility of the states and territories.

Substances (including mixtures and solutions) and articles subject to ADG Code 7.4 are assigned to one of nine classes according to the hazard or the main hazard they present. The various classes and divisions of dangerous goods have matching labels (or diamonds).

The classes and divisions are listed in Appendix 2. Their numerical order does not denote degrees of danger. Explosives are further subdivided into divisions and compatibility groups.

## 5.2 Transport by road and rail

ADG Code 7.4 provides procedures and protocols for the transport of non-Class 1 dangerous goods. The code provides detailed specifications and requirements covering:

- classification of dangerous goods, packaging methods and instructions for each and every dangerous good, marking and labelling of packages and placarding of vehicles, freight containers and tanks
- construction, design and performance testing of dangerous goods packages, including intermediate bulk containers and the construction of tank vehicles, portable tanks and pressure receptacles
- the Dangerous Goods List, which gives the UN entries of all dangerous goods, with their proper shipping name and classification (this list assists manufacturers and importers to classify most dangerous goods without recourse to expensive testing in accordance with the UN *Manual of tests and criteria*)
- consigning of dangerous goods for transport, including loading, stowage, load restraint and segregation
- provision of transport documentation describing the dangerous goods being transported, their proper shipping name, their quantities and packaging method and appropriate emergency information for those goods
- transfer of liquid and gaseous dangerous goods to storage vessels and procedures during transport for parking and breakdown, and provision of safety equipment.

Class 1 dangerous goods (explosives) are regulated by the third edition of the Australian Explosives Transport Code.<sup>53</sup> Like ADG Code 7.4, the Explosives Transport Code adopts the classification, packaging and labelling system from the UN's *Recommendations on the transport of dangerous goods—model regulations*, 18th edition (2014).

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52 National Transport Commission, *Australian code for the transport of dangerous goods by road and rail*, ADG Code 7.4, 2016, [http://www.ntc.gov.au/Media/Reports/\(6DDF9385-CCB9-4CB8-95E7-3D5296001894\).pdf](http://www.ntc.gov.au/Media/Reports/(6DDF9385-CCB9-4CB8-95E7-3D5296001894).pdf).

53 Safe Work Australia, *Australian code for the transport of explosives by road and rail*, 3rd edition, 2009, <http://www.safeworkaustralia.gov.au/sites/swa/about/publications/pages/cp2009actransportofexplosivesbyroadandrail3rdedition>.

The explosion risk during the transport of two large-volume dangerous goods is examined in detail in the next sections:

- ammonium nitrate emulsion or suspension or gel, intermediate for blasting explosives of UN 3375 (ANEs)
- solid ammonium nitrate (AN) of UN 1942 and 2067.

### 5.3 Road transport of ammonium nitrate, AN and ANEs

About 2.5 million tonnes of AN are transported each year by road from Australian manufacturing plants and ports to mine sites for conversion into bulk explosives. This type of AN is classified as UN 1942 and is mostly low-density porous prill for conversion into ammonium nitrate – fuel oil explosive (ANFO). Each year, more and more ANEs are being transported, because of the increasing demand for water-resistant bulk explosives with superior properties compared to ANFO.

AN and ANEs have significantly lowered the transport risk to the community. They are Division 5.1 oxidising substances used as the precursor chemicals in the manufacture of bulk explosives at the mine site, thereby removing the need to transport Class 1 explosives by road and rail, except for detonators, detonating cord and relatively low volumes of packaged explosives used as primers for initiating the bulk explosives.

This section provides an appraisal of the explosion risk of AN and ANE and recommends practical safety controls to minimise the explosion risk during road transport.

#### 5.3.1 Classification

AN and unsensitised ANEs are too insensitive to be classified as Class 1 explosives. While these precursor chemicals are not explosives, their main hazard is an explosion risk, albeit one that is much lower than that for Class 1 explosives.

The explosives industry and government authorities have ensured that the explosion sensitivity of AN and ANEs is low by making use of Test Series 2 and 8 in the *United Nations manual of tests and criteria*. Negative-no-explosion test results ensure that these substances must be classified as Division 5.1 and not as Class 1. These substances are insensitive to explosion when subjected to heating under confinement, or to shock from an explosive primer. They are also thermally stable to prolonged heat under the hottest possible ambient transport conditions in Australia. ANEs are even more explosion insensitive than AN on two counts:

- They are less shock sensitive than low-density AN prill, because of the greater shock energy used in the *ANE gap test* of Test Series 8 compared to the *UN gap test* of Test Series 2 in the *UN manual of tests and criteria*. Even the most energetic traffic collision will not result in an explosion.
- ANEs' heat resistance is higher than for solid AN, since explosions cannot occur until most of the water is driven off through the pressure-relief device, giving some time for emergency services to evacuate the area surrounding a tank vehicle fire.

AN will not burn but can increase the intensity of an external fire. Once molten, it becomes explosion sensitive and an explosion may occur because of one or more of:

- **contamination** with organic substances of any type, such as diesel fuel, molten plastics, molten aluminium or magnesium and a very large range of incompatible substances

- **confinement** of molten AN in circumstances when the decomposition gases that arise in the melt above 210°C cannot escape freely and as a consequence the gas pressure builds up. This will change the decomposition chemistry and lead to a rapid rise in temperature and the evolution of toxic orange/red nitrogen dioxide
- **shock applied by an energetic missile**, can arise from an exploding fuel tank.

The superior explosion insensitivity of ANEs over AN seems to be reflected in their superior accident history, although a proper comparison needs to take into account the much higher volumes of AN transported over the years. The accident record of ANEs is unblemished after 50 years of transport—there has been no documented accidental explosion during transport, although there has been an explosion of a mobile processing unit (MPU) carrying both AN and ANE on a mine site after a vehicle fire in Norway on 17 December 2013.

### Case study: Solid ammonium nitrate accident history in Australia

Ammonium nitrate (AN) has been involved in at least three road vehicle explosions overseas and two in Australia.

#### Taroom explosion on 30 August 1972

An electrical fire is thought to have started in the cabin of the prime mover of a semitrailer loaded with 18.5 tonnes of UN 1942 in 80-pound polythene bags on a road north of Taroom in outback Queensland. The fire burned for 30–60 minutes before a powerful explosion killed the driver and two farmhands, who were watching the fire from close range. The vehicle was demolished.

#### Angellala Creek explosion on 5 September 2014

A Type 1 road train combination vehicle loaded with 44 bulk bags (1.2-tonne flexible intermediate bulk containers) containing 52.8 tonnes of UN 1942 drove off the bridge at Angellala Creek on the Mitchell Highway approximately 30 km south of Charleville in outback Queensland. The truck crashed into the dry creek bed, injuring the driver and causing a fire. Two other truck drivers, police and fire crews were tending to the injured driver when a small explosion occurred. Everyone was beginning to move to a position further away from the burning vehicle when a very large second explosion occurred, approximately 1 hour and 20 minutes after the crash.

All the eight people at the scene were injured, and the driver suffered serious burns. The road train, two fire trucks and the road bridge were destroyed. A crater of about 12 metres by 6 metres with a depth of 5 metres was formed in sandy loam.

Fire incidents not leading to explosions are more common than those causing explosions.

In an incident on 12 September 2004 near Glenden in Queensland, a truck loaded with bulk prill was allowed to burn out overnight without an explosion. Vehicle fires not resulting in explosions are at least as common as vehicle fires that result in explosions.

## 5.3.2 Safety measures for transporting AN and ANEs

The main causes of fires include the following:

- **Traffic collisions or single-vehicle crashes:** Issues to be addressed include the roadworthiness of the vehicles, especially their tyres and brakes, as well as the driver's health and fitness and measures to avoid driver fatigue.



- **Poor maintenance of the vehicle:** Typically, wheel fires are caused by seized bearings, ‘dragging’ brakes and overheating tyres. Electrical faults also lead to fires.

### *Safety measures to minimise adverse consequences of a vehicle fire*

Transporters need to provide the driver with the ability to fight small vehicle fires in an effective way by making sure that:

- fire extinguishers are fit for purpose and meet the minimum requirements of Table 12.1 of ADG Code 7.4 and are maintained in accordance with AS 1851—*Maintenance of fire protection systems and equipment*
- an eye-wash kit, chemically resistant gloves, an electric torch and three breakdown warning signs are carried
- the driver has been trained in the use of fire extinguishers and emergency response procedures for AN and ANEs and carries in the cabin the required emergency information inside a special emergency information holder, as prescribed in Chapter 11 of ADG Code 7.4.
- emergency information consists of an emergency procedure guide for a vehicle fire and a separate one to address spills and fires involving ammonium nitrate
- the driver understands the need to evacuate to a safe distance in the case of a fire that cannot be controlled with a fire extinguisher (if the fire involves only the trailer, the driver should unhitch the trailer if it is safe to do so and drive the prime mover to safety).

Transporters need to review and practise their emergency response. Good communication between transporter, driver and emergency services is a key necessity to facilitate a fast and effective response.

### *Emergency responders*

Emergency responders have a difficult decision to make: whether to fight a fire or withdraw to a safe distance from a potential explosion.

In the case of AN, there have been too many explosions overseas in which emergency responders were killed fighting an AN fire in storage or transport situations. The time between the start of the fire and the explosion covers a very large time frame and gives no guidance to fire fighters—the explosion behaviour of AN in fires is therefore unpredictable.

If firefighters have plenty of water and the fire is small, a firefighting response may be successful. If bulk bags are contained in shipping containers, it is important to open the containers to provide less confinement and easier access for the water.

If the fire is large and involves molten ammonium nitrate, all firefighters and the public need to evacuate quickly and expect an explosion. This is especially true if toxic orange-red nitrogen dioxide is given off—a sure indication that the decomposition of AN has entered a more dangerous phase.

In all events, responders should be familiar with and refer to the required emergency procedure *Guide 50—Ammonium nitrate* and *Guide 51—Ammonium nitrate emulsion, gel or suspension (UN 3375)* of SAA/ SNZ HB 76:2010—*Dangerous goods—Initial emergency response guide*. The guides require, in the case of a large fire, an evacuation distance of 1,600 metres to completely protect against an explosion. While such a large distance is desirable, for remote and rural locations of low population density an evacuation distance of at least 800 metres is recommended. This shorter distance will eliminate any blast overpressure dangers and greatly reduce (but not eliminate) the risk posed by shrapnel.

### 5.3.3 Modes of transport

The following photographs show the transport of ANEs with four types of containment systems and purpose-built vehicles that incorporate safe construction methods.

**Licensed road tank vehicles** made from steel or aluminium complying with AS2809 Parts 1 and 4 and with effective pressure-relief devices carry most UN 3375 substances.



*Licensed road tank vehicle.*

Source: Dr Peter Drygala.

**Licensed MPUs** have the dual purpose of transporting UN 3375 substances, AN prill and sensitising agents in separate steel or aluminium compartments and then converting the UN 3375 substances into Class 1 explosives and transferring the explosive into blast holes on the bench at the mine site. While they are mainly used on mine sites, they are permitted on public roads when transporting non-Class 1 ingredients.



*Licensed mobile processing unit.*

Source: Dr Peter Drygala.

**Composite intermediate bulk containers (CIBCs)** are approved by a national determination given by the Australian Competent Authorities Panel allowing for certain types of CIBCs. They most commonly consist of a rigid inner plastic container and an outer rigid steel-mesh protective casing conforming to IBC design code 31 HA1.



*Composite intermediate bulk container.*

Source: Dr Peter Drygala.

**Specific types of multimodal portable tanks (isotainers)** with effective pressure-relief devices are internationally approved. They are steel tanks that are twist-locked onto road and rail platforms and carry 18 kilolitres of product. They must be used for sea transport under the International Maritime Dangerous Goods Code.



*Isotainer.*

Source: Dr Peter Drygala.



*Road train carrying ammonium nitrate in flexible IBCs (left); close-up of flexible IBC (right).*  
 Source: Dr Peter Drygala.

## 5.4 Road and rail transport of metal concentrates

As part of the product stewardship and ADG transport code requirements, testing of metal concentrates using the GHS classification criteria has found that a number of metal concentrates are now classified as Class 9, UN 3077, Environmentally hazardous substance, solid, n.o.s. (not otherwise specified). Previously, testing methodology and criteria were not available for low-soluble metal compounds, so those materials did not attract special transport requirements. However, the publication of ADG Code 7 in 2007 included reference to Class 9, UN 3077 and included the GHS testing protocols.

Metal concentrates that may be affected are copper, lead, nickel and zinc. The major requirement for the transport of Class 9, UN 3077 materials as detailed in ADG Code 7.4 is for bulk containers that comply with BK2 requirements (that is, the concentrates are transported in closed bulk containers). This means a rigid top covering the top of the container. Consequently, there has been an increased use of containers and side tippers that comply with the BK2 requirement for transporting metal concentrates. BK1 sheeted bulk containers, such as kibbles with tarpaulin sheets, can be used for materials that are not classified.

In Western Australia, BK1 sheeted bulk containers, such as kibbles, are acceptable for the transport of UN 3077 materials. There is also an exemption from the licensing of drivers and vehicles for UN 3077. The placarding is simplified so that only a Class 9 diamond is required, instead of an emergency information panel as per the ADG Code. More details are on the website of the Department of Mines and Petroleum.<sup>54</sup>

<sup>54</sup> WA Department of Mines and Petroleum, [http://www.dmp.wa.gov.au/Documents/Dangerous-Goods/DG\\_IS\\_\\_UN3077EnvHazSubstanceSolid.pdf](http://www.dmp.wa.gov.au/Documents/Dangerous-Goods/DG_IS__UN3077EnvHazSubstanceSolid.pdf).



*Truck with BK2 containers.*

Source: Kalari Pty Ltd.

Traditionally, metal concentrates were loaded into tarped kibbles at the mine site, then transported by trucks and rail cars to bulk storage sheds at the port. The metal concentrate would then be loaded in bulk onto a conveyor and then onto the ship. The conveyor systems were designed to minimise dust to protect workers' health and to prevent community concerns.

In recent years, particularly since the Magellan incident (see case study below), more scrutiny, greater demands for lower dust emissions and improved handling efficiencies have led to the introduction of more innovative approaches to materials handling, ranging from the containerisation of minerals to dust suppression systems such as sprays or extraction systems.

Improved bulk transport of metal concentrates has been achieved using specially designed sealed containers to integrate into rotating spreaders, as seen in the photographs below. This allows the mineral product to be safely secured in the sealed containers and stored at port until the ship arrives. The ore is then loaded by the rotating spreader into the ship's hold, removing the need for traditional storage sheds and loaders. This results in a clean process that reduces potentially harmful dust emissions: it bypasses several transfer points between open stockpiles and conveyors, exposing the material only at the bottom of a storage hold.



*Bulk transport of metal concentrates using sealed containers and rotating spreaders.*

Source: Qube Ports and Bulk.

## **Case study: Dust emissions during transfers of lead concentrate from mine to port**

The focus on product stewardship and risks associated with the transport of metals was well documented in an incident in 2007 involving the world's largest lead carbonate mine in the Wiluna region of Western Australia.

The mining company mined the lead carbonate ore body by open cut and concentrated the ore using a flotation process. Bulk transport by tarped kibbles on rail flat rolling stock was used to transfer the lead concentrate to Esperance, where it was loaded via conveyors into ships' holds. Fine particles of lead carbonate dust were blown into Esperance port and the surrounding town during ship loading, resulting in the contamination of the port, rainwater tanks and nearby residential areas. Bird deaths were observed and elevated lead levels were detected in children.

The Western Australian Government held an inquiry in 2007, which resulted in a number of changes to the transport of lead carbonate from mine to port to reduce dust emissions. The incident resulted in a multi-million dollar cost to clean up the contaminated soil along the transport route and in the port area, and transport was suspended until new operational practices were implemented.

In 2011, the government gave Magellan Metals permission to resume exports of lead carbonate concentrate under strict new conditions, which included the development of an emergency response plan and packing the concentrate in UN-approved double-lined 2-tonne bulki-bags inside sealed shipping containers. The containers were washed before leaving the site for road and rail transportation to Fremantle. Soil monitoring along the transport route was conducted.

An important lesson to be drawn from this incident was that the lead carbonate had been misclassified and the wrong dangerous goods entry used. Correct testing and classification would have resulted in a totally different transport plan, avoiding the emission problem in the port. The lead carbonate had been classified as UN 3077, Environmentally hazardous substance, solid, n.o.s. of Class 9 (Miscellaneous dangerous substances). It should have been classified as Class 6.1 (Toxic substances) for the purpose of transport and storage as UN 2291—Lead compound, soluble, n.o.s. A toxic substances classification would have been likely to have put a stop to the use of kibbles and would have forced the transport plan to use intermediate bulk containers in freight containers shipped out of the port of Fremantle.

Unlike lead sulphide, lead carbonates are soluble in dilute hydrochloric acid, allowing absorption of lead into the bloodstream of people and animals. All lead ores that are soluble, or are likely to be soluble, in dilute acid (to imitate stomach conditions) need to be tested for their solubility in 0.07M hydrochloric acid in accordance with Special Provision 199 of ADG Code 7.4.

The report of the 2007 inquiry, with the full history of the incident and the government recommendations, is on the website of the Western Australian Parliament.<sup>1</sup>

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1 Education and Health Standing Committee, Parliament of Western Australia, *Inquiry into the Cause and Extent of Lead Pollution in the Esperance Area*, 2007, [http://www.parliament.wa.gov.au/Parliament%5Ccommit.nsf/\(Report+Lookup+by+Com+ID\)/28F900665F5C386048257831003E970C/\\$file/COMPLETE+REPORT.FINAL.PT1.pdf](http://www.parliament.wa.gov.au/Parliament%5Ccommit.nsf/(Report+Lookup+by+Com+ID)/28F900665F5C386048257831003E970C/$file/COMPLETE+REPORT.FINAL.PT1.pdf).

## 5.5 Rail transport of coal

In recent years, concerns have been raised by the communities near railway lines and coal mines about respiratory health effects of PM<sub>2.5</sub> and PM<sub>10</sub>. Comprehensive information about rail and terminal coal dust controls have been issued by the Queensland Department of Environment and Heritage Protection.<sup>55</sup> The department's website refers to QR Network's Coal Dust Management Plan, which was developed with coalminers.<sup>56</sup>

The main sources of coal dust emissions from coal trains are:

- wind erosion of the coal surface of loaded wagons during transit
- leakage of coal particles from the doors of loaded wagons
- wind erosion of spilled coal in the rail corridor

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55 Queensland Department of Environment and Heritage Protection, *Coal dust emissions*, 2013, <https://www.ehp.qld.gov.au/management/coal-dust/emissions.html>.

56 QR Network, *Aurizon Dust Management Plan*, [http://www.aurizon.com.au/Downloads/Coal\\_Dust\\_Management\\_Plan.pdf](http://www.aurizon.com.au/Downloads/Coal_Dust_Management_Plan.pdf).

- residual coal dust from unloaded wagons and leakage from doors
- coal or coal dust deposited on sills and wagon bogies.

Key rail components of the Coal Dust Management Plan include improved loading techniques, load profiling, veneering and sill sweeping:

- Improved loading techniques at mines aim to reduce the parasitic load on horizontal surfaces, reducing wagon overfilling and hence coal spillage during transport.
- Load profiling involves profiling the loaded coal into a garden-bed shape, reducing profile and aerodynamic drag and consequently dust lift-off.
- Veneering refers to the implementation of veneering stations at rail load-out facilities at Queensland coal mines. A veneer applied to the surface of the loaded coal wagon ensures that dust lift-off is reduced. Veneering involves spraying a biodegradable binding polymer onto the surface of loaded coal wagons before they leave the mine rail-loading facility, forming a flexible binding layer to the surface of a loaded coal wagon. The degree of dust reduction depends on a number of factors but experience to date indicates a reduction.

## 5.6 Dust management at receipt and export ports

Dust management measures implemented at terminals that handle minerals and coal typically comprise the following:

- Unloading
  - The rail receipt station is an enclosed facility, which helps to contain dust.
  - Exhaust fans create negative air pressure within the facility, extract dust particles from the air and pass them through an air-handling system that redirects fines into the hopper, while air is filtered and expelled.
  - Wagon vibrators are installed at some rail receipt stations to dislodge remnant ore and minimise carry-back in the rail wagons.
  - Regular cleaning of the in-loading facility also redirects small particles and remnants into the hopper.
  - Water sprays at the rail receipt hoppers allow the adjustment of moisture levels as ore is transferred to terminal stockpiles.
- Conveyors
  - Covered conveyors are used to minimise dust dispersal.
  - Belt washing stations clean belts and reduce dust and ore carry-back and spillage.
  - Water sprays are located at transfer points to dampen ore as it is transported.
- In the stockyard
  - Water sprays are located around terminal stockyards, and are controlled at some terminals by an automatic system connected to real-time weather monitoring stations. Changes in weather conditions and dust levels initiate automatic responses, but the water sprays can be activated manually if needed.
  - Stockpiles are generally limited in height to make them less susceptible to wind and reduce the likelihood of dust particles becoming airborne.
  - Earth mounds and trees are maintained as windbreaks to reduce the impact of high winds and reduce dust lift-off.
  - Vacuum trucks are used to remove dust from sealed roadways and other hard surface areas.



- Training in various techniques to minimise dust emissions is provided to all staff, including managers, operational staff and machine operators.
- On the wharf
  - Covered conveyors are used to transport ore to the wharf and shiploader. Pans below the conveyors prevent spillage into the river/harbour and minimise the effect of wind on the product.
  - Vacuum trucks are used to remove ore residue or spillage on the wharf.
  - Shiploaders feature a telescopic boom, allowing the mineral to be deposited deep inside the hold of each vessel. The boom has an enclosed section that minimises the exposure of product to wind during ship loading.
- Weather monitoring
  - Weather forecasts consisting of three-day and daily forecasts are accessed from the Bureau of Meteorology (BoM) website.
  - Continuous BoM observational data is monitored at regional sites to assist operational planning and to complement information available from onsite weather stations.
- Dust monitoring and reporting
  - Air-quality monitoring systems are established at onsite and surrounding terminals to provide regular air-quality monitoring and reporting.

## 5.7 Marine transport of ores and concentrates

The shipping of concentrates, minerals and ores is controlled by the International Maritime Organization (IMO) to ensure safe cargoes and prevent adverse impacts on humans and the environment during transport and accidental releases.<sup>57</sup> In Australia, this shipping is regulated through the Australian Maritime Safety Authority (AMSA).<sup>58</sup>

Three regularly updated international marine codes are applied by Australian and international legislation:

- the International Maritime Dangerous Goods Code (IMDG Code), which is updated every two years and gives the rules for dangerous goods transport packaging, freight containers, and portable tanks and bulk containers for solids
- the International Maritime Solid Bulk Cargo Code (IMSBC Code) covers the rules for uncontained solids, including a few dangerous goods permitted to be carried in the hold of a ship without a container
- the International Convention for the Prevention of Pollution from Ships (MARPOL).

A comprehensive reference for shipping requirements is the ICMM's *Hazard assessment of ores and concentrates for marine transport*.<sup>59</sup>

*Carrying solid bulk cargoes safely* also provides valuable advice and examples of hazards while shipping minerals.<sup>60</sup>

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<sup>57</sup> IMO, <http://www.imo.org>.

<sup>58</sup> AMSA, <https://www.amsa.gov.au/>.

<sup>59</sup> ICMM, *Hazard assessment of ores and concentrates for marine transport*, October 2014, <http://www.icmm.com/document/7852>.

<sup>60</sup> Lloyd's Register, *Carrying solid bulk cargoes safely*, 2013, [http://www.lr.org/en/\\_images/213-35783\\_IMSBC\\_Code\\_pocket\\_guide\\_final\\_web\\_tcm155-247233.pdf](http://www.lr.org/en/_images/213-35783_IMSBC_Code_pocket_guide_final_web_tcm155-247233.pdf).

Classification changes published in recent years now require that all minerals concentrates and minerals being transported by ship be assessed, tested as required, and classified according to the new criteria by toxicologists.

## 5.7.1 International Maritime Solid Bulk Cargoes Code

The aim of the IMSBC Code is to ensure the safe maritime transport of solid bulk materials. The code specifies requirements related to the safe stowage and shipment of solid bulk cargoes that may give rise to relevant onboard risks, such as structural damage due to improper cargo distribution, loss or reduction of stability during a voyage, and chemical reactions in cargoes, such as spontaneous combustion, emissions of toxic or explosive gases and corrosion. The IMSBC Code categorises cargoes into three groups:

- **Group A**—cargoes that may liquefy if shipped at a moisture content exceeding their transportable moisture limit (TML). TML is the maximum moisture content considered safe for carriage. Liquefaction means that the cargo becomes fluid or liquefies. On ships, this happens when the cargo is compacted by the ship's motion. Cargoes that are prone to liquefaction contain a certain quantity of moisture and small particles, although they may look relatively dry and granular when loaded. Liquefaction can lead to cargo shifting and even to the capsize of the ship.
- **Group B**—cargoes that involve a chemical hazard that could give rise to a dangerous situation on a ship
- **Group C**—cargoes that are neither liable to liquefy (Group A) nor involve chemical hazards (Group B), but might still be hazardous.

Cargoes can be in Group A, B or C, or Group A and B.

Group B cargoes are those that meet either the IMDG Code's dangerous goods hazard criteria or the IMSBC Code's 'materials hazardous only in bulk' (MHB) criteria. MHB cargoes are materials that involve chemical hazards when transported in bulk but that do not meet the criteria for inclusion in the IMDG classes above. However, they present significant risks to health and safety when carried in bulk and require special precautions.

In recent years, the development of testing protocols for low-solubility mineral compounds as well as internationally agreed environmental criteria for metals such as copper, lead, nickel and zinc have led to some metal concentrates being classified as Class 9, UN 3077, Environmentally hazardous substance, solid, n.o.s. Hence, those metal concentrates, depending on the mineralogy, may trigger the Group B classification and therefore be considered both a Group A and a Group B cargo. The criteria for MHB Group B cargoes have been expanded to include health and safety classifications largely based on the GHS (see Appendix 3 for criteria).

There has been significant research to better understand the liquefaction and the prevention of shipping incidents. A good resource on the dangers of solid bulk cargoes, including iron ore, is the Gard publication *Dangerous solid cargoes in bulk: DRI, nickel and iron ores*.<sup>61</sup>

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<sup>61</sup> Gard, *Dangerous solid cargoes in bulk: DRI, nickel and iron ores*, <http://www.gard.no/ikbViewer/Content/6227919/Dangerous%20solid%20cargoes%20in%20bulk%20January%202014.pdf>.

## Case history: Iron ore classification changes

In 2013, an important research project was undertaken to better understand the liquefaction of iron ore cargoes and appropriate classification criteria.

Classification criteria changes have been made based on particle size and composition to classify cargoes as either Group A or Group C products.

As a result, the new test—known as the modified Proctor/Fagerberg test procedure for iron ore fines for characterising the transportable moisture limit (TML) of bulk cargoes—has been introduced by the Australian Maritime Safety Authority (AMSA).<sup>1</sup>

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<sup>1</sup> AMSA, *Early implementation of draft amendments to the IMSBC Code related to the carriage and testing of iron ore fines*, IMO, London, 15 November 2013, <http://www.amsa.gov.au/vessels/ship-safety/cargoes-and-dangerous-goods/documents/DSC.1-Circ.71.pdf>.

## 5.7.2 MARPOL Annex V for marine transport of solid bulk cargoes

MARPOL Annex V implementation guidelines were adopted in 2012. The amendments prohibit the discharge of any garbage into the sea, unless explicitly permitted. Dry cargo residues and wash water containing such residues are defined as garbage and subject to the provisions of the annex.

Cargo residue not classified as harmful to the marine environment (HME) can be discharged to the sea outside special areas. The amendments specify that residues and wash waters of HME cargoes shall be discharged at adequate port reception facilities. The criteria to identify HME cargoes are based on the GHS environmental and human health toxicity end points. They include any combination of:

- Acute aquatic toxicity Category 1
- Chronic aquatic toxicity Category 1 or 2
- Carcinogenicity Category 1A or 1B, combined with not being rapidly degradable and having high bioaccumulation
- Mutagenicity Category 1A or 1B, combined with not being rapidly degradable and having high bioaccumulation
- Reproductive toxicity Category 1A or 1B, combined with not being rapidly degradable and having high bioaccumulation
- Specific target organ toxicity repeated exposure Category 1, combined with not being rapidly degradable and having high bioaccumulation
- Solid bulk cargoes containing or consisting of synthetic polymers, rubber, plastics or plastic feedstock pellets (this includes materials that are shredded, milled, chopped or macerated or similar materials).

## 5.8. Transport of hazardous / controlled waste materials

### 5.8.1 The Basel Convention, covering international transport

The Basel Convention<sup>62</sup> covers the trans-boundary movement of hazardous waste materials. The convention obliges its parties to ensure that hazardous and other wastes are managed and disposed of in an environmentally sound manner in the country of import. This particularly affects hazardous materials, such as smelter by-products.

Australia signed the Basel Convention in 1992. The convention is implemented in Australia by the *Hazardous Waste (Regulation of Exports and Imports) Act 1989* under the jurisdiction of the Australian Government.<sup>63</sup>

The convention requires that, before an export may take place, the authorities of the country of export notify the authorities of prospective countries of import and transit, providing them with detailed information on the intended movement. The movement may only proceed if and when all countries concerned have given their written consent.

Hazardous wastes are those designated by the convention in various annexes (specifically, annexes I, III and VIII) plus others considered to be hazardous wastes by the domestic legislation of the country of export, import or transit.

Wastes are defined by the convention as 'substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law'.

Disposal is defined by the convention in two categories as operations leading to the possibility of resource recovery, recycling, reclamation, direct re-use or alternative uses and those that do not.

The Hazardous Waste (Regulation of Exports and Imports) Act, which covers hazardous waste only, defines hazardous waste as:

- waste prescribed by the Regulations, where the waste has any of the characteristics mentioned in Annex III to the Basel Convention, which include:
  - explosive
  - flammable liquids/solids
  - poisonous
  - ecotoxic
  - infectious substances
- wastes that belong to any category contained in Annex I to the Basel Convention, unless they do not possess any of the hazardous characteristics contained in Annex III; wastes in Annex I include:
  - clinical wastes
  - waste oils/water, hydrocarbons/water mixtures, emulsions
  - wastes from the production, formulation and use of resins, latex, plasticisers, glues/adhesives
  - wastes resulting from surface treatment of metals and plastics
  - residues arising from industrial waste disposal operations

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62 Basel Convention, <http://www.basel.int/>.

63 Department of the Environment, *Hazardous Waste (Regulation of Exports and Imports) Act 1989: about the Act*, <http://www.environment.gov.au/protection/hazardous-waste/about>.

- wastes that contain certain compounds such as copper, zinc, cadmium, mercury, lead and asbestos
- household waste
- residues arising from the incineration of household waste.

## 5.8.2 Transport within Australia

Within Australia, the National Environment Protection (Movement of Controlled Waste between States and Territories) Measure (NEPM) provides details about the movement of controlled waste between states and territories.

The Controlled Waste NEPM is a national system for identifying and handling controlled wastes and transporting them across state and territory borders. It is administered by state and territory regulators. The NSW EPA summarises the core elements of the NEPM as a nationally agreed list of guidelines for tracking waste transport, including

- a national system of notification and approval before waste is moved
- licences for transporters to move waste interstate
- a requirement for transporters to carry approved waste transport certificates
- consultation between states and territories about the appropriateness of waste movements
- enforcement activity.<sup>64</sup>

Lists of controlled waste categories and controlled waste characteristics are presented in Schedule A of the NEPM.<sup>65</sup>

For example, the Western Australian Schedule A materials are listed as:

- A Plating and heat treatment
- B Acids
- C Alkalis
- D Inorganic chemicals
- E Reactive chemicals
- F Paints, resins, inks, organic sludges
- G Organic solvents
- H Pesticides
- J Oils
- K Putrescible and organic wastes
- L Industrial wash water
- M Organic chemicals
- N Soils and sludge
- R Clinical and pharmaceutical
- T Miscellaneous.

<sup>64</sup> NSW EPA, *Controlled waste NEPM*, 2015, <http://www.epa.nsw.gov.au/wasteregulation/controlled-waste-nepm.htm>.

<sup>65</sup> Standing Council on Environment and Water (SCEW), National Environment Protection (Movement of Controlled Waste between States and Territories) Measure, 1998, <http://www.scew.gov.au/nepms/movement-controlled-waste>; NSW EPA, *Controlled waste NEPM*, 2015, <http://www.epa.nsw.gov.au/wasteregulation/controlled-waste-nepm.htm>.

Classifying hazardous waste as a dangerous good is appropriate if the waste meets the testing criteria requirements of the designated class.

## 5.9 Transport of radioactive materials

The ADG Code does not apply to the transport of radioactive material and refers to the ARPANSA Code of Practice for the Safe Transport of Radioactive Material.

The 2014 edition of the Code for the Safe Transport of Radioactive Material, RPS C-2 (commonly referred to as the Transport Code) replaces the Code of Practice for the Safe Transport of Radioactive Material (2008) (RPS 2).<sup>66</sup> It adopts the International Atomic Energy Agency Regulations for the Safe Transport of Radioactive Material, 2012 edition (No. SSR-6). It is intended to establish uniform requirements for the transport of radioactive material in Australia by road, rail or those waterways not covered by the maritime legislation.

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<sup>66</sup> ARPANSA, *Code for the safe transport of radioactive material (2014)*, Radiation Protection series no. C-2, 2014, <http://www.arpansa.gov.au/publications/codes/rpsc-2.cfm>.

# 6.0 MANAGING RISKS OF HAZARDOUS MATERIALS

## Purpose

This section presents risk management strategies that may be implemented, as they relate to hazardous materials.

### Key messages

- Procedures are required to ensure that all hazardous materials coming on site are assessed for their hazards and risks.
- The substitution of hazardous materials by less hazardous materials and robust engineering control measures, such as ventilation and containment, reduce exposures to hazardous materials.
- Accountability must be assigned to ensure that the critical controls are maintained and their effectiveness verified.
- Hazard awareness, training and clear communications are critical to the success of risk management.

## 6.1 Risk management

Risk management must minimise the risks that hazardous chemicals pose to health, the environment and assets through unwanted exposures or releases. It is performed by a variety of safety professionals. This includes chemists and chemical engineers as well as occupational hygienists and environmental specialists, depending on the hazards and risks posed by the storage, transfers and processes used to avoid explosions, fires and loss of containment.

The ICMM's *Health and safety critical control management: good practice guide* provides guidance on high-consequence activities and how to identify and manage critical controls that can either prevent serious incidents or minimise their consequences.<sup>67</sup> The principles can be applied not just to general safety but to hazardous materials. Evidence from major incidents in mining, metals and other industries indicates that, although the risks were known, the controls were not always effectively implemented. The ICMM document provides specific guidance on:

- identifying the critical controls
- assessing their adequacy
- assigning accountability for their implementation
- verifying their effectiveness in practice.

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<sup>67</sup> ICMM, *Health and safety critical control management good practice guide*, 2015, <http://www.icmm.com/document/8570>.

The principles can be applied to a variety of situations. A simple risk assessment for all new chemicals being introduced on site is discussed in Section 6.2.4.

Risk management of exposures to hazardous materials can range from high-level qualitative assessments through to detailed quantitative assessments based on collected data, such as from personal and static air monitoring. The range is discussed in more detail in Section 7.

Chemical storage, transfers and process safety have traditionally been minimised with the help of regulations covering the storage and handling of dangerous goods and 'major hazard facilities'. Section 6.4 is focused on those safety risks. Australia's legislation is currently changing from dangerous goods classifications to the GHS classification system. It is therefore expected that chemical storage, transfer and process safety will increasingly refer to 'hazardous chemicals', rather than 'dangerous goods', in the future.

Historically, risk management approaches have focused on the technical aspects of risk management. Contemporary risk approaches (AS/NZS ISO 31000:2009 *Risk management—principles and guidelines*) now place more emphasis on communication at each stage of risk management. It is important for risk practitioners and managers to fully appreciate the relationship between effective risk management, risk communication and the technical risk assessment process. More information about risk management is in the *Risk management* leading practice handbook. Section 7 of this handbook also has more detail.

## 6.2 Worker hazard awareness

### 6.2.1 Legislation

Under the various OHS Acts, employers have the following responsibilities:

- They must provide the information needed to allow the safe handling of hazardous chemicals used at work.
- They must ensure that all employees have ready access to safety data sheets (SDSs), either as paper copies or in databases.
- They should encourage employees to read SDSs for the hazardous substances that they may be exposed to in their work.
- They should ensure that the SDSs on site are current (within five years of the issue date).
- They must provide appropriate personal protective equipment (PPE) to handle the hazardous material and perform the task safely.
- In some states, mining legislation requires that a risk assessment of every product be conducted and the risks be controlled through safe work procedures or effective controls. This occurs by a default reference to a guideline, but is nevertheless a legal requirement.

### 6.2.2 Safety data sheets and labelling

#### *Safety data sheets*

SDSs, previously known as material safety data sheets, were established around 30 years ago to fulfil 'workers' right to know' legislation in the United States. Even when a product is not classified as a hazardous chemical or a dangerous good, it is recommended that an SDS be prepared for the mine site to enable workers and managers to store and handle the product safely. SDSs should also include information about the health hazards in terms that are meaningful to workers, rather than just the GHS hazard codes or toxicological data. SDSs should include PPE details and safe handling requirements, as well as environmental information.



A similar approach should be taken for waste material that requires disposal off site or inherently hazardous materials such as in by-products and process streams.

## *Labelling*

All containers of hazardous chemicals supplied to, used in or handled at the workplace or transported off site should be appropriately labelled to allow them to be handled safely and to minimise environmental impacts. Again, information on the label should be meaningful to workers, and not just GHS coded statements.

Bulk storage vessels should be appropriately labelled or placarded in accordance with ADG Code 7.4. Hazardous chemicals that are not dangerous goods should also be appropriately labelled with the name of the hazardous chemical or product name. The SDS should be located nearby in a storage container.

Smaller containers that are transported from site, such as bulki-bags and samples for testing at offsite laboratories, should be labelled to comply with the Safe Work Australia Labelling of Workplace Chemicals Code of Practice, as well as with extra statements considered appropriate for safe handling and handling in an emergency specific to the hazardous material in question.

Using the original hazardous substances codes of practice, hazardous chemicals can be described by a series of risk and safety phrases that allow the user to understand the hazards and required precautions. However, under GHS classification and labelling of chemicals, changes will be made to the terminology, such as:

- signal word
- hazard statements
- precautionary statements covering prevention, response, storage and disposal.

The pictograms used in GHS for health and environmental hazards are included in Appendix 5.

## *Identification of hazardous chemicals in enclosed systems*

Where a hazardous chemical in a workplace is contained in an enclosed system, such as a pipe, piping system or process vessel, it must be identified to people who may be exposed to the contents. This is particularly important for systems containing cyanide or acid solutions.

Suitable means of identification include colour coding in accordance with:

- AS 1319 Safety signs for the occupational environment
- AS 1345 Identification of the contents of piping, conduits and ducts.

## *Manufactured hazardous materials*

SDSs are also important for product liability reasons, to ensure that hazards associated with the hazardous substance throughout its life cycle from mine and transport to customer are adequately detailed. Hence, metal concentrates must have an SDS.

Depending on the hazardous material in question, an appropriate health, safety and environment (HSE) assessment should be completed to ensure that the correct GHS HSE classifications are applied.

## *Imported hazardous materials*

Mine operators that directly import chemicals must ensure that those chemicals are listed in the Australian Inventory of Chemical Substances, which is managed through the National Industrial Chemicals Notification and Assessment Scheme (NICNAS), which has a stated role of aiding in the protection of the

Australian people and the environment.<sup>68</sup> In the case of a mixture or blended product, such as a lubricant, its components must be listed. In addition, the importing company becomes responsible for preparing an SDS to meet the legal guidelines.

The key documents, which are on the Safe Work Australia website, are:

- *Code of practice for the preparation of safety data sheets for hazardous chemicals* (mandatory from 1 January 2017)<sup>69</sup>
- *Labelling of workplace hazardous chemicals* (mandatory from 1 January 2017)<sup>70</sup>
- *National code of practice for the preparation of material safety data sheets*, 2nd edition, NOHSC 2011 (2003)<sup>71</sup>
- *National code of practice for the labelling of workplace substances*, NOHSC 2012 (1994).<sup>72</sup>

### **Hazardous waste / controlled materials**

The hazards of waste materials, particularly when transporting them off site, should also be assessed and an appropriate SDS, label and signage prepared to ensure that the workers handling the material onsite or offsite can do so safely and minimise environmental impacts.

Hazardous waste products should be identified and correctly classified as far as is reasonably practicable using the relevant state waste guidelines and the GHS. Where it is not reasonably practicable to undertake a complete hazard classification of waste material, the hazard classification must be determined or estimated using a precautionary approach based on the known or likely constituents of the waste.

## **6.2.3 Registers and manifests**

All hazardous chemicals on site must be on a site register, which is often a computerised SDS database. For all hazardous chemicals, the register should include the product name, the SDS, the quantity of the chemical, and the locations in which the material is stored and used. The register should be updated as new hazardous chemicals are introduced to the workplace and the use or production of other hazardous chemicals is discontinued. The register can either be centrally located or kept in the workplace to which it pertains.

Dangerous goods must be recorded in a site manifest that complies with the dangerous goods legislation. All workers, emergency services and relevant public authorities should have ready access to the site manifest. The manifest must be kept at the site entrance for access by emergency responders.

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68 NICNAS, <http://www.nicnas.gov.au>.

69 Safe Work Australia, *Code of practice for the preparation of safety data sheets for hazardous chemicals*, 2011, <http://www.safeworkaustralia.gov.au/sites/swa/about/publications/pages/safety-data-sheets-hazardous-chemicals-cop>.

70 Safe Work Australia, *Labelling of workplace hazardous chemicals*, 2011, <http://www.safeworkaustralia.gov.au/sites/swa/whs-information/hazardous-chemicals/labelling/pages/labelling>.

71 Safe Work Australia, *National code of practice for the preparation of material safety data sheets*, 2nd edition, NOHSC 2011 (2003), <http://www.safeworkaustralia.gov.au/sites/swa/about/publications/pages/cp2003materialsafetydatasheets2ndedition>.

72 Safe Work Australia, *National code of practice for the labelling of workplace substances*, NOHSC 2012 (1994), <http://www.safeworkaustralia.gov.au/sites/swa/about/publications/pages/cp1994labellingofsubstances>.

## 6.2.4 New chemicals coming on site

The following rules apply when a new chemical comes onto a site:

- Procedures must be in place to assess the hazards and risks of new products or chemicals before they come on site.
- A risk assessment must be conducted and signed off by a competent person based on the SDS and technical information sheets. The risk assessment should include the compatibility risk in an integrated storage area and the use with the existing chemicals on site.
- Before a hazardous chemical is used at the site, an SDS must accompany the first supply of the substance.
- Any necessary controls on the use of the substance must be established in the workplace.
- After the risk assessment, a procedure must be generated to ensure that the workers can handle the hazardous material safely. This should include the disposal of waste materials generated during the use of the product.

Figure 2: Sample risk assessment checklist

Identification - (completed by person bringing chemical to site)				
Product name:				
Supplier:				
Site:			Location:	
Department/contractor:				
Person requiring product:				
Intended use:				
Application method:			Average use (eg litres/hour):	
Frequency of use	Daily:	Weekly:	Monthly:	Hour in use:
Dangerous goods class:		Poison schedule:		UN No:
Storage quantities:			Container size:	
Storage location:				
Risk assessment - (completed by safety officer)				
	High	Medium	Low	
Eye				
Inhalation				
Skin				
Ingestion				
Fire hazard				
Overall rating				
Control - (completed by safety officer)				
Determine the appropriate level of control from the evaluation above.				
1. Can the use of this product be avoided or eliminated?				
2. Are safer substitutes available?				
3. Can the product be isolated?				
4. Engineering controls to reduce the risk				
<input type="checkbox"/> Open ventilation <input type="checkbox"/> Forced ventilation <input type="checkbox"/> Atmospheric monitoring <input type="checkbox"/> Additional lighting <input type="checkbox"/> Warning signs			<input type="checkbox"/> Barricades / guards <input type="checkbox"/> Fire extinguisher <input type="checkbox"/> Training <input type="checkbox"/> Written procedure <input type="checkbox"/> Other	
5. What special personal protective equipment is required				
<input type="checkbox"/> Splash proof goggles <input type="checkbox"/> Full face shield <input type="checkbox"/> Standard rubber gloves <input type="checkbox"/> Special gloves <input type="checkbox"/> Particulate mask <input type="checkbox"/> Half face respirator			<input type="checkbox"/> Full face respirator <input type="checkbox"/> Air flow hood / mask <input type="checkbox"/> Disposable coveralls <input type="checkbox"/> PVC apron/coveralls <input type="checkbox"/> other	

<b>Environment - (completed by environmental superintendent)</b>				
The product (or components) is reportable under the National Pollutant Inventory?				
Storage containment / bunding required?				
Special waste disposal requirements?				
Spill control procedures are necessary?				
<b>Stores - (completed by store superintendent)</b>				
Storage compatibility:				
Storage requirements:				
<b>Recommendations/actions/comments</b>				
	<b>SAFETY</b>	<b>ENVIRONMENT</b>	<b>WAREHOUSE</b>	<b>TECHNICAL EXPERT</b>
<b>REVIEWED BY</b>				
<b>SIGNED</b>				
<b>DATE</b>				
<b>DEPARTMENT MANAGER APPROVAL</b>				
<b>SIGNATURE:</b>			<b>DATE:</b>	

Source: Newcrest Mining Ltd.

## 6.2.5 Training

All companies have a duty of care to inform their workforce about the hazards and risks associated with hazardous materials and about safe handling procedures.

All workers and personnel working regularly on the site who work with hazardous chemicals or dangerous goods must be trained on the hazards and risks. The training should include:

- recognition of the material as hazardous at the operation
- adequate information about the health or environmental effects of the material
- information on the symptoms of overexposure to the material
- first aid and emergency procedures
- PPE requirements, including the selection, use, maintenance and storage of PPE
- information on environmental clean-up procedures
- firefighting requirements.

An SDS or other useful information in the language of the workforce should be available for this purpose. Refresher training should be conducted at set periods and training records kept.

Emergency drills simulating worker exposure and environmental releases of high-risk hazardous chemicals should be conducted periodically and be evaluated for effectiveness. The evaluation should include an assessment of whether all personnel involved have the necessary knowledge and skill to carry out the required work.

All visitors and contractors need to be inducted so that they are aware of the basic safety and PPE requirements of the site and of emergency procedures. They should be accompanied by suitable site-appointed personnel while on site.

## 6.3 Community awareness

Community concerns about hazardous materials with impacts on public health and the environment continue to increase. The concern is often about toxicity and respiratory impacts of materials handled on site or transported to ports. Hence, it is important that site workers are well informed of the hazards and risks, so that they can contribute to discussions about the concerns of the community, friends and family.

It is important to acknowledge the hazards associated with certain materials, but also to draw a distinction with risk. Any successful management of risk reduces it to acceptably low levels, regardless of the high hazard potential.

Engagement with communities is covered in detail in many publications. People in the mining and mineral processing industries should consult the *Community engagement and development and Community health and safety* leading practice handbooks, as they have been written specifically for mining operations.

The following case study developed by Nyrstar Port Pirie is of an excellent example of community engagement concerning a hazardous material, in this case lead. Since the recent redevelopment of the smelter, this program has now been named the Total Lead Abatement Program.

### **Case study: Tenby10 Program, Nyrstar Port Pirie smelter**

In a unique, world-leading partnership known as the Tenby10 Program, the Port Pirie Regional Council, the South Australian Department of Health, the South Australian Environment Protection Authority, Nyrstar Port Pirie Smelter and the Port Pirie community worked together to find a solution to the elevated blood lead levels of children in Port Pirie. The goal is to lower children's blood lead levels to below the World Health Organization standard of 10 µg/dL (micrograms per decilitre) of blood by the end of 2010. What was acceptable in the past is no longer acceptable. This program began operating as Tenby10, became Ten for Them, and is now known as the Total Lead Abatement Program.<sup>1</sup>

Port Pirie is an integrated multi-metal smelter and refinery with the flexibility to process a wide range of lead-containing feedstocks to produce refined lead, silver, zinc, copper and gold. The smelter was built in 1889 and became the world's biggest lead smelter by 1934.

Lead can enter the human body through eating lead-contaminated food, water, soil, dust or paint chips and through breathing in lead dust particles. A common way of absorbing lead, particularly for young children, is through contaminated hand-to-mouth movements.

Blood lead levels above 10µg/dL can interfere with the development of organ systems, in particular the central nervous system. This affects babies and young children, whose bodies are developing rapidly, more than adults. Adverse effects in neuro-behavioural function, particularly in intellectual performance (decreasing IQ) and behaviour, and impaired haemoglobin synthesis appear to be the most common and damaging effects of lead exposure.

Adults absorb about 10% of ingested lead, whereas children's less mature digestive systems can absorb around 50% because lead resembles calcium and their gastrointestinal tracts take up calcium at greater rates than those of adults. Nutritional deficiencies of iron and calcium can also lead to greater absorption, exacerbating the toxic effects of lead.

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<sup>1</sup> Targeted Lead Abatement Program, <http://www.tenforthem.com.au/>.

The Tenby10 project had significant success in reducing the blood lead levels of Port Pirie's children. Results in 2008 showed that 63.1% of children tested had levels below the World Health Organization standard of 10 µg/dL—an 8% improvement on results in 2007. The project made running improvements each year after it began.

This result was achieved through substantial investment by Nyrstar in onsite emissions control measures and environmental programs. In addition, extensive community education and awareness programs increased people's understanding of the interactions of lead dust in the environment and of how to limit children's exposure to lead dust in the home.

Source: Nyrstar Port Pirie Smelter.

## 6.4 Dangerous goods

The expectation is that a documented and robust risk assessment will be performed for dangerous goods, especially as quantities of dangerous goods can be significantly greater than quantities of most hazardous materials.

Much of this section has been referenced in the Western Australian Department of Mines and Petroleum's *Dangerous goods safety guidance note: Risk assessment for dangerous goods*.<sup>73</sup> That document also contains good templates for risk assessments, including the one shown in Figure 3 (below), which provides guidance on the risk assessment process for dangerous goods.

Anyone carrying out a risk assessment should be familiar with the requirements of the relevant state storage and handling regulations and associated approved codes of practice. The codes of practice include industry codes and Australian Standards and give ready-made, practical and reliable control measures without the need for a risk assessment from first principles. It is only in the absence of a relevant code of practice that it makes sense to engage in the risk assessment. However, risk assessments are unavoidable for all chemical processes for which suitable codes are simply not available. A risk assessment is also necessary in order to justify alternative control solutions and to cover situations not covered by a code. A comprehensive list of codes of practice for dangerous goods and process safety is in Appendix 4.

For a dangerous goods site, a risk assessment is a document that identifies all hazards relating to the dangerous goods at the site for each hazard. The process can be summarised as follows:

- Assess the probability of the hazard causing a dangerous goods incident.
- Assess the consequences of the incident for people, property and the environment.
- Prioritise the risks.
- Identify the risk control measure or measures.
- Rank controls in order of greatest impact and financial considerations.
- Explain the rationale behind the judgements made.

A separate hazard identification and risk assessment should be done for each dangerous good and for each dangerous goods installation.

<sup>73</sup> Western Australian Department of Mines and Petroleum, *Dangerous goods safety guidance note: Risk assessment for dangerous goods*, 2013, [http://www.dmp.wa.gov.au/Documents/Dangerous-Goods/DGS\\_GN\\_RiskAssessmentForDangerousGoods.pdf](http://www.dmp.wa.gov.au/Documents/Dangerous-Goods/DGS_GN_RiskAssessmentForDangerousGoods.pdf).

Figure 3: Risk management process for dangerous goods

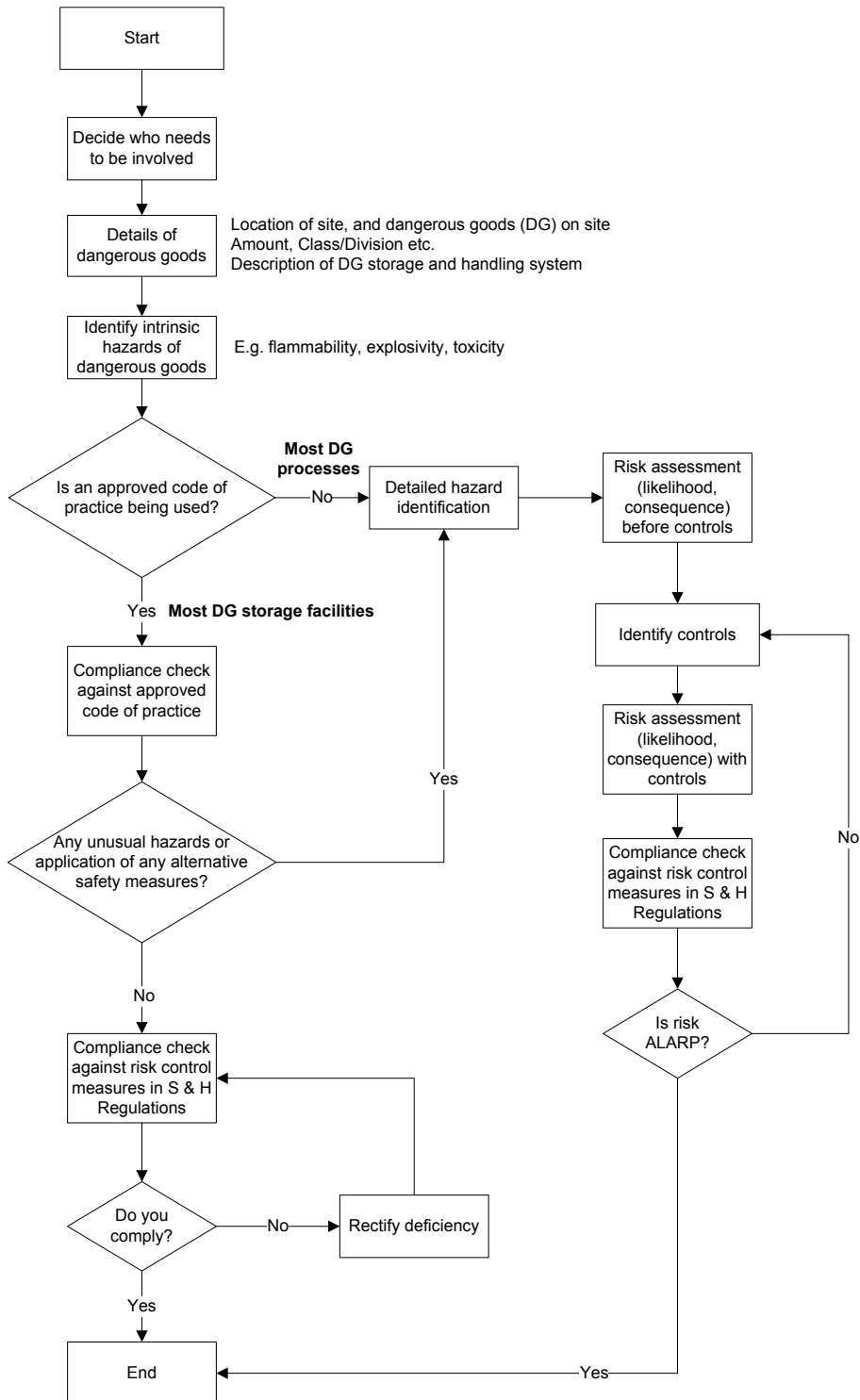


Table 4 shows the main types of intrinsic hazards associated with various dangerous goods classes and divisions. It is most important that all relevant hazards be identified. A hazard is any activity, procedure, plant, process, substance, situation or circumstance that could be the cause of an accident involving a dangerous good.

It helps to understand that dangerous goods hazards arise from five major causes and to ask the following five questions.

In what ways could

- loss of containment from the storage or handling system (such as containers, tanks, reaction vessels or pipes) occur?
- external fire impinge on the dangerous goods?
- ignition sources cause a fire or explosion (where explosives or explosive atmospheres are a potential problem during transfer operations)?
- unwanted mixing or contamination of the dangerous goods with incompatible substances occur and lead to a violent chemical reaction?
- the stability of inherently unstable dangerous goods be compromised (such as by the loss of small concentrations of an inhibitor, by exceeding a maximum control temperature, or through impact, friction or ignition sources)?

Robust risk assessments which prevent process safety incidents and consequently loss of containment such as through fire, spillage and explosion protect not only the workers but also the community and the environment.

### 6.4.1 Major hazard facilities

The storage of significant quantities of dangerous goods and their complexity may result in a site being classified as a major hazard facility (MHF), depending on definitions in the state or territory legislation. More information about the risk assessment and documentation guidelines can be obtained through the OHS authorities. An example of the Western Australian requirements is in the state's dangerous goods safety guidance note on generating the supporting documentation for an MHF safety report.<sup>74</sup>

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<sup>74</sup> Western Australian Department of Mines and Petroleum, *Dangerous goods safety guidance note M01/09: Generating the supporting documentation for a MHF safety report*, 2009, [http://www.dmp.wa.gov.au/Documents/Dangerous-Goods/DGS\\_GN\\_RiskAssessmentForDangerousGoods.pdf](http://www.dmp.wa.gov.au/Documents/Dangerous-Goods/DGS_GN_RiskAssessmentForDangerousGoods.pdf).



Table 4: Intrinsic hazardous properties of dangerous goods

HAZARD	CLASS/DIVISION (INCLUDING SUB-RISKS)											
	2.1	2.2	2.3	3	4.1	4.2	4.3	5.1	5.2	6.1	8	9
Flammability	✓			✓	✓	✓	✓		✓			✓
Chemical explosion	✓			✓	✓							
Physical explosion	✓	✓	✓									
Physical and chemical explosion	✓				✓							
Explosive atmosphere	✓			✓		✓						
Toxic by inhalation			✓							✓		
Toxic by skin/eye contact										✓	✓	
Toxic by ingestion										✓		
Temperature sensitivity					✓	✓			✓			
Asphyxiation risk	✓	✓										
Hot liquid												✓ <sup>a</sup>
Corrosivity											✓	
High reactivity					✓	✓	✓	✓	✓			
Cryogenic burns		✓										✓
Chemical instability					✓	✓		✓	✓			
Hazardous decomposition products					✓	✓	✓	✓		✓	✓	
Environmental pollutant										✓		✓

<sup>a</sup> Hazard applies to some Class 9 goods.

Note: This table is not intended to cover all the hazardous properties of dangerous goods. Additional hazards may apply.

## 6.4.2 Storage of incompatible dangerous goods

When incompatible hazardous materials come into contact with one another during a spill or release, the goods can react together adversely to cause fire, explode or release toxic, flammable or corrosive vapours.

Workplaces where dangerous goods or combustible liquids are stored or handled must have systems and procedures to prevent them coming into contact.

To manage the storage of incompatible goods, operations must:

- identify each of the dangerous goods intended to be stored on site
- recognise goods or other materials that are incompatible.

Compatibility and segregation charts can be used to determine whether each combination of dangerous goods and combustible liquids is likely to be compatible. The charts are only a guide and not meant to replace an SDS or a risk assessment.

An important part of identifying incompatible goods and materials is a review of the storage and handling information in the SDS for each dangerous good. After reviewing the SDS information, operators should list each incompatible dangerous good or other material mentioned in the SDS and take appropriate measures to keep them apart.

The factors influencing compatibility are complex. Assessments should consider the following factors:

- A violent reaction (fire or explosion) between one or more highly reactive chemicals may occur.
- A reaction between two or more spilled goods may liberate flammable, toxic or corrosive vapours or gases. Such reactions can be rapid or occur slowly over time until a build-up of a hazardous material creates an emergency.
- Released or spilled goods may deteriorate, contaminate or destroy the packaging materials of another incompatible product to worsen a situation.
- Flammable goods stored next to other toxic or corrosive materials may catch fire, causing rapid dispersal of those materials into the environment.
- Flammable materials may catch fire and set fire to other products stored nearby (for example, gas cylinders, resulting in rupturing of a cylinder).
- Fire suppression compounds suitable for one type of dangerous good may be incompatible with other dangerous goods stored in the same area.
- Materials used in the construction of spill catchment systems may react with dangerous goods spilled on them (for example, hydrochloric acid will rapidly corrode concrete walls used as a spill containment system).

## 6.5 Environmental risks

The impacts of hazardous material on air, water and soil are well documented and regulated through national and state environmental authorities. This section is included to illustrate the considerations required for environmental risk assessments of hazardous materials. In this example, the impacts are on water.

The Western Australian Department of Water's *Water quality protection note 65: toxic and hazardous substances* (2015), provides guidance on how impacts on the environment may result from:

- leakage of fluids from damaged or corroded chemical storage systems
- accidental spills during the transport or maintenance of equipment
- poor chemical handling, misuse or vandalism
- the dispersion of a chemical spill or leakage by water used to control fire at hazardous substance storage facilities
- the dispersion of chemical concentrates in uncontrolled stormwater run-off.

The impact on the environment, particularly on sensitive water resources, from hazardous materials used and generated by mining and mineral processing is discussed in the *Preventing acid and metalliferous drainage, Cyanide management, Water stewardship and Tailings management* leading practice handbooks.

Sensitive water resources include:

- those proclaimed or assigned as public drinking water source areas
- those used as private drinking water supply sources (for consumption by humans or animals)
- waters with specific qualities necessary to support commercial or industrial activities (such as aquaculture, food processing or crop irrigation)
- waterways
- wetlands that are pristine or conservation-valued
- groundwater aquifers that sustain important ecological functions (such as cave ecology)

- locations where contact with surface water or groundwater from the watertable is likely to affect people's health or wellbeing (such as garden, recreation or irrigation sources)
- water bodies or wetlands meeting recognised cultural or social needs (such as those used for swimming or recreational fishing or valued for their visual appeal).

## 6.6 Risk controls

### 6.6.1 Hierarchy of control for hazardous materials

Table 5 provides the listing of the hierarchy of control as well as examples for both dangerous goods and hazardous materials.

Table 5: Hierarchy of risk controls with practical examples

RISK CONTROLS	EXAMPLES
<b>ELIMINATING THE RISK</b>	<ul style="list-style-type: none"> <li>• Use a non-harmful substance instead of dangerous goods</li> <li>• Replace asbestos with safer synthetic substitutes, such as glass foam, rock and glass wool</li> </ul>
<b>SUBSTITUTING THE SYSTEM OF WORK, SUBSTANCE OR PLANT FOR SOMETHING LESS HAZARDOUS</b>	<ul style="list-style-type: none"> <li>• Change the type of dangerous goods kept on site</li> <li>• Use a pelletised form of the hazardous substance, rather than a powdered form</li> <li>• Vacuum or use an industrial sweeper to clean up concentrate dusts, rather than manually sweeping them up</li> <li>• Paint by brush or roller instead of by spray gun application</li> <li>• Select a product with less volatile ingredients ( eg MDI over TDI)</li> <li>• Reduce the quantities of dangerous goods kept on site</li> </ul>
<b>ISOLATING THE HAZARD</b>	<ul style="list-style-type: none"> <li>• Introduce a restricted work area</li> <li>• Do not locate potentially hazardous materials or processes near frequently used thoroughfares and buildings</li> <li>• Use remote storage for hazardous materials (e.g. explosives, fuel tank farms)</li> <li>• Enclose the system</li> <li>• Separate goods from other hazards</li> <li>• Segregate incompatible substances</li> </ul>
<b>INTRODUCING ENGINEERING CONTROLS</b>	<ul style="list-style-type: none"> <li>• Use forced ventilation to remove fumes</li> <li>• Use ventilation as the main method of control of airborne chemical hazards, particularly contaminants in underground mines and sample preparation areas when pulverising samples</li> <li>• Use spill containment</li> <li>• Use impact protection</li> <li>• Use flameproof or intrinsically safe electrical equipment in hazardous areas</li> <li>• Use safety relief valves</li> <li>• Use overfill protection</li> </ul>

RISK CONTROLS	EXAMPLES
<b>ADMINISTRATIVE CONTROLS</b>	<ul style="list-style-type: none"> <li>• Modify the system of work, such as by changing the times at which certain tasks are done</li> <li>• Use placards or hazard warning signs</li> <li>• Use housekeeping and labelling to limit inadvertent (especially skin) exposure to workplace hazards</li> <li>• Provide specific training and work instructions</li> <li>• Rotate staff</li> <li>• Use schedules to remove workers from exposure (e.g. remove lead miners from the area of exposure if their blood lead levels exceed a certain level; do not permit uranium miners to receive more than a maximum radiation dose over a specified period)</li> </ul>
<b>PERSONAL PROTECTIVE EQUIPMENT (PPE) AND SAFETY EQUIPMENT</b>	<ul style="list-style-type: none"> <li>• Provide eye, respiratory and hand protection for workers (and instruction on when and how to use it)</li> <li>• Provide firefighting equipment</li> <li>• Provide safety showers</li> <li>• Provide spills clean-up equipment</li> </ul>

More information about the hierarchy of controls for hazardous substances is in the *Risk management* leading practice handbook.

## 6.6.2 Personal protective equipment

All sites use PPE, although it is the least preferred means of protecting workers. PPE must be managed and a PPE program must be in place to ensure that it provides the right protection for the worker's health, as it is the last barrier to harm.

PPE is used when other means of exposure control cannot be employed or to supplement the use of existing higher order controls (such as ventilation). The use of any PPE places restrictions on workers: it reduces the flexibility of the worker's operation and may contribute to heat load on the worker's body and possibly result in heat stress. Poor selection of PPE can affect the worker's ability to do the task safely. Importantly, the use of PPE does not remove the hazard.

The selection of PPE is based on the risk assessment for the task, and care is needed to provide the correct level of protection. In some situations, excessive use of PPE can compromise the worker's ability to work safely by introducing thermal and physical risks.

Emergency response may require different PPE because the risk of exposure is greater, so emergency responders are another key group to consider, along with operational and maintenance staff.

### 6.6.2.1 Gloves

Good practice when selecting gloves involves a risk assessment of the hazard and consulting the workers (as dexterity and 'feel' are important for their acceptance).

Leather, knitted or stitched gloves are good for protecting against sparks or scraping against rough surfaces, but are not suitable for handling hazardous substances. Making the correct choice requires knowledge of the chemical and permeation resistance of different glove materials. Major glove manufacturers publish data on the internet on the resistance of their glove material to permeation by common solvents used in industry.

## *Respiratory protective equipment and programs*

Respiratory protective equipment (RPE) and respiratory protection programs are often used at mine sites to protect against dusts, chemicals and welding fumes.

The key requirements of a respiratory protection program include:

- management to administer the program
- knowledge of respiratory hazards
- workplace risk assessment of the respiratory hazards
- selection and purchase of the appropriate type of RPE, with the appropriate protection factor
- workers' acceptance of the RPE
- fit testing, to ensure the facial fit of half- and full-face masks
- training in RPE use
- medical assessment of RPE users, in certain cases
- the need for workers to be clean shaven
- written procedures and guidelines, available at the site
- inspection, maintenance and repair of RPE
- audit and review of the program.

The person selecting and supervising the RPE program will also require training, which can often be provided by the equipment supplier.

Respiratory protection programs should be in keeping with the requirements of:

- AS/NZS 1715 Selection, use and maintenance of respiratory protective devices.
- AS/NZS 1716 Respiratory protective devices.

## *Respirators*

Particulate respirators contain filters that trap dusts, mists or fumes and allow the worker to breathe local air. There are two main forms—the traditional replaceable filter type and the maintenance-free (disposable) type.

It is important to select the correct class of respiratory protection for the process and not treat all respirators as equal. Australian Standard 1715-2009 classifies particulate respirators as:

- Class P1 for mechanically generated particulates (dusts and mists)—particles generated from operations such as grinding, blasting, spraying and powder mixing, and containing, for example, asbestos, silica, caustic mist or lead (as standards change, it will be necessary to review these definitions).
- Class P2 for thermally generated particulates (fumes)—diesel particulate matter, particles (metal fumes) generated by high-temperature operations such as welding, soldering, brazing and smelting.
- Class P3—highly toxic particulates, such as radioactive compounds and beryllium.

Dusts, mists and vapours include particles of various sizes that are distributed differently in the respiratory system. Particles smaller than 100 µm are generally considered to be inhalable, but cannot be seen by the naked eye under normal light. Particles smaller than that (approximately 10–50 µm) can penetrate to the upper part of the lungs, and particles smaller than 10 µm can penetrate to the depths of the lungs and are referred to as respirable dust.

## *Protection factors*

Inexperienced and untrained personnel should not attempt to select correct RPE.

Two pieces of numerical information are crucial in applying RPE successfully:

- the concentration of contaminant in the workplace
- the target concentration inside the respirator.

Based on this data, it is possible to calculate the required minimum protection factor (PF) expected from particular RPE using the formula:

$$\text{Required minimum PF} = \frac{\text{concentration in workplace}}{\text{occupational exposure standard (or other target)}}$$

## *Occupational exposure standard (or other target)*

The concentration and the workplace exposure standard should be in the same units (ppm or mg/m<sup>3</sup>). AS/NZS 1715 contains an excellent decision tree for arriving at suitable RPE for most applications. The standard deals with respirator selection under the simplified headings of 'Contaminant', 'Task' and 'Operator'.

## *Filter service life and breakthrough*

A filter's service life depends on its construction and on workplace factors such as exposure conditions, the concentration of the contaminant, temperature, humidity, and the worker's breathing rate and general respiratory competence. Service life must include some unexpended reserve capacity as a safety margin. Importantly, filters should not be used beyond the expiry of their shelf life.

To some extent, how long the filter in a respirator will last can only be determined by experience, so it is better to rely on outside experience or advice from manufacturers than to chance unsafe practices. Some suppliers have online systems into which concentrations can be entered to get an estimate of the expected service life.

For any type of respirator, the wearer's acceptance is also an important factor. For particulate filters, filtration efficiency usually increases with use as dust particles slowly block the filter. This causes increased inhalation resistance. This may have adverse effects for the wearer when RPE is used for continuous work or if the wearer has a medical respiratory condition that makes respirator use difficult. The service life of such filters is over when the wearer can no longer tolerate the increased breathing resistance.

For gas and vapour filters, minimum service lifetimes can be calculated only if there is reliable data on exposure conditions. Otherwise, scheduled maintenance and replacement programs with a reasonable margin for safety must be scrupulously adhered to.

Breakthrough of the contaminant, as indicated by odour, is a totally unreliable means of determining the end of a respirator filter's service life. Some contaminants are odourless and colourless, and others have workplace exposure standards well below their odour threshold. With some substances, such as hydrogen cyanide, breakthrough might have disastrous consequences—particularly because only half the population is genetically able to detect hydrogen cyanide by odour.

## *Fit testing, inspection, maintenance and repair*

The employer must provide all the RPE required for any operation involving hazardous materials, and most mines keep the bulk of the RPE in stores. Small quantities of stock should also be available in workshops and plant areas where they might be needed. This particularly applies during night shifts when stores may be closed, or in more remote working locations. This stock is to be kept in a clearly marked, dedicated area, such as a wall- or post-mounted cabinet, to which employees have ready access.

For RPE, a proper maintenance program needs to be developed. The program should follow manufacturers' instructions and include:

- cleaning and sanitising of equipment
- storage
- repair
- inspection for defects
- training in use.

The following program format addressing respiratory protection is from AS1715:2009, but can be modified for most forms of RPE:

- identification of the hazard
- reasons for respirators
- respirator selection
- use and proper fitting of respirators
- fit testing
- wear time
- limitations of respirators
- maintenance and storage.

It is essential to use proper storage in between use. Gas and vapour filters can continue to absorb contaminants when not in use, further exhausting their capacity. Plastic sealable food storage containers or zip-lock plastic bags are ideal for between-use storage.

Each wearer should be provided with their own individual RPE. Fit testing is also conducted with individual workers to ensure that they achieve the right facial fit with the RPE recommended for the hazard and prevent leakages negating the protection factor.

Where air compressors are used for air-supplied respirators, there should also be a maintenance, inspection and testing program in place for the compressors to ensure that the air quality is acceptable. Parameters such as air temperature, water vapour and oil mist should be regularly monitored. Appendix A of AS1715: 2009 *Selection, use and maintenance of respiratory protection* provides guidance on breathing-air quality testing.

## *Medical assessment for suitability of RPE for some users*

Wearing RPE has some physiological and psychological limitations. A number of medical conditions can prevent a worker from using RPE, including diabetes, asthma, emphysema, skin sensitivity, a punctured eardrum or chronic airway disease.

Some workers feel claustrophobic when wearing a normal filter respirator, but may find a powered air-purifying respirator more acceptable.

### **Case study: The control of pneumoconiosis in the New South Wales coal industry**

Coal workers pneumoconiosis (CWP) results from the gradual accumulation of coal dust particles in lung tissue. In dusted lungs, nodules form in the upper zones of both lungs, resulting in a debilitating disease with reduced lung function. Detection of pneumoconiosis is usually by chest X-ray. CWP is a preventable disease that can be eliminated by effective control and monitoring strategies.

In 1948, the overall prevalence of CWP in New South Wales was 16%—a totally unacceptable situation by both modern and historical standards. Coal Services Health data shows that numbers of new cases of CWP have dropped away. The drop in new cases is the result of the coal industry's efforts to control dust through ventilation and dust suppression procedures, and through monitoring (including workplace environmental monitoring and monitoring miners' health with regular chest X-rays and lung function testing). These important prevention and surveillance measures have ensured the steady decline in the incidence of new cases of pneumoconiosis since a peak in 1970–73. However, many new miners are entering the industry, making it vitally important not to forget the OHS lessons of the past or the importance of dust suppression and health surveillance.

To that end, the New South Wales coal industry supports the Coal Services' Standing Committee on Dust Research and Control, which comprises personnel from mine operations, statutory authorities and health specialists who overview every workplace dust sample collected in the industry and investigate regular exceedences. The Committee also conducts research into relevant industry issues (such as diesel particulates and inhalable dust) and better methods of dust suppression and workplace monitoring.

An untiring focus over more than 50 years has significantly reduced this debilitating disease from the New South Wales coal industry. The importance of the principles of effective control as well as vigilant monitoring cannot be overstated. A problem might be under control, but it can easily re-emerge if control and monitoring procedures are discarded.



# 7.0 PERFORMANCE MANAGEMENT

## Purpose

This section provides information on monitoring, reporting and auditing to manage risks of hazardous materials.

### Key messages

- The development and implementation of targeted monitoring programs are an important basis of performance management.
- Targets based on critical controls will deliver better lead KPIs and improved performance.
- Auditing by second and third parties can provide new insights into improved performance.

Best practice performance management is achieved by monitoring, auditing and reviewing performance. This involves processes to identify trends, measure progress, assess compliance and drive continual improvement.

The *Evaluating performance: monitoring and auditing* leading practice handbook is an excellent guide that includes detailed case studies. In addition, the processes involved in the performance management of hazards and risks have been well described in the ICMM's *Health and safety critical control management: good practice guide*.<sup>75</sup> That guide's section 'Step 5 Define performance and reporting' is core to the elements defining performance management. This is discussed in more detail in Section 7.6.

Section 7 focuses on hazardous materials, exposure assessments and performance measurements.

## 7.1 Monitoring and auditing

Monitoring is the gathering, analysis and interpretation of information, in this case for the assessment of performance. Monitoring in the resources industry commonly includes monitoring water quality, impacts on flora and fauna (as well as recovery following control or rehabilitation measures), air quality and greenhouse gas emissions.

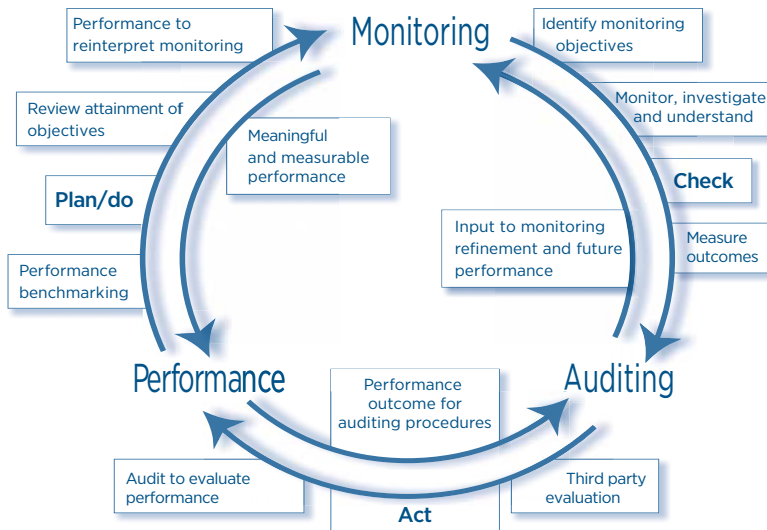
Auditing is systematically reviewing monitoring procedures and results and checking that all commitments have been fulfilled or completed, by comparing the audit findings against agreed audit criteria. Auditing can be undertaken internally, by experts in specific disciplines who provide a check on methods or success against internal company standards, or externally, by an independent consultant or expert who can demonstrate transparency and add value to the audit process.

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<sup>75</sup> ICMM, *Health and safety critical control management: good practice guide*, 2015, <http://www.icmm.com/document/8570>.

In any leading practice management program, the elements of monitoring and auditing for evaluating performance are inextricably linked. This is illustrated in Figure 4.

Figure 4: Evaluating performance: monitoring and auditing



Source: *Evaluating performance: monitoring and auditing* leading practice handbook.

All health, safety and environment (HSE) management systems include the requirement to measure performance, such as by using injury rates or spillages. Metrics must include leading and lagging indicators and be based on quantitative data. Performance should be measured on a regular basis and include an evaluation of:

- the extent to which objectives are being met
- progress against targets
- effectiveness of controls
- proactive conformance measures
- reactive or historical performance measures.

Procedures for measuring and monitoring controls for process safety, occupational health exposure and environmental impacts should be in place as part of the HSE management system. Monitoring results must be collected and analysed, based on the level of risk, using descriptive statistics on a regular basis for:

- trends and potential exceedences of legal and other requirements (such as operating criteria or occupational exposure limits)
- inconsistent or unusual results
- evaluating the effectiveness of existing controls
- conformance against stated objectives and targets
- continual improvement opportunities.

Monitoring of safety performance is well documented and established in the mining and mineral processing industries. However, monitoring of occupational health and environmental performance using lead and lag indicators is less developed. The principles that apply to safety performance and controls of risks can equally apply to health and environmental performance. This is discussed in sections 7.3 and 7.4.

## 7.2 Safety performance monitoring

Traditional safety performance monitoring was focused on losses such as injuries. Using strict definitions, management could determine lost time injury frequency rates (LTIFR) and total recordable injury frequency rates (TRIFR) for comparisons throughout the company and across various mine sites.

More recently, a focus on tasks that cause major impacts on workers' lives and assets have led to the development of more targeted failure prevention through process safety – critical task monitoring. (More information is in the ICMM's *Health and safety critical control management: good practice guide*.<sup>76</sup>)

However, safety performance monitoring does not lend itself to gaining information about long-term health outcomes, such as cancer. This is discussed further in Section 7.6.

## 7.3 Occupational health / hygiene performance monitoring

Monitoring not only assesses performance against recognised and sometimes legislated criteria, but is also a measure of the effectiveness of risk controls. Depending on the hazardous materials involved, this could be through a combination of workplace monitoring, such as air monitoring, and medical surveillance of workers.

The three main routes of exposure to hazardous substances are respiratory, oral and dermal. Respiratory and dermal exposures are both especially important in the workplace. Skin exposure becomes particularly important when poor personal hygiene and smoking are involved, as they are key routes of exposure, particularly for metals such as lead. Oral exposure, including the fate of metals once they reach the gastrointestinal tract (systemic absorption and toxicokinetic effects), is also important for public health and environmental exposures.

### 7.3.1 Workplace monitoring

There are two types of workplace exposure assessment: qualitative and quantitative (see the Queensland Resource Council website for pertinent detail<sup>77</sup>).

Qualitative assessments are based on observation and provide a preliminary assessment of the health risk without air sampling measurements. The types of information that need to be considered include:

- the nature of the hazard (particulate, liquid or gas) and the route of entry
- whether the hazard produces acute or chronic effects
- whether exposures are continuous, irregular or one-off
- the number of people engaged in the task
- the processes used and how that may determine the route of entry
- the way the task is performed by various people
- the engineering controls and PPE used.

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<sup>76</sup> ICMM, *Health and safety critical control management: good practice guide*, 2015, <http://www.icmm.com/document/8570>

<sup>77</sup> Queensland Resource Council, *Health exposure assessment: a 'step change' in occupational hygiene management*, [http://www.qrc.org.au/conference/\\_dbase\\_upl/farry\\_Health%20Exposure%20Assessment.pdf](http://www.qrc.org.au/conference/_dbase_upl/farry_Health%20Exposure%20Assessment.pdf).

Simply identifying a risk does not determine its significance; however, evaluating the risk makes it possible to answer these questions:

- Is the particular risk from exposure acceptable?
- Does it meet regulatory requirements?
- Will it need controlling to make it healthy and safe?
- Are there certain susceptible individuals or groups that may be at elevated risk (such as those already sensitised to chemicals, or people with asthma)?
- Are there special controls for this hazard?
- How much control is needed?
- What is the most effective control mechanism for this process?

In many situations, the evaluation of the risks may show that no action is needed.

Experience can be a guide to assessing risk without measurement, provided there are adequate indicators (such as odour or visual cues) and production parameters are known. However, it usually takes an experienced occupational hygienist to be able to make such judgements using validated monitoring methods and analytical techniques. This usually involves specialist sampling and collection equipment.

Quantifying high to medium risks is preferred both to meet regulatory requirements and to assure management and workers that the work environment is safe.

## Western Australia Risk Based Hygiene Monitoring

In Western Australia, the contaminant monitoring (CONTAM) exposure monitoring program has been implemented by the Department of Mines and Petroleum. The recently updated 2015 publication *Risk-based hygiene management planning and CONTAM system procedures* is a valuable resource on risk-based hygiene monitoring.<sup>78</sup>

Mine sites are required to perform a nominated number of exposure monitoring samples for workers, subdivided into various similar exposure groups (SEGs), such as 'diesel loader driver'. Results are reported to both the Department of Mines and Petroleum and the individual who participated in the monitoring. Exceedences require special reporting and an action plan to reduce the exposure.

Exposure standards or guidelines for many substances have been established in Australia and internationally (see Section 7.3.2). Based on those standards and guidelines, monitoring programs must be established to specifically address each identified high-risk or medium-risk substance. The program should cover all operations on the site in which identified materials are handled, received, stored, used or produced as product, by-product or waste.

Occupational hygiene monitoring and assessment of workers' exposure can be complex because of the variability in their activities during a shift. Useful reference sources are:

- Australian Institute of Occupational Hygienists: *Simplified monitoring strategies*<sup>79</sup>
- Occupational Hygiene Training Association Ltd, (OHTA): *Student manual: measurement of hazardous substances*<sup>80</sup>

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78 Western Australian Department of Mines and Petroleum, *Risk-based hygiene management planning and CONTAM system procedures*, [http://www.dmp.wa.gov.au/Documents/Safety/MSH\\_G\\_RiskbasedHygieneMgmtPlanning.pdf](http://www.dmp.wa.gov.au/Documents/Safety/MSH_G_RiskbasedHygieneMgmtPlanning.pdf).

79 Australian Institute of Occupational Hygienists, <http://www.aioh.org.au/>.

80 Occupational Hygiene Training Association Ltd, *Student manual: measurement of hazardous substances*, February 2009, <http://www.ohlearning.com/Files/Student/JA29%20v1-0%2012Apr10%20W501%20Student%20Manual1.pdf>.

- American Industrial Hygiene Association: *A strategy for assessing and managing occupational exposure*.<sup>81</sup> These references cover issues such as monitoring strategies, statistical analyses of results and shift/roster adjustments of exposure standards.

The results of the monitoring program must be recorded, documented and reviewed at regular intervals for effectiveness and potential modification to improve procedures and keep them updated with the latest Australian and international research.

Monitoring results can also be used to identify at-risk SEG work groups and determine the priority for control interventions and future monitoring requirements.

### 7.3.2 Occupational exposure standards

In workplace exposure monitoring, exposure standards refer to the level of exposure, via inhalation, that should not cause ill-health in a healthy adult over a working life. The results from air sampling can be compared against exposure standards and used as a guide to assist in the control of health hazards. Exposure standards are also variously known as:

- Threshold Limit Values TLVs.
- Occupational Exposure Standards OESs.
- Workplace Exposure Limits WELs.

In general, all such terms are interchangeable. In many cases, exposure standards are based on the 'no observed adverse effect level'; in other cases, they are based on the 'lowest observed adverse effect level'. Some are given by reference to similar substances for which better datasets are available. For many chemicals, there seems to be a threshold dose below which no significant adverse effect occurs in most people. Epidemiological and toxicological studies, coupled with occupational hygiene measurements, help to identify that threshold.

Occupational exposure standards are developed by Safe Work Australia and regulated through state legislation. (The Safe Work Australia website's pages on hazardous chemicals and exposure standards are a useful resource in this area.<sup>82</sup>)

The standards refer to airborne levels of hazardous substances, including dust and crystalline silica generated during mining, to which it is believed nearly all workers may be repeatedly exposed over a working life without adverse health effects. (The ICMM's *The setting and use of occupational exposure limits: current practice* is a good source of further detail.<sup>83</sup>)

An exposure standard represents an airborne concentration of a particular substance in the worker's breathing zone. According to current knowledge and for nearly all workers, exposure to that concentration should not cause adverse health effects or discomfort. The exposure standard can be in one of three forms:

- **Time-weighted average (TWA)** is an 8-hour time-weighted average for a workday and a 40 hour working week.

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81 American Industrial Hygiene Association, *A strategy for assessing and managing occupational exposure*, 4th edition, 2015, <https://www.aiha.org/publications-and-resources/TheSynergist/AIHANews/Pages/Just-Published-Fourth-Edition-of-A-Strategy-for-Assessing-and-Managing-Occupational-Exposures.aspx>.

82 Safe Work Australia, *Hazardous chemicals*, <http://www.safeworkaustralia.gov.au/sites/swa/whs-information/hazardous-chemicals/pages/hazardous-chemicals-other-substances>.

83 ICMM, *The setting and use of occupational exposure limits: current practice*, 2007, <http://www.icmm.com/document/17>.

- **Short-term exposure limit** (STEL) is a 15-minute TWA exposure that should not be exceeded at any time during the workday, even if the 8-hour TWA is within the exposure limit.
- **Peak** (sometimes called ‘ceiling’) is the concentration that should not be exceeded during any part of the working exposure.

These standards are based on the concept of the ‘threshold of intoxication’—for each substance, no matter how toxic, there is a dose (the threshold of intoxication) that the human body can accept and detoxify without injury.

The exposure standards established for chemical agents are based on a number of factors, including toxicity, physiological response (biological action) and epidemiological studies. Examples of such factors include:

- **irritants** (such as hydrochloric acid fumes, ammonia)—ability to cause inflammation of mucous membranes
- **asphyxiants** (simple asphyxiants such as nitrogen, carbon dioxide and helium and chemical asphyxiants such as carbon monoxide)—ability to deprive the tissues of oxygen
- **anaesthetics** (such as ether and chloroform)—depressant action on the central nervous system, particularly the brain
- **carcinogens** (such as asbestos, crystalline silica, DPM)
- **unbearable odour** (for example, mercaptans, carbon disulphide from xanthates)
- **teratogenic effect** (such as lead)
- **toxic effect** (such as cyanide).

Frequently used 8-hour TWA exposure standards for the mining industry are:

- respirable dust: 3 mg/m<sup>3</sup> (8-hour TWA)
- respirable crystalline silica (quartz): 0.1 mg/m<sup>3</sup> (8-hour TWA)
- diesel particulates: 0.1 mg/m<sup>3</sup> (8-hour TWA), as measured by elemental carbon (EC).

Where such exposure standards exist, it is best practice and in many cases a statutory requirement to maintain workplace exposures below the exposure limits. Many organisations introduce their own ‘safety factor’ by initiating mitigating action at an ‘action level’, which in many cases is 50% of the exposure standard.

### *Adjusting exposure standards for 12-hour shifts*

The national exposure standards are based on 8-hour shifts and must be adjusted when workers are working 12-hour shifts. Some mining regulators have special formulas that take into account 12 hour shifts as well as the mining roster, particularly for fly-in, fly-out (FIFO) operations. Guidance on adjusting exposure standards with 12-hour shifts and rosters is in the Australian Institute of Occupational Hygienists’ position paper *Adjustment of workplace exposure standards for extended work shifts*.<sup>84</sup>

### *When no exposure standard is assigned to hazardous material*

Some hazardous substances used in the resources industry have not been assigned an occupational exposure standard by Safe Work Australia. An example of this is 1-bromopropane (1BP), a common component of industrial solvents used in underground coal mines due to its relatively high flashpoint.

<sup>84</sup> Australian Institute of Occupational Hygienists, *Adjustment of workplace exposure standards for extended work shifts*, <http://www.aioh.org.au/documents/item/14>.

Excessive exposure to 1BP is known to cause severe damage to the nervous system. Currently, Safe Work Australia lists no exposure standard, so in this case it would be prudent to consult other recognised standards, such as those of:

- the American Conference of Governmental Industrial Hygienists (TLVs)<sup>85</sup>
- the US Occupational Safety and Health Administration, Permissible, Exposure Limits (PELs)<sup>86</sup>
- the UK Health and Safety Executive, Workplace Exposure Limits, (WELs)<sup>87</sup>

Although these exposure standards have no legislative recognition in Australia, they provide a useful and relevant guide. In addition, the 'as low as reasonably achievable' (ALARA) principle, which promotes best practice and encourages continuous improvement, should always be followed.

### 7.3.3 Exposure monitoring compliance

Exposure standards are not fine dividing lines between safe and unsafe conditions. Similarly, a handful of personal exposure measurements does not always provide a reliable indicator that a process is either well or poorly controlled. For that reason, a more rigorous assessment of exposures across a workgroup is often necessary to gain a better understanding of control. To do that, some form of statistical analysis of personal monitoring results for each SEG is needed, so it is important to decide which metric will be used to assess control as part of the occupational hygiene monitoring program.

Calculating the simple mean exposure for a SEG is not considered acceptable practice. This is because it may often be below the exposure standard, but potentially many workers in the SEG will be exposed to concentrations above the limit. Best practice suggests ensuring that the upper 95th percentile for each SEG is below the exposure standard. This approach is conservative but provides a high degree of confidence that a process is well controlled. Commercially available computer-based statistical packages are available to assist in this procedure and are relatively simple to use.

Assessing compliance can often be a more complex exercise, particularly where limited sampling data is available. The BOHS publication *Testing compliance with OELs for airborne substances* is a useful guideline.<sup>88</sup> The American Industrial Hygiene Publication, "A Strategy for Monitoring and Assessing Occupational Exposures", is widely used in the mining industry.

### 7.3.4 Occupational health / medical surveillance

'Health surveillance' means any risk-based health assessment or biological monitoring used to identify changes in the health of workers. In some situations, usually defined by statutory authorities, medical surveillance will be needed, such as for lead process workers. Medical surveillance should be conducted under the guidance of an occupational physician.

Miners and contractors should be given a pre-employment medical examination to ensure that they do not have pre-existing conditions that could be aggravated and damaging to their health when they work at the

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85 American Conference of Governmental Industrial Hygienists, <http://www.acgih.org/>.

86 Occupational Safety & Health Administration, <https://www.osha.gov/>.

87 UK Health and Safety Executive, <http://www.hse.gov.uk/>.

88 BOHS, *Testing compliance with OELs for airborne substances*, 2011, <http://www.bohs.org/library/technical-publications/>.

mine site. The most well established system is that in New South Wales for coalminers, who have five-yearly full medical examinations.

Monitoring of occupational exposures to respirable dust, respirable crystalline silica, DPM, lead or particular hazardous chemicals may determine that certain workers should undergo routine medical surveillance, despite protection from PPE. The risk assessment can be used by an occupational physician to determine the appropriate health surveillance and frequency of testing.

Biological monitoring is often part of the health monitoring program, and each plays a critical role for certain hazardous substances. Health surveillance involves the medical examination or medical screening of the worker to look for a change in health function or the presence of a condition. A program for ongoing health surveillance should then be implemented at regular intervals to detect changes from the baseline at the earliest opportunity. For some substances, health surveillance is mandatory and the intervals for testing are regulated.

### **7.3.5 Biological monitoring**

Biological monitoring involves monitoring the worker for the presence of a certain substance or metabolite in order to make an assessment of exposure. Monitoring results are compared against guideline values, referred to as biological exposure indices (BEI). Biological monitoring has particular application where the major route of entry into the body is via skin absorption or ingestion.

Where the route of entry for a substance may be inhalation, dermal absorption and ingestion, biological monitoring in conjunction with personal air monitoring should be considered. An example of a biological monitoring program has been described for methylene biphenyl diisocyanate (MDI), which is an ingredient in the catalyst of polyurethane and urea silicate resins used for strata stabilisation in underground coalmining. Coalmine workers required to handle and inject these resins should undergo baseline health surveillance before commencing work. This typically includes lung function testing, a respiratory questionnaire and a skin examination. This process should be repeated at intervals of six months or less to assess for deviations from the baseline or to identify occupational skin disorders. At more frequent intervals, these workers should be participating in a biological monitoring program that examines their urine for the presence of isocyanate. That information can then be used to assess the effectiveness of current controls and to identify poor work practices. In addition, it may also be prudent to conduct personal air monitoring of the isocyanate to gain an understanding of the inhalation risk. The frequency of biological and personal monitoring should be risk based and established as part of the mine's occupational hygiene program.

Biological monitoring is important for workers involved in refining or smelting to reassure them that they have not been exposed to levels of heavy metals, such as arsenic, that might cause adverse health effects. Blood lead monitoring of workers in smelters and certain mining activities (including maintenance workers) highlights the importance of personal hygiene in preventing exposures and damage to workers' health. In some lead mine and processing sites, workers are not allowed to smoke on site, as skin contamination is an important source of exposure.



Biological monitoring and health surveillance techniques are listed in:

- Western Australian Department of Mines and Petroleum: *Health surveillance and biological monitoring*<sup>89</sup>
- Safe Work Australia: *Guidelines for health surveillance*.<sup>90</sup>

## 7.4 Environmental performance monitoring

Site- or project-specific plans should be developed to monitor the environment. The plans should focus on identified key risk and monitor against baseline conditions for the site or project. Such monitoring will include parameters for the potential exposure of humans, livestock, wildlife and other biota to hazardous materials through the release of those materials to the air, soil, surface water or groundwater.

Most mining and mineral processing operations have an environmental monitoring program as a requirement of their environmental licence or permit. The program covers a wide range of issues, including air, water, waste, energy, soils and subsidence, as well as target issues identified through previous studies, such as the project's initial environmental impact assessment. The monitoring plan or program may include specific advice on various types of emissions that might result from hazardous material because the effects of chemicals can vary according to the receiving environment. To assess the quantitative and qualitative effects, relevant standards, guidelines and procedures need to be consulted, such as:

- NHMRC: *Australian drinking water guidelines*<sup>91</sup>
- Department of Health: *Guidelines for assessing human health risks from environmental hazards*<sup>92</sup>
- National Pollutant Inventory: emissions estimation technique manuals<sup>93</sup>
- National Environment Protection Measures,<sup>94</sup> notably the ones relating to hazardous materials:
  - air toxics
  - ambient air quality
  - assessment of site contamination
  - diesel vehicle emissions
  - movement of controlled waste
  - the National Pollutant Inventory
- AS/NZ 5667.1: 1998 Water quality sampling
- AS 4482.1-2005 Guide to the investigation and sampling of sites with potentially contaminated soil –Non-volatile and semi-volatile compounds
- EPA NSW: Approved methods for the sampling and analysis of air pollutants in New South Wales.<sup>95</sup>

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89 Western Australian Department of Mines and Petroleum, *Health surveillance and biological monitoring*, [http://www.dmp.wa.gov.au/Documents/Safety/MSH\\_G\\_RiskBasedHealthSurveillanceAndBiologicalMonitoring.pdf](http://www.dmp.wa.gov.au/Documents/Safety/MSH_G_RiskBasedHealthSurveillanceAndBiologicalMonitoring.pdf).

90 Safe Work Australia, *Guidelines for health surveillance*, <http://www.safeworkaustralia.gov.au/sites/swa/about/publications/pages/gn1995healthsurveillance>.

91 NHMRC, *Australian drinking water guidelines*, <https://www.nhmrc.gov.au/guidelines-publications/eh52>.

92 Department of Health, *Guidelines for assessing human health risks from environmental hazards*, 2012, available in electronic format by email request to [enHealth.Secretariat@health.gov.au](mailto:enHealth.Secretariat@health.gov.au).

93 Department of the Environment, National Pollution Inventory, *Emission estimation technique manuals*, <http://www.npi.gov.au/reporting/industry-reporting-materials/emission-estimation-technique-manuals>.

94 Standing Council on Environment and Water (SCEW), *National Environment Protection Measures (NEPMs)*, <http://www.scew.gov.au/nepms>.

95 NSW EPA, *Approved methods for the sampling and analysis of air pollutants in New South Wales*, <http://www.epa.nsw.gov.au/resources/>.

The collection, preservation and transport of samples (solution, soil and air) and the assay techniques to be used for them should be negotiated with a laboratory accredited with the National Association of Testing Authorities (NATA) to ensure that best practice is achieved and decisions are based on reliable data.<sup>96</sup>

## 7.5 Auditing

An audit is a systematic investigation or appraisal of documented procedures, systems and operations to determine whether they conform to prescribed procedures, guidelines, standards and regulations. The audit is based on verifiable information, records or statements of fact. *Systems audits* can ensure that processes are in place and effective, as described in the HSE management system; *technical audits* can assess operational issues, such as dangerous goods compliance.

Three types of audits are practised:

- A **first-party audit** is an internal audit carried out by officers of the company or by a consultant commissioned to conduct the audit. It is often programmed as a series of phased audits that extend to the whole of the management system. In small organisations, a first-party audit may lack objectivity.
- A **second-party audit** is an external audit carried out by a customer. It may be scheduled, but unannounced audits are common. It is usually restricted to that part of the management system, operations and procedures that relates to the customer's work.
- A **third-party audit** is an external audit carried out by an independent organisation to certify, register or verify. This may include a certification body or a regulator to confirm compliance.

### 7.5.1 Regulatory compliance

Companies are required to operate under licence according to relevant state or national legislative instruments, including Acts, Regulations and licences.

A *compliance audit* carried out by independent auditors determines whether the company's operations are in accordance with all applicable legislation or relevant management systems, or whether a specific licence is in accordance with the relevant legislation or code. It also includes observed performance according to the documented management system. The audit report state whether the operation is fully compliant with the legislation or codes, is compliant subject to the rectification of listed non-conformances, or is not compliant.

Dangerous goods and explosives regulations are often prescriptive and refer to mandatory codes. A compliance audit includes auditing the control measures mandated by those codes. Less prescriptive dangerous goods regulations allow operators to select relevant non-mandatory codes of practice against which a dangerous goods installation can be audited, because the non-mandatory codes are regarded as benchmarks of what is reasonably practicable under the general duty to minimise risk from dangerous goods.

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<sup>96</sup> National Association of Testing Authorities, <http://www.nata.com.au/nata/>.

## 7.5.2 Health and safety auditing

The auditing of OHS management systems has been well developed in the mining industry. Auditing the processes is important but also technical audits of the content of procedures and verification with the actual work environment are critical to deliver a safe work environment. Examples of hazardous materials technical audits concern the storage and handling of dangerous goods, explosives and radioactive materials which are required to demonstrate compliance with regulations.

Occupational health and hygiene technical audits should also be completed to demonstrate good governance and to deliver safe operations involving hazardous materials and compliance with regulations (such as for respirable dust and silica exposures).

Examples of occupational health related audits, including audit guidelines and templates, are available on the Western Australian Department of Mines and Petroleum website.<sup>97</sup> Available guidelines for audits include:

- surface atmospheric contaminant management
- surface dust management
- underground ventilation management
- noise.

## 7.5.3 Environmental auditing

An environmental audit investigates the impact of operations on the environment, the processes instigated by the company to eliminate or minimise that impact, and the effectiveness of those processes.

The *Evaluating performance: monitoring and auditing* leading practice handbook covers the reasons for environmental auditing and the suggested methodology in detail.

Environmental audits include the following types:

- An **environmental performance audit** is directed at verifying the mine's environmental status against specific predetermined audit criteria. The audit program objectives should articulate senior management's or the board's expectations for the audit program.
- An **environmental management system (EMS) audit** is a type of environmental performance audit in which the audit scope is defined as the EMS or selected parts of it. The audit criteria are the internal environmental policies, procedures, standards, codes of practice and so on of the EMS and their implementation. The EMS audit is designed to determine whether the mining or mineral processing operation is doing what it says it will do in its documentation of the EMS, and whether the EMS has been effectively implemented throughout the site or that part of it selected for the EMS audit. An EMS audit may assess conformance with a standard such as ISO 14001 or the company's specific EMS criteria (which might or might not be based on ISO 14001).

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<sup>97</sup> Western Australian Department of Mines and Petroleum, *What tools are available for inspections, audits and other reviews?*, 2015, <http://www.dmp.wa.gov.au/Safety/What-tools-are-available-for-7941.aspx>.

## 7.6 Performance indicators

Although mine business plans contain safety key performance indicators (KPIs) as part of performance contracts, that is not always the case for health and environment indicators. Safety KPIs are based on lead and lag indicators to prevent accidents that result in injuries to workers. The principles used for safety could well be extended to hazardous materials impacts on human health and the environment.

This section is not aimed as being an authoritative document on OHS or environmental KPIs, but offers some ideas and excellent references for looking at better ways to build health and the environment into performance monitoring.

In developing lead and lag performance indicators, the SMART concept is very useful when selecting operational indicators, which should be:

- Simple (easily interpreted and monitored)
- Measurable (statistically verifiable, reproducible and showing trends)
- Accessible (regularly monitored, cost-effective and consistent)
- Relevant (directly addresses issues or agreed objectives, such as for biodiversity conservation)
- Timely (provide early warning of potential problems).

Two other important desirable characteristics of indicators are that they should be administratively practical and cost-effective to monitor.

### *Global Reporting Initiative*

Environmental KPIs have a similar purpose to other KPIs, which is to provide quantitative measures of performance with the goal of continuous improvement. There are many guidelines on environmental KPIs, but one of the more relevant and comprehensive is in the Global Reporting Initiative (GRI), which encompasses all sustainability aspects, including health, safety and stakeholders as well as the environment. The GRI now requires the identification of material aspects of an organisation, which are defined as 'those that reflect the organisation's significant economic, environmental and social impacts'. Particularly relevant are the GRI sector disclosures, especially the G4 sector disclosures for mining and metals.<sup>98</sup>

Environmental disclosures come under the categories of:

- materials
- energy
- water
- biodiversity
- emissions
- effluents and waste
- products and services
- compliance

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<sup>98</sup> GRI, *G4 sector disclosures: mining and metals*, 2013, <https://www.globalreporting.org/resourcelibrary/GRI-G4-Mining-and-Metals-Sector-Disclosures.pdf>.

- transport
- overall
- supplier environmental assessment
- environmental grievance mechanisms.

Monitoring environmental performance can be based on those categories.

### *Critical control performance reporting*

Performance reporting in the mining sector is based on lead and lag KPIs. The lead KPIs are parameters that can be managed directly by site management. The ICMM has invested considerable time in OHS performance indicators to produce:

- *Overview of leading indicators for occupational health and safety in mining*<sup>99</sup>
- *Health and safety performance indicators*<sup>100</sup>
- *Health and safety critical control management: good practice guide*.<sup>101</sup>

The ICMM, *Health and safety critical control management good practice guide* provides guidance on the selection of critical control parameters that can be used as lead indicators for safety but also health and environment KPIs.

Hazardous materials incidents involving acute toxicity are often collected with the safety KPIs (for example 'overcome by toxic gases' or 'burnt by acids'). Health KPIs have been difficult to develop because of the latency of many of the diseases associated with exposures. Cancer linked to diesel particulate matter (DPM) exposures or silicosis and pneumoconiosis can occur some 20 years after the exposure.

The ICMM's *Health and safety critical control management: good practice guide* is an excellent resource for investigating the use of critical controls as lead indicators for preventing incidents. Using the critical control approach, health KPIs can be based on exposures and control measures. For example, a health KPI could be based on respirable silica exposures being below the occupational exposure standards, and another KPI could be developed based on the engineering controls to prevent or reduce exposures.

Figure 5 shows two pages from the ICMM guide titled 'Step 5 Define performance and reporting' as an example of best practice. The principles apply to all hazardous materials. An example that considers the critical controls needed to prevent DPM exposures in vehicle cabins is included.

For example, the critical controls are:

- a positive-pressure cabin environment maintained to a level that prevents the ingress of DPM
- a pressure differentiator indicator alarm that signals when pressure drops below a critical level
- an air intake filter operating at greater than 99% efficiency.

These controls can be developed into target performances for critical control and used as a lead indicator. For example, 100% of inspections and tests either are satisfactory or repairs are done before the truck is put back into operation.

Managers can deliver these KPIs as part of their daily operations and are critical to the prevention of both short-term and long-term risks from hazardous materials.

99 ICMM, *Overview of leading indicators for occupational health and safety in mining*, 2012, <http://www.icmm.com/document/4800>.

100 ICMM, *Health and safety performance indicators*, 2014, <http://www.icmm.com/health-and-safety-indicators>.

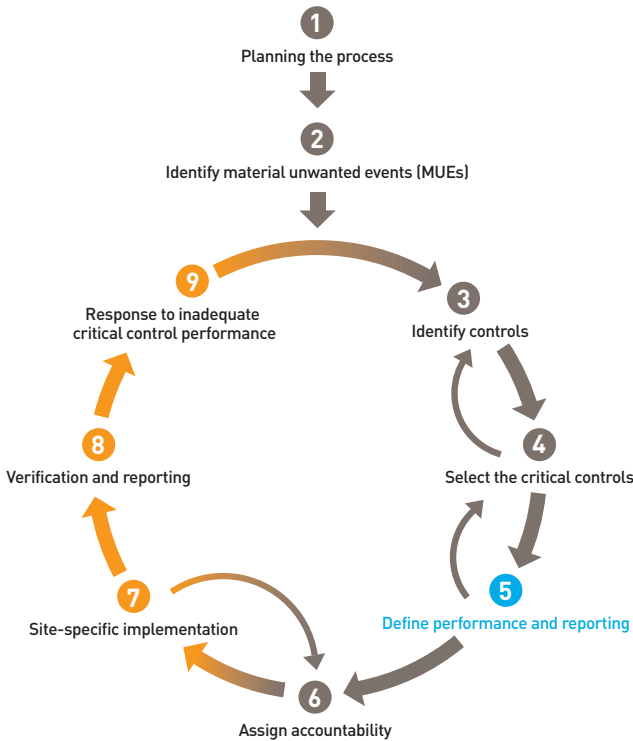
101 ICMM, *Health and safety critical control management: good practice guide*, 2015, <http://www.icmm.com/document/8570>.

# CRITICAL CONTROL MANAGEMENT

## STEP 5: Define performance and reporting

### Target outcome

Define the critical controls' objectives, performance requirements and how performance is verified in practice.



### Key actions

- Define objectives and performance requirements for each critical control.
- Identify current activities that affect the critical control's performance.
- Describe activities to verify performance and reporting requirements.
- Identify what would trigger immediate action to stop or change the operation and/or impose the performance of the critical control.

Step 5 involves examining the objectives, performance requirements (including current performance) and reporting mechanisms for a critical control. The following questions should be considered when defining each of these points:

- What are the specific objectives of each critical control?
- What performance is required of the critical control? (This is sometimes referred to as a performance standard.)
- What activities support or enable the critical control to perform as required and specified?
- What checking is needed to verify that the critical control is meeting its required performance? How frequent is the verification needed? What type of verification is needed?
- What would initiate immediate action to shut down or change an operation or improve the performance of a critical control?

### Control information summary

For each critical control the following information is needed:

- The name of the critical control
- What are the specific objectives of the critical control?
- What performance is needed from the critical control?
- What activities support the performance of the control to the standard?
- What verification activities are needed to ensure the critical control is meeting its required performance?

An example of a critical control system for a specific MUE is provided in Table 3.

# CRITICAL CONTROL MANAGEMENT

## STEP 5: Define performance and reporting *continued*

**Table 3:** Health example (a critical control system)

<b>1 What is the name of the critical control for diesel particulate overexposure (MUE)?</b> Enclosed cab on mining equipment		
<b>2 What are its specific objectives related to the MUE?</b> To restrict the access of diesel particulates into the operators' environment to levels well below the occupational exposure limit		
<b>3 What are the critical control performance requirements to meet the objectives?</b>	<b>4 What are the activities within the management systems that support having the critical control able to do what is required?</b>	<b>5 What can be sampled from the set of activities for verification, providing a clear image of the critical control status?</b>
Positive pressure cabin environment maintained to level that prevents ingress of diesel particulates  Pressure differentiator indicator that alarms when pressure drops below critical level	Scheduled maintenance and calibration of indicator according to manufacturer's requirements	Review maintenance and calibration records  Review alarm log and corrective action taken
Air intake filter operating at greater than 99% efficiency	Pre-shift filter housing inspection for damage  Filter inspection at planned maintenance every 500 hours  Filter change-out every 1,000 hours	Review documented pre-start inspections  Review 500-hour inspection records  Review 1,000-hour change-out records
<b>6 What is the target performance for critical control?</b> 100 per cent of inspection and tests either satisfactory or repair is done before truck is put back into operation		
<b>7 What is the critical control performance trigger for shutdown, critical control review or investigation?</b> 5 per cent of inspections and tests indicate cab ventilation issues that cannot be resolved or are not resolved before truck returned to service		

# APPENDIX 1 – ARPANSA Codes

The full listing is on the ARPANSA website.<sup>102</sup>

## **Radiation Protection series**

RPS F-1 Fundamentals for protection against ionising radiation (2014)

Proposed RPS C-1 Code of practice for radiation protection in planned exposure situations as applied to workers, the public and the environment (publication pending)

RPS C-2 Code for the safe transport of radioactive material (2014)

RPS No. 5 Code of practice and safety guide for portable density/moisture gauges containing radioactive sources (2004)

RPS No. 6 National directory for radiation protection (February 2014)

RPS No. 7 Recommendations for intervention in emergency situations involving radiation exposure (2004)

RPS No. 9 Code of practice and safety guide for radiation protection and radioactive waste management in mining and mineral processing (2005)

RPS No. 11 Code of practice for the security of radioactive sources (2007)

RPS No. 12 Radiation protection standard for occupational exposure to ultraviolet radiation (2006)

RPS No. 13 Code of practice and safety guide for safe use of fixed radiation gauges (2007)

RPS No. 15 Safety guide for the management of naturally occurring radioactive material (NORM) (2008)

RPS No. 16 Safety guide for the predisposal management of radioactive waste (2008)

RPS No. 20 Safety guide for classification of radioactive waste (2010)

## **Radiation Health series**

RHS No. 13 Code of practice for the disposal of radioactive wastes by the user (1985)

RHS No. 28 Code of practice for the safe use of sealed radioactive sources in borehole logging (1989)

RHS No. 31 Code of practice for the safe use of industrial radiography equipment (1989)

RHS No. 35 Code of practice for the near-surface disposal of radioactive waste in Australia (1992)









RHS No. 38 Recommended limits on radioactive contamination on surfaces in laboratories (1995)








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<sup>102</sup> ARPANSA, *Publications*, <http://www.arpansa.gov.au/Publications/index.cfm>.



# APPENDIX 2 - DANGEROUS GOODS CLASSES AND EXAMPLES

	CLASS AND/OR DIVISION	DESCRIPTION	EXAMPLES
 	<p>1</p> <p>1.1</p> <p>1.2</p> <p>1.3</p> <p>1.4</p> <p>1.5</p> <p>1.6</p>	<p><b>Explosives</b></p> <p>Substances and articles which have a mass explosion hazard</p> <p>Substances and articles which have a projection hazard but not a mass explosion hazard</p> <p>Substances and articles which have a fire hazard and either a minor blast hazard or a minor projection hazard, but not a mass explosion hazard</p> <p>Substances and articles which present no significant hazard</p> <p>Very insensitive substances which have a mass explosion hazard</p> <p>Extremely insensitive substances which have a mass explosion hazard</p>	<p>Detonators, emulsion explosives, flares,</p>
 	2.1	<p><b>Flammable gases -</b> <i>easily ignited and readily combustible</i></p>	<p>Liquefied petroleum gas (LPG)</p> <p>Liquefied natural gas (LNG)</p> <p>Acetylene</p> <p>Oxygen</p> <p>Methane</p>
 	2.2	<b>Non-flammable, non-toxic gases</b>	<p>Nitrogen</p> <p>Carbon dioxide</p> <p>Compressed air</p> <p>Helium</p>
	2.2 subrisk 5.1	<b>Oxidising gases</b>	Oxygen
	2.3	<p><b>Toxic gases</b> <i>Poisonous</i></p>	<p>Ammonia</p> <p>Hydrogen cyanide</p> <p>Sulphur dioxide</p> <p>Carbon monoxide</p>

	CLASS AND/ OR DIVISION	DESCRIPTION	EXAMPLES
	3	<b>Flammable liquids</b> <i>—easily ignited and readily combustible</i>	Unleaded petrol Kerosene Aviation fuel
	4.1	<b>Flammable solids</b> <i>-Easily ignited and readily combustible</i>	Sulphur
	4.2	<b>Substances liable to spontaneous combustion</b> <i>—can burst into flames without being lit</i>	Pyrite-bearing coal Some base metal sulphides in the presence of pyrite Xanthates
	4.3	<b>Water reactive substances</b> <i>—produce flammable or toxic gases if wet or react violently if mixed with water</i>	
	5.1	<i>—although not necessarily combustible themselves, can cause or contribute to combustion of other material</i>	Caro's acid Ammonium nitrate Ammonium nitrate emulsion, suspension or gel, intermediate for blasting explosives, UN 3375 Hydrogen peroxide Potassium permanganate Calcium hypochlorite
	5.2	<b>Organic peroxides</b> <i>—thermally unstable and liable to react violently with other material</i>	Benzoyl peroxide
	6.1	<b>Toxic substances</b> <i>—poisonous</i>	Sodium cyanide

	<b>CLASS AND/ OR DIVISION</b>	<b>DESCRIPTION</b>	<b>EXAMPLES</b>
	6.2	<b>Infectious substances</b>	Clinical waste from medical centres
	7	<b>Radioactive material</b>	Uranium Measuring instruments using radioactive sources
	8	<b>Corrosive substances</b> <i>—cause tissue burns or severely corrode certain metals</i>	Nitric acid Sulphuric acid Hydrochloric acid Caro's acid Sodium hydroxide Calcium hydroxide Calcium oxide Lead acid batteries
	9	<b>Miscellaneous dangerous goods</b> <i>—present a danger not covered by other classes. It includes environmentally hazardous substances to the aquatic environment.</i>	Asbestos Some metal concentrates
Not required to be labelled for transport 	Not a dangerous good for transport	<b>C1 Combustible liquids</b> <i>—liquids that burn but are more difficult to ignite than flammable liquids</i>	Diesel

# APPENDIX 3 – CRITERIA FOR INTERNATIONAL MARITIME SOLID BULK CARGOES CODE FOR GROUP B CARGOES

Group B cargoes are those cargoes which have been identified as 1) dangerous goods by the IMDG (International Maritime Dangerous Goods) code or 2) those cargoes identified as “Materials Hazardous only in Bulk form” (MHB). Criteria have now been adopted by IMO to identify “Materials Hazardous only in Bulk form”. These MHB criteria are based on the UN-GHS criteria and include the following:

Combustible solids (if not already identified as Class 4.1 under IMDG), or

Self-heating solids (if not already identified as Class 4.2 under IMDG), or

Solids that evolve into flammable gas when wet (if not already identified as Class 4.3 under IMDG), or

Solids that evolve toxic gas when wet or

Toxic solids:

- Acute toxicity Category 4—Inhalation, dermal routes, or
- STOT-SE Category 1—Inhalation, dermal routes, or
- STOT-RE Category 1—Inhalation, dermal routes, or
- Carcinogenicity Category 1A or 1B, or
- Mutagenicity Category 1A or 1B, or
- Reproductive Toxicity Category 1A or 1B

Corrosive Solids

- Corrosive to metals, or
- Respiratory sensitiser Category 1, or
- Skin corrosion/irritation Category 2, or
- Serious Eye Damage Category 1 or Eye Irritation Category 2A




# APPENDIX 4 – RELEVANT CODES OF PRACTICE AND STANDARDS

<b>AUSTRALIAN EXPLOSIVES INDUSTRY AND SAFETY GROUP INC.</b>	
Code of Practice	Mobile Processing Unit
Code of Practice	Storage and Handling of UN 3375
Code of Practice	Elevated Temperature and Reactive Ground
Code of Practice	Prevention and Management of blast generated NOx gases in surface blasting
Code of Practice	Blast guarding in an open-cut mining environment
Code of Practice	Segregation barriers for transporting mixed loads of detonators and high explosives
<b>AUSTRALIAN STANDARDS</b>	
AS/NZS 1020	AS/NZS 1020 The control of undesirable static electricity
AS 1210	AS 1210 Pressure vessels
AS 1345	AS 1345 Identification of the contents of pipes, conduits and ducts
AS 1375	Industrial fuel-fired appliances
AS 1530.4	Methods for fire tests on building materials, components and structures—Fire-resistance test of elements of construction
AS/NZS 1596	The storage and handling of LP gas
AS/NZS 1677.2	Refrigerating systems—Part 2: Safety requirements for fixed applications
AS 1692	Steel tanks for flammable and combustible liquids
AS/NZS 1715	Selection, use and maintenance of respiratory protection equipment
AS/NZS 1716	Respiratory protective devices
AS/NZS 1768	Lightning protection
AS/NZS 1850	Portable fire extinguishers—classification, rating and performance testing
AS 1851	Routine service of fire protection systems and equipment
AS 1894	The storage and handling of non-flammable cryogenic and refrigerated liquids
AS 1915	Electric equipment for explosive atmospheres - Battery operated vehicles
AS 1939	Degrees of protection provided by enclosures of electrical equipment (IP code)
AS 1940- (2004ed)	The storage and handling of flammable and combustible liquids (note that subsection 11.2(b) of AS 1940 does not apply, as it is in conflict with Regulation 73 'Fire Protection' of the Dangerous Goods Safety (Storage and Handling of Non-explosives) Regulations 2007)
AS/NZS 2022	Anhydrous ammonia—storage and handling
AS/NZS 2106	Methods for the determination of the flashpoint of flammable liquids (closed cup)—Abel closed cup method
AS 2118	Automatic fire sprinkler systems—general systems
AS 2187.1	Explosives—Storage, transport and use—Part 1: Storage
AS 2337	Gas cylinder test stations (all parts)
AS 2359	Powered industrial trucks (all parts), including Part 12 Hazardous areas
AS 2441	Installation of fire hose reels
AS 2507	The storage and handling of agricultural and veterinary chemicals
AS 2714	The storage and handling of organic peroxides
AS 2809	Road tank vehicles for dangerous goods (all parts)
AS 2832	Cathodic protection of metals (all parts)
AS 2865	Confined spaces
AS 2885	Pipelines—Gas and liquid petroleum (all parts)

AS 2896	Medical gas systems—Installation and testing of non-flammable medical gas pipeline systems
AS/NZS 2906	Fuel containers – Portable – plastic and metal
AS/NZS 2927	The storage and handling of liquefied chlorine gas
AS 3745	Planning for emergencies in facilities
AS 3780	The storage and handling of corrosive substances
AS/NZS 3788	Pressure equipment—Operation and maintenance
AS/NZS 3833	The storage and handling of mixed classes of dangerous goods in packages and intermediate bulk containers
AS 3846	The handling and transport of dangerous cargoes in port areas
AS 3873	Pressure equipment—In-service inspection
AS 3961	The storage and handling of liquefied natural gas
AS 3978	Non-destructive testing—visual inspection of metal products and components
AS 4041	Pressure piping
AS/NZS 4081	The storage and handling of liquid and liquefied polyfunctional isocyanates
AS 4289	Oxygen and acetylene gas reticulation systems
AS 4326	The storage and handling of oxidizing agents (note that AS 4326 is not applicable to solid ammonium nitrate. For the safe storage of solid ammonium nitrate please refer to the DMP code of practice)
AS 4332	The storage and handling of gases in cylinders
AS/NZS 4452	The storage and handling of toxic substances
AS/NZS 4645.2	Gas distribution networks—Steel pipe systems
AS/NZS 4681	Storage and handling of Class 9 (miscellaneous) dangerous goods and articles
AS/NZS 4745	Code of practice for handling combustible dusts
AS 4775	Emergency eye wash and shower equipment
AS/NZS 4801	Occupational health and safety management systems—Specification with guidance for use
AS 4839	The safe use of portable and mobile oxy-fuel gas systems for welding, cutting, heating and allied processes
AS 4971	Inspection and integrity monitoring of large steel vertical petroleum storage tanks
AS 4976	The removal and disposal of underground petroleum storage tanks
AS 4977	Petroleum products—Pipeline, road tanker compartment and underground tank identification
AS 4979	Flammable and combustible liquids—Precautions against electrostatic ignition during tank vehicle loading
AS/NZS 5026	The storage and handling of Class 4 dangerous goods
AS 5092	CNG refuelling stations
AS/NZS ISO 31000	Risk management—Principles and guidelines
AS/NZS 60079.10.1	Explosive atmospheres—Classification of areas—Explosive gas atmospheres
AS/NZS 60079	9 Explosive atmospheres (all parts)
AS 61508	Functional safety of electrical/electronic/programmable electronic safety-related systems (all parts)
AS IEC 61511.1	Functional safety—Safety instrumented systems for the process industry sector—Framework, definitions, systems, hardware and software requirements
AS IEC 61511.2	Functional safety—Safety instrumented systems for the process industry sector—Guidelines for the application of AS IEC 61511.1
AS IEC 61511.3	Functional safety—Safety instrumented systems for the process industry sector—Guidance for the determination of the required safety integrity levels
<b>ASIA INDUSTRIAL GASES ASSOCIATION</b>	
AIGA 051/08	Code of Practice Phosphine (harmonised publication)
AIGA 050/08	Code of Practice Arsine (harmonised publication)
AIGA 081/13	Safe practices for the storage and handling of nitrous oxide (harmonised publications)
AIGA 022/13	Code of Practice Acetylene
AIGA 068/10	Carbon dioxide (harmonised publication)

<b>AMERICAN PETROLEUM INSTITUTE (USA)</b>	
API RP 521	Guide for pressure relieving and depressurizing systems
API 579-1/ASME FFS-1	Fitness-for-service
API RP580	Risk-based inspection
API RP581	Risk-based inspection technology
API 620	Design and construction of large, welded, low-pressure storage tanks
API 650	Welded steel tanks for oil storage
API 652	Lining of aboveground petroleum storage tank bottoms
API 653	Tank inspection, repair, alteration and reconstruction
API RP 752	Management of hazards associated with location of process plant permanent buildings
API RP 753	Management of hazards associated with location of process plant portable buildings
<b>STEEL TANK INSTITUTE (USA)</b>	
SP001	Standard for the inspection of aboveground storage tanks
F921	Standard for aboveground tanks with integral secondary containment
<b>UNDERWRITERS LABORATORIES (USA)</b>	
UL 142	Standard for steel aboveground tanks for flammable and combustible liquids
UL 971	Standard for non-metallic underground piping for flammable liquids

# APPENDIX 5 – GLOBALLY HARMONISED SYSTEM (GHS)—HEALTH AND ENVIRONMENTAL PICTOGRAMS

	CLASS	DESCRIPTION
	Toxic	Acute toxicity (oral, dermal, inhalation), categories 1, 2, 3
	Corrosive	Skin corrosion, categories 1A, 1B, 1C Serious eye damage, category 1
	Irritant	Acute toxicity (oral, dermal, inhalation), category 4 Skin irritation, categories 2, 3 Eye irritation, category 2A Skin sensitization, category 1 Specific target organ toxicity following single exposure, category 3 Respiratory tract irritation Narcotic effects
		Respiratory sensitization, category 1 Germ cell mutagenicity, categories 1A, 1B, 2 Carcinogenicity, categories 1A, 1B, 2 Reproductive toxicity, categories 1A, 1B, 2 Specific target organ toxicity following single exposure, categories 1, 2 Specific target organ toxicity following repeated exposure, categories 1, 2 Aspiration hazard, categories 1, 2
No pictograms		Acute toxicity (oral, dermal, inhalation), category 5 Eye irritation, category 2B Reproductive toxicity—effects on or via lactation
	Environmentally damaging	Acute hazards to the aquatic environment, category 1 Chronic hazards to the aquatic environment, categories 1, 2
No pictograms		Acute hazards to the aquatic environment, categories 2, 3 Chronic hazards to the aquatic environment, categories 3, 4



# GLOSSARY AND ABBREVIATIONS

<b>Acid</b>	An inorganic or organic compound that has a pH of less than 7, neutralises bases or alkalis and turns litmus paper red. Acids are corrosive to human tissue and are to be handled with care.
<b>Acute exposure</b>	Short-term exposure, usually occurring at high concentration.
<b>Acute health effect</b>	An effect that develops either immediately or a short time after exposure.
<b>ADG Code</b>	Australian Dangerous Goods Code
<b>Alkali</b>	Any compound having highly basic properties, with a pH above 7 and able to turn litmus paper blue. Alkalis are very corrosive to human tissue and are to be handled with care.
<b>AMD</b>	Acid and metalliferous drainage.
<b>Analysis</b>	A process used to identify the kinds or quantities of ingredients in a substance.
<b>ANFO</b>	Ammonium nitrate – Fuel Oil
<b>Asbestosis</b>	A chronic lung disease caused by inhaling asbestos fibres.
<b>Asphyxiant</b>	A vapour or gas that can cause unconsciousness or death by suffocation (lack of oxygen).
<b>Asthma</b>	A disease caused by spasmodic contraction of the bronchioles in the lungs.
<b>Biological monitoring</b>	The measurement and evaluation of hazardous substances or their metabolites in the body tissues, fluids or exhaled air of a person.
<b>Boiling point</b>	The temperature at which a liquid changes from a liquid to a gas at normal atmospheric pressure.
<b>Carcinogens</b>	Agents/compounds that can induce cancer in humans. A full listing of carcinogens and their group classification is at <a href="http://monographs.iarc.fr/ENG/Classification/ClassificationsGroupOrder.pdf">http://monographs.iarc.fr/ENG/Classification/ClassificationsGroupOrder.pdf</a> .
<b>CAS registry number</b>	A number assigned to a chemical substance by the Chemical Abstracts Service (CAS) of the American Chemical Society as a unique identifier.

<b>Chemical formula</b>	A formula that indicates the elements that make up a compound; sometimes called the molecular formula.
<b>Chemical name</b>	The proper scientific name of the active ingredient in a product.
<b>Compressed gas</b>	A material that is a gas at room temperature (20°C) and pressure but is packaged as a pressurised gas, dissolved gas or gas liquefied by compression or refrigeration.
<b>Density</b>	The weight of a material in a given volume, usually given in grams per millilitre (g/mL).
<b>Dermal</b>	Used on or applied to the skin.
<b>Dermatitis</b>	Inflammation of the skin.
<b>Dose</b>	The amount of an agent that has entered the body through the various routes of entry.
<b>Dust</b>	Solid particles formed by mechanical action and suspended in air.
<b>Emphysema</b>	An irreversible lung disease resulting in an excessive loss of lung capacity.
<b>Exposure</b>	The intensity, frequency and duration of any contact with an agent that is present in the environment. A person is exposed to a hazardous substance if they absorb or are likely to absorb the substance by ingestion, by inhalation or through the skin (dermal absorption) or mucous membrane.

**Exposure limits**

Established concentrations which, if not exceeded, will not generally cause adverse effects to the exposed worker. Exposure limits differ in name and meaning depending on origin. For example:

- TWA: An 8-hour time-weighted average exposure standard is the average airborne concentration of a particular substance permitted over an 8-hour working day and a 5-day working week. These are the most common types of exposure standards.
- STEV: Short-term exposure value is the time-weighted maximum average airborne concentration of a particular substance permitted over a 15-minute period.
- Peak limitation exposure standards are maximum or peak airborne concentrations of a particular substance determined over the shortest analytically practicable period of time which does not exceed 15 minutes. A peak limitation exposure standard must not be exceeded at any time.
- SKIN: Indicates that direct or airborne contact with the product may result in significant absorption of the product through the skin, mucous membranes or eyes. This notation is intended to suggest that preventive action be taken against absorption of the agent through these routes of entry.
- TLV: TWA threshold limit value. TWA is the time-weighted average concentration for a normal 8-hour work day and a 40-hour work week, to which nearly all workers may be repeatedly exposed, day after day, for a working lifetime, without adverse effect.
- TLV-STEL: Threshold limit value—short-term exposure limit. A 15-minute time-weighted average exposure that should not be exceeded at any time during a work day, even if the 8-hour TWA is within the TLV. Exposures at the STEL should not be repeated more than four times a day, and there should be at least 60 minutes between successive exposures at the STEL
- TLV-C: Threshold limit value—ceiling. The concentration that should not be exceeded during any part of the working exposure.

**Flashpoint**

The lowest temperature at which a liquid gives off enough vapour to form an ignitable mixture of vapour and air immediately above the liquid surface.

**Fume**

An airborne dispersion consisting of minute solid particles arising from the heating of a solid.

**Gas**

A formless fluid that occupies the space of its enclosure.

**GHS**

Globally Harmonized System of Classification and Labelling of Chemicals.

**Hazard**

The potential for harmful effects.

<b>Health surveillance</b>	The monitoring of people to identify changes (if any) in their health due to exposure to a hazardous substance. Includes biological monitoring but does not include the monitoring of atmospheric contaminants.
<b>IARC</b>	International Agency for Research on Cancer.
<b>Ignition temperature</b>	The lowest temperature at which a combustible material will catch fire in air and continue to burn independently of the original source of heat.
<b>Ingestion</b>	Taking a material into the body by eating it.
<b>Inhalation</b>	Taking a material into the body by breathing it in.
<b>International Council on Mining and Metals (ICMM)</b>	An organisation that represents many of the world's leading mining and metals companies, as well as regional, national and commodity associations, and is committed to the responsible production of minerals and metals.
<b>Irritant</b>	A material that irritates whatever tissue it comes into contact with.
<b>Key performance indicators (KPIs)</b>	Predetermined targets that help an organisation define and measure progress towards organisational goals.
<b>Leading Practice Sustainable Development Program for the Mining Industry</b>	A program that integrates the environmental, social and economic aspects of 17 key themes across all phases of the mining industry, from exploration, construction and operation, through to mine closure and rehabilitation.
<b>Mist</b>	Suspended liquid droplets in air caused by condensation or spraying.
<b>Mutagen</b>	An agent that affects the genes or cells of exposed people in such a way that it may cause cancer in the exposed individual or an undesirable mutation in a later generation.
<b>NIOSH</b>	National Institute of Occupational Safety and Health.
<b>NOHSC</b>	National Occupational Health and Safety Commission.
<b>Odour threshold</b>	The airborne concentration, usually in parts per million, at which an odour becomes noticeable.
<b>Parts per million (ppm)</b>	A measure of the concentration of a substance in a gas, vapour, solid or liquid. For example, 1 ppm of a gas means that 1 unit of the gas is present for every 1 million units of air.
<b>pH</b>	A measure of the acidity or basicity (alkalinity) of a material when dissolved in water.

<b>Pneumoconiosis</b>	A general term given to any lung disease caused by dusts that are breathed in and then deposited deep in the lungs, causing damage. The dust particles remain in the lung, where they can cause inflammation or fibrosis (scarring).
<b>PPE</b>	Personal protective equipment (devices or clothing worn to help isolate a worker from direct exposure to hazardous substances).
<b>RPE</b>	Respiratory protective equipment.
<b>Safe Work Australia</b>	The national authority for occupational health and safety model legislation and guidelines.
<b>SDS</b>	Safety data sheets.
<b>Silicosis</b>	A condition characterised by shortness of breath, caused by exposure to silica dusts.
<b>Solubility</b>	The ability of a material to dissolve in water or another liquid.
<b>Solvent</b>	A chemical that is capable of dissolving a substance.
<b>SSAN</b>	Security sensitive ammonium nitrate.
<b>Stability</b>	The ability of a material to remain unchanged in the presence of heat, moisture or air.
<b>Supplier</b>	An importer, manufacturer, wholesaler or distributor of workplace substances, but not a retailer.
<b>Teratogen</b>	An agent that causes an abnormality following foetal exposure during pregnancy.
<b>TLV</b>	see Exposure limits.
<b>Toxicity</b>	The ability of a substance to cause harmful effects.
<b>UN number</b>	A four-digit number assigned to a potentially hazardous material or class of materials. UN (United Nations) numbers are internationally recognised and are used by firefighters and other emergency response personnel to identify materials during emergencies.
<b>Use of a substance</b>	The use, production, handling, storage, transport or disposal of the substance.
<b>Vapour</b>	A gaseous form of a material that is normally solid or liquid at room temperature and pressure.
<b>Vapour pressure</b>	The pressure of a vapour in equilibrium with its liquid or solid form.
<b>Ventilation</b>	The provision of fresh air to provide a safe work environment.



*Leading Practice Sustainable Development Program for the Mining Industry*