

HAZARDOUS MATERIALS MANAGEMENT

LEADING PRACTICE SUSTAINABLE
DEVELOPMENT PROGRAM FOR
THE MINING INDUSTRY



OCTOBER 2009

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Leading Practice Sustainable Development Program for the Mining Industry.

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Cover image: Transporting hazardous substances. Source: CSBP Limited

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FOREWORD

A strong commitment to leading practice sustainable development is critical for a mining company to first gain and then maintain its 'social licence to operate'.

The handbooks in the Leading Practice Sustainable Development Program for the Mining Industry series integrate environmental, economic and social aspects through all phases of mineral production from exploration to construction, to operation and finally mine site closure. The concept of leading practice is simply the best way of doing things for a given site. Leading practice is as much about approach and attitude as it is about a fixed set of practices or a particular technology.

The International Council on Mining and Metals (ICMM) defines sustainable development as investments that are technically appropriate; environmentally sound; financially profitable; and socially responsible. *Enduring value: the Australian minerals industry framework for sustainable development* provides guidance for operational-level implementation of the ICMM principles and elements by the Australian mining industry.

A wide range of organisations have helped develop this handbook, which will assist all sectors of the mining industry to reduce the impacts of minerals production on the community and the environment by following the principles of leading practice sustainable development.



The Hon Martin Ferguson AM MP

Minister for Resources and Energy, Minister for Tourism





1.0 INTRODUCTION

Hazardous Materials Management is one of 14 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 supplemented by case studies that identify sustainable approaches for the mining industry.

Leading practice sustainable development management is an evolving discipline. As new problems emerge and new solutions are developed, or better solutions are devised for existing problems, it is important that leading practice 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. This handbook builds on and complements the management principles and practices developed in the Best Practice Environmental Management Series handbook on hazardous materials management, storage and disposal.

The primary audience for the handbook are the mine, exploration and mineral processing staff who will come into contact with hazardous materials through their work activity: health and safety and emergency response staff, mine planners and mineral processing designers. In addition, people with an interest in leading practice in the mining industry will find this handbook relevant, including mining company directors, managers, community relations practitioners, environmental officers, mining consultants, suppliers to the mining industry, governments, regulators, non-government organisations, mining communities, neighbouring communities, and students. It has been written to encourage those people to play a critical role in continuously improving the mining industry's sustainable development performance.

The handbook has been constructed in four main sections:

- **Principles** contains definitions and identifies sources of relevant Australian handling and storage legislation.
- **Materials of concern** discusses naturally occurring hazardous substances that may be encountered during mining, materials imported to the site (such as processing chemicals), and substances and mining wastes that are generated during mining and processing.
- **Risk management** presents risk management strategies that may be implemented at corporate or mine site level, including the use of material safety data contained in Material Safety Data Sheets (MSDS) and personal protective equipment (PPE).
- **Performance management** presents information about techniques, such as monitoring, reporting and auditing, that provide information about the use of and exposure to hazardous substances.

References and further reading contains a list of references and resource documents used to compile this handbook.

There are 14 handbooks in this series. Some discuss the management of hazardous substances, including:

- Tailings management
- Cyanide management
- Managing acid and metalliferous drainage.

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

- Mine closure
- Materials stewardship
- Evaluating performance: monitoring and auditing
- Airborne contaminants, noise and vibration
- Water management
- Risk assessment and management.

This handbook has been designed to identify guiding principles and leading practices in the handling and storage of hazardous materials through the mine life cycle. It provides links to relevant source material and state and federal legislation and guidelines for further reading and detail.

While a primary consideration of hazardous materials management is worker health and safety, the handbook recognises the potential for impacts from hazardous materials used and exposed during mining and mineral processing on the natural environment and the need to manage them to minimise those impacts. The environmental impacts from such materials are also discussed in the other leading practice handbooks listed above.



2.0 PRINCIPLES

Purpose

This section presents the regulatory regime and the principles on which the identification and management of hazardous materials are based.

Key messages

- Industrial chemicals manufactured in or imported into Australia are assessed by an Australian Government agency under the *Industrial Chemicals (Notification and Assessment) Act 1989*.
- Hazardous substances are governed by two key types of legislation (the National Model Regulations for the Control of Workplace Hazardous Substances and the Australian Dangerous Goods Code), but compliance is a matter for states and territories.
- Not all hazardous substances encountered in the mining industry are classified as 'dangerous goods'.
- Exposure standards have been established for worksites, including mine sites, to reduce risks for people working with hazardous substances.
- Health surveillance, as either biological monitoring or regular routine medical examinations, is regulated at the state level to protect the health of workers at some mine sites.

2.1 Legislation and regulation

This section summarises the national and state legislation controlling importing, supply, storage, handling and disposal of industrial chemicals.

2.1.1 Chemical imports

Where a mining company plans to import directly chemicals for use at their site, rather than use an Australian supplier, it must comply with NICNAS (the National Industrial Chemicals Notification and Assessment Scheme, www.nicnas.gov.au). If the chemical or the chemical components in the mixture are not registered in Australia, extensive toxicity data are required for registration.

2.1.2 Handling and storage legislation

The states and territories control the use of industrial chemicals mainly by exercising their extensive powers relating to prohibition, application of occupational exposure standards, and health surveillance requirements. Many of the controls on industrial chemicals focus on controlling a chemical at a particular stage of its life cycle or in a particular situation. These areas include worker safety, transport, public health, environmental protection and the handling of hazardous substances, including their disposal as waste.

The key model codes for mine sites are those covering hazardous substances and dangerous goods, which can be found on the Safe Work Australia website.¹

The centrepieces are the *National Model Regulations for the Control of Workplace Hazardous Substances* [NOHSC:1005 (1994)] and the *National Standard for the Storage and Handling of Workplace Dangerous Goods* [NOHSC:1015(2001)].

'**Hazardous materials**' is an umbrella term used to describe any substances that, because of their chemical, physical or biological properties, can cause harm to people, property or the environment. The term collectively describes substances according to the hazard they present, and includes 'dangerous goods', 'combustible liquids' and 'hazardous substances'.

Legislation dealing with hazardous materials treats them on the one hand as 'dangerous goods', or on the other as 'hazardous substances'. The two categories are classified according to different criteria:

- **Dangerous goods** are classified on the basis of *immediate physical or chemical effects*, such as fire, explosion, corrosion and poisoning that might affect property, the environment or people. Petrol, pool chlorine and some pesticides are examples.
- **Hazardous substances** are classified on the basis of *health effects*, whether immediate or long-term, particularly in relation to workplaces. For example, exposure to hazardous substances can cause adverse health effects such as asthma, skin rashes, allergic reactions, allergic sensitisation, or cancer and other long-term diseases.

Dangerous goods are extensively regulated and controlled for transport by the National Transport Commission, which is responsible for the Australian Dangerous Goods Code, now in its seventh edition (ADG7).²

In 2007, the Australian Government initiated changes to the national codes at the federal level, and there is a plan to harmonise the framework of national and state model codes and regulations. The new framework will use the Globally Harmonized System of Classification and Labelling of Chemicals (GHS) as the basis for hazard classification and hazard communication elements on labels and MSDS.

1 <http://www.safeworkaustralia.gov.au/swa/HealthSafety/OHSstandards/>

2 <http://www.ntc.gov.au/viewpage.aspx?Areald=35&DocumentId=1147>

State and territory government mining and natural resources authorities' websites provide local occupational health and safety (OHS) and environmental legislation:

Northern Territory	www.nt.gov.au/d/Minerals_Energy/
Queensland	www.dme.qld.gov.au/
Western Australia	www.dmp.wa.gov.au/
New South Wales	www.dpi.nsw.gov.au/
South Australia	www.safework.sa.gov.au/
Tasmania	Department Primary Industries, Parks, Water and Environment, Tasmania www.dpiwe.tas.gov.au Mineral Resources Tasmania (MRT) www.mrt.tas.gov.au Workplace Standards Tasmania www.wst.tas.gov.au
Victoria	www.worksafe.vic.gov.au

Information papers prepared by various state government agencies provide additional information on legislation; for example:

- Information Paper No. 9, *Hazardous materials legislation in Queensland: a guide developed by the Chemical Hazards and Emergency Management (CHEM) Services with the assistance of the Inter-Departmental Hazardous Substances Co-ordinating Committee.*

2.1.3 Workplace exposures and health surveillance

The National Exposure Standards control exposures to many of the hazardous substances used in the mining industry known to have acute health effects.

State authorities also impose regulated health examinations for mining occupations considered to be high risk. For example, in NSW, coal miners are required to undergo a full medical examination every five years. In addition, Safe Work Australia has examined health surveillance (such as biological monitoring for lead exposure during lead mining) and established biological exposure standards in the Hazardous Substances Information System.

2.2 Exposure standards

Occupational exposure standards are developed by Safe Work Australia and regulated through state legislation. The standards refer to airborne levels of hazardous substances, including dust and crystalline silica generated in the mining process. It is believed that nearly all workers can be repeatedly exposed to such levels for a working life without adverse health effects. In Australia, the levels are referred to in the National Exposure Standard and are listed in the Hazardous Substances Information System.³

More information on exposure standards can be found in Section 5 (Performance management).

3 <http://www.safeworkaustralia.gov.au/swa/HealthSafety/HazardousSubstances/HSIS>



3.0 MATERIALS OF CONCERN

Purpose

This section presents an overview of hazardous materials of various types and the situations in which they may be encountered.

Key messages

- Natural materials encountered in mining and processing operations may be hazardous to human health and the environment.
- Chemical substances used in mining, such as explosives, flotation chemicals, solvents, acids and gases, may be hazardous.
- Wastes and by-products of mining operations, such as dusts and acid-generating sulfides, may also be hazardous.
- Some materials used in the mining industry are subject to restrictions because of security risks.

3.1 Naturally occurring hazardous materials

3.1.1 What law applies?

All Australian states and territories have legislative requirements for handling, storing and transporting naturally occurring materials that can be classed as hazardous when exposed by mining, particularly asbestiform minerals, silica and radioactive minerals. Details can be obtained through state mines department websites.

3.1.2 What are naturally occurring hazardous materials?

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 3.1).

Table 3.1: Asbestiform and non-asbestiform minerals

Asbestiform variety	Chemical composition	Non-asbestiform variety
Serpentine group		
Chrysotile (white asbestos)	$Mg_3(Si_2O_5)(OH)_4$	antigorite, lizardite
Amphibole group		
Crocidolite (blue asbestos)	$Na_2Fe_3Fe_2(Si_8O_{22})(OH,F)_2$	riebeckite
amosite (grunerite) (brown asbestos)	$(Mg,Fe)_7(Si_8O_{22})(OH)_2$	cumingtonite-grunerite
anthophyllite	$(Mg,Fe)_7(Si_8O_{22})(OH,F)_2$	anthophyllite
tremolite	$Ca_2Mg_5(Si_8O_{22})(OH,F)_2$	tremolite
actinolite	$Ca_3(Mg,Fe)_5(Si_8O_{22})(OH,F)_2$	actinolite

Amphibole, and to a lesser extent serpentine, minerals are widely distributed in the Earth's crust, so asbestos can occur as an accessory mineral. These minerals are found in mafic and ultramafic rocks, skarn deposits and associated igneous rocks in contact with limestone, such as porphyry copper deposits. They are commonly associated with faults and shears in these rocks and geological settings. Asbestos can occur as an accessory mineral with other industrial minerals (such as amphibole asbestos with vermiculite and talc). Fibrous minerals may be associated with carbonate-facies iron formations.

Serpentine and amphibole that are found in mafic and ultramafic rock formations can have fibrous and non-fibrous structures. The fibrous form is called asbestos and is rare compared to other asbestiform minerals and non-asbestiform amphibole minerals. It is important to note that non-fibrous forms can have similar chemical composition, but do not have the same health effects as the fibrous forms. Some other minerals are similar to asbestos in their particle shape, but do not possess the characteristics required to classify them as asbestos.

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 best known asbestos deposits are near Wittenoom in the Pilbara region of Western Australia and at Woodsreef near Armidale 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.

Safe Work Australia defines a respirable asbestos fibre as one with a diameter less than 3 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 the most likely to remain in the lungs. Fibres larger than this tend to be removed by the normal clearing mechanism of the lungs.

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.

Issues to be considered in mining operations and exported materials are as follows:

- Product liability
 - affected by international and national laws
 - community, consumer and end user issues
 - cradle-to-grave documentation of risks and exposures.
- Sustainable development
 - potential impacts on the community where waste, tailings and materials are stored and transported (including environmental and product liability risks)
 - contamination of widespread areas, requiring clean up.
- Occupational health and safety risks to workforce
 - industrial relations impacts (asbestos has caused more disputes in the work environment than other hazardous substances)
 - litigation by workers
 - increased costs for detailed medical surveillance and occupational exposure monitoring.

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 address the following key areas:

- Information, instruction, training and supervision should be provided to all employees.
- Written procedures should be developed.
- Airborne fibre levels should be monitored.
- Regular surveillance of all mined rock should be undertaken to ensure minimal disturbance of fibrous material.

(continued)

- Access to all areas containing fibres should be strictly controlled and monitored.
- To the extent that is reasonably practicable, dust should be suppressed at source and workers should be isolated from dust by the provision of appropriate equipment and facilities. Dust containment, collection and handling facilities should be introduced to minimise airborne fibre levels.
- Approved disposal procedures should be implemented for fibrous waste.

The Western Australian Department of Mines and Petroleum has developed comprehensive reference sources on asbestiform materials (www.dmp.wa.gov.au/6751.aspx).

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

Silica

Silica minerals make up the matrix or occur in association with the targeted mineral in ore bodies. They include quartz, a common gangue mineral and a constituent in many minerals in igneous and metamorphic rocks. Silica minerals are often concentrated by the same natural process that results in sulfide ore bodies. They are stable until ground or blasted into a dust.

Crystalline silica dust is classified as a Group 1 carcinogen by the International Agency for Research on Cancer.⁴ Hence, the National Exposure Standard is low at 0.1 mg/m³. The dust is also an irritant to the lungs.

Management of silica minerals is discussed in more detail in Hustrulid (1982), Karmis (2001), Hedges & Djukic (2008), and Hedges et al. (2007, 2008ab).

Acid and metalliferous drainage

Acid and metalliferous drainage (AMD) can occur naturally when rocks containing metal sulfide minerals are exposed to oxygen and water, or when sulfidic rock material is disturbed and exposed to oxidation as a result of mining, highway construction or coastal land development (acid sulfate soils). The predominant acid-generating sulfide mineral is pyrite (FeS₂); other acid-generating minerals include pyrrhotite (FeS), marcasite (FeS₂), chalcopyrite (CuFeS₂) and arsenopyrite (FeAsS).

The reaction of pyrite with oxygen and water produces a solution of ferrous sulfate and sulfuric acid. Ferrous iron can be oxidised, producing additional acidity. Iron and sulfur oxidising bacteria are known to catalyse these reactions at low pH, thereby increasing the rate of reaction by several orders of magnitude (Nordstrom & Southam 1997).

4 <http://monographs.iarc.fr/ENG/Monographs/vol68/index.php>

In undisturbed natural conditions, acid generation is a relatively slow process over geological time. Mining and processing of rocks and materials containing metal sulfide substances greatly enhances the acid-generating process because it rapidly exposes those substances to oxidising conditions.

Not all sulfide minerals are acid-generating during oxidation, but most have the capacity to release metals on exposure to acidic water. During mining, reactive sulfides can be routinely exposed to air and water in waste rock piles, ore stockpiles, tailings storage facilities, pits, underground mines, and heap and dump leach piles. Leading practice AMD management involves strategies to minimise the interaction between reactive sulfides and air, water or both (DITR 2007). Because large masses of sulfide minerals are exposed quickly during mining and milling, the surrounding environment often cannot attenuate the resulting low pH conditions.

Metals found in water draining from mine sites include Ag, Al, As, Ba, Be, Cd, Co, Cr, Cs, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Ra, Sb, Se, Sr, Th, Tl, U, V and Zn. Metal concentrations increase in waters at lower pH. Once released, metals will persist in the environment. Their concentration in water can be reduced through physical removal (sorption, precipitation, biological uptake) (Smith 2007).

Metals increase the toxicity of mine drainage (Earle & Callaghan 1998) and act as metabolic poisons. Iron, aluminium, and manganese are the most common heavy metals compounding the adverse effects of mine drainage. Heavy metals are generally less toxic at circum-neutral pH. Trace metals, such as zinc, cadmium, and copper, which may also be present in mine drainage, are toxic at extremely low concentrations and may act synergistically to suppress algal growth and affect fish and benthos (Hoehn & Sizemore 1977). In addition to dissolved metals, iron or aluminium hydroxide precipitate may form in streams receiving mine discharges with elevated metals concentrations. Ferric and aluminium hydroxides decrease oxygen availability as they form; the precipitate may coat gills and body surfaces, smother eggs, and cover the stream bottom, filling in crevices in rocks, and making the substrate unstable and unfit for habitation by benthic organisms (Hoehn & Sizemore 1977).

Aluminium rarely occurs naturally in water at concentrations greater than a few tenths of a milligram per litre; however, higher concentrations can occur in acidic drainage from mine sites as a result of the breakdown of clays (Hem 1970). The chemistry of aluminium compounds in water is complex. It combines with organic and inorganic ions and can be present in several forms. Aluminium is least soluble at a pH between 5.7 and 6.2; above and below that range, it tends to be in solution (Hem 1970, Brown & Sadler 1989). Once acid drainage is created, metals are released into the surrounding environment, and become readily available to biological organisms. Historically, AMD, characterised by acidic metalliferous conditions in water, is responsible for physical, chemical and biological degradation of stream habitat in many areas of the world where mining has occurred.

While the main impact of AMD is on environmental values, in extreme cases it can potentially affect human health through contamination of water supplies and heavy metal take-up in aquatic organisms used as food. *Managing acid and metalliferous drainage* (DITR 2007) 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.

Reactive clays and salinity

In many parts of Australia, mining is associated with salinity. Salinity is a result of two separate occurrences: aeolian deposition of salt from the sea, including salt basins being deposited and leached into the regolith, over the past two million years; and connate salts laid down with the ore body. In both cases, salt-laden overburden is deposited with the waste rock in overburden or waste rock dumps. Leaching of salt from the overburden and disposal of salt-enriched groundwater can be the greatest regional impact from mining. Many sedimentary basins, including the Hunter Valley and the Bowen Basin, contain connate water that is salty. Salty water (starting above about 10% of seawater's salt concentration) has an osmotic potential too high for freshwater biota and most terrestrial plants to survive. Therefore, it does not take much salt to destroy a riparian environment. Victorious armies sometimes ploughed salt into the farmland of enemies to render it useless. They were successful—that land remains unusable today. Careful management of waste rock, overburden and groundwater discharges is required to ensure that the environmental impacts of salinity are avoided.

Although saline groundwater is enriched in sulfate, discharges of saline water into dams or ephemeral streams might have no apparent short-term impacts. However, in the presence of organic matter under aerobic conditions, the sulfate is converted to monosulfide black ooze that collects at the bottom of the water body or as amorphous pyrite in waterlogged soil. A drop in water level due to a climate change or change in process may expose the ooze, which can be oxidised and rapidly produce sulfuric acid, causing plant and fish kills.

Reactive clays and sodicity

Although at first sight clay minerals do not appear to be 'hazardous', the physical changes in their structure brought about by exposure to certain chemicals can damage mineral processing equipment and the environment. The primary minerals concerned include kaolinite and bentonite, while secondary minerals such as smectite and illite may result from weathering. Clay minerals have an excess of negative charge across the crystal, which is balanced by cations from the pore water. Because of the mineral structure, clay minerals clump together into domains with cations between the clay sheets within the domain and in a cloud around the domain. Certain clay mineral clumps swell and disperse (break up) or clump tighter together (coagulate) depending on cations in the surrounding pore water. These minerals include clays of the montmorillonite group (smectite, bentonite, high-charged vermiculite) and illite and interstratified minerals. The type, molar strength and total ionic activity of cations in solution affects these swelling clays, causing swelling and coagulation depending on the chemical state. The cations can swap with each other, depending on their valency and ionic strength, and are known as 'exchangeable' cations.

In the native state, the exchangeable cations consist of calcium, sodium and magnesium. When the exchangeable sodium content (relative to the cation exchange capacity) exceeds 4% in the presence of swelling clays, the domains will disperse, leading to high sediment, piping erosion and poor returns of water and reagents from tailing dams. The inverse also happens to clays prone to swelling. The introduction of saline water, acid water, or water rich in ammonium, divalent and trivalent cations will cause swelling clay domains to excessively coagulate to the particle-size equivalent of silt or fine sand. This can cause natural clay liners or imported bentonite liners to leak. The potential for leaching water into the clay to do this is defined as 'sodium adsorption ratio for mine waters' (SAR-Mining). This needs to be interpreted by someone with expertise in clay minerals.

Failure to consider the occurrence of these clay minerals can have a substantial impact on recoverable efficiencies, problems with piping failure, high sediment load in dams, creeks and ponds, and, in the worst case, catastrophic earthen dam failure. It can also result in dam liners leaking at a rate up to 1000 times greater than expected.

Radioactivity

All minerals contain radionuclides that are members of the naturally occurring radioactive decay chains. The impact of these radionuclides needs to be considered in certain types of mining. Igneous and certain metamorphic rocks are more radioactive than most sedimentary rocks. Thus living in Armidale you will be exposed to elevated background radioactivity compared to living in Sydney. This radioactivity obviously increases in uranium orebodies, but can also be elevated in mineral sands, rock phosphate and other ores.

Exposure to elevated radioactivity levels can also occur during rare earth production, bauxite production, and oil and gas extraction, amongst many examples. The level of potential hazard from radioactive minerals depends on the type of radioactivity and its half-life. One of the major radiological risks in mining is associated with inhalation of radon (a radioactive gas with a short half-life) and its short-lived radioactive decay products. Radon is produced by the radioactive decay of radium. Radon can be a major problem in underground mines and needs to be carefully considered.

There are a number of laws covering radioactivity. You should contact the radioactivity liaison officer in your state department of mines for more information, or refer to the *Code of Practice and Safety Guide for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing (2005)* on the website of the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA).⁵

Methane

Methane 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.

3.1.3 Managing naturally occurring hazardous materials

Management of naturally occurring hazardous materials begins with their correct identification during pre-feasibility planning, followed by proper characterisation of the orebody, waste rock, overburden, mine process residues and natural soil under the mine infrastructure. If problematic naturally occurring minerals are encountered during mining, activities should cease until the hazard has been properly evaluated and corrective action has been planned.

Proper characterisation and hazard assessment will involve the use of an experienced environmental geochemist or soil chemist and occupational hygienists. These professionals should be involved during the planning stage to prepare a mitigation or avoidance program or corrective action.

Hazards from naturally occurring substances depend not only on the concentration of the substances but also on their chemical form and the surrounding environment. A risk assessment is undertaken to determine whether the natural geology and environment can continue to accommodate the substances without causing an adverse impact on human health or the environment. This is done by confirming

5 <http://www.arpansa.gov.au/pubs/rps/rps9.pdf>

the concentrations of the substances and comparing those concentrations with published criteria or threshold levels that are likely to cause harm to human health or the environment. However, threshold levels and published criteria are often 'guidelines', and site-specific levels are often more suitable because of variations in geological and environmental conditions.

For example, reactive clays are not dispersive until sodium is added at low concentrations. Adverse reactions with reactive clays are more common in the gold industry in eastern Australia, where sodium hydroxide is used to elevate pH to control cyanide, than in the goldfields regions of Western Australia. This is because although the sodium content is high, the sodium is present in sodium chloride, so the salinity is very high and the clay is so weathered that minimal reactive clays occur. In some cases, it is better to use another caustic agent both for environmental protection and for gold recovery because the sodium promotes dispersion, which increases the potential for failures in tailings dam structures and leaks into waterways.

Work practices and procedures for a safe and environmentally acceptable mine site start well before any mining commences, and are ideally developed during detailed or bankable feasibility study stages. These practices are designed to mitigate the risk to the environment and worker health during construction and operation of the mine and associated facilities, and should demonstrate continued improvement over time in accordance with changes in relevant legislation, standards and guidelines.

Typically, an environmental geochemist and occupational hygienist or similar suitably qualified professional should be involved in the identification of potentially hazardous naturally occurring substances, and in the design of waste emplacement facilities to mitigate the potential environmental impact from those substances.

3.2 Hazardous substances

To understand the workplace health and safety requirements for hazardous materials, legal obligations must be considered and relevant legislation and codes of practice must be understood.

3.2.1 What law applies?

State legislation, codes of practice and guidance documents must be considered. The regulatory regime is not the same in all states. Details can be obtained through the websites of state mines departments or workplace authorities (listed in Section 2.1.2).

3.2.2 What are hazardous substances?

Hazardous substances are materials that can have an adverse effect on human health due to their physical, chemical, and biological properties. A chemical or mixture of chemicals is classified as a hazardous substance if it meets the toxicological criteria in the *Approved criteria for classifying hazardous substances* [NOHSC: 1008(2004)], which addresses short-term and long-term health effects. More information about hazardous substances can be found on the Safe Work Australia website.⁶

Under the National Model Regulations for the Control of Workplace Hazardous Substances [*NOHSC:1005 (1994)*], a hazardous substance is one that:

- is included on the List of Designated Hazardous Substances [or]
- has been classified as a hazardous substance by the manufacturer or importer in accordance with the *Approved criteria for classifying hazardous substances*.

If hazardous substances are not stored or handled correctly, they harm workers, members of the public, property and the environment. Detailed requirements are outlined in state hazardous substances legislation for labelling, MSDS, risk assessments, control strategies, training and health surveillance of workers.

Hazardous materials include many commonly found industrial, commercial, pharmaceutical, agricultural and domestic chemicals, many of which are found in mine sites, as well as dusts, metal fumes and metal concentrates. Examples are flotation chemicals, solvents, cleaning agents, petroleum products, compressed gases, and biocides.

Some chemicals and proprietary mixtures are hazardous substances, including many dangerous goods for which a manufacturer or importer must prepare, amend, provide and review an MSDS. All MSDS for industrial products introduced on site will have a statement ('Classified as a Hazardous Substance' or 'Not Classified as a Hazardous Substance') that alerts the user to apply appropriate engineering controls to protect workers.

Hazardous substances classifications are:

- Very Toxic
- Toxic (includes acute toxic chemicals; carcinogens, categories 1 and 2; mutagenic agents, categories 1 and 2; and reproductive toxic agents, categories 1 and 2)
- Harmful (includes carcinogens, category 3; mutagenic agents, category 3; reproductive toxic agents, category 3)
- Corrosive
- Irritant
- Sensitiser.

6 <http://www.safeworkaustralia.gov.au/swa/HealthSafety/HazardousSubstances/>

Each hazardous substance MSDS will include a series of risk and safety phrases to assist the worker to handle it safely and be aware of the hazards. The Safe Work Australia website includes information on hazard substance labelling.⁷

Many hazardous substances are also classified as dangerous goods, but chemicals with long-term health effects (such as carcinogens and sensitisers) are not classified as Class 6 Toxic and Infectious Substances under the Australian Dangerous Goods Code (ADG7).

In the next few years, it is intended to introduce the **Globally Harmonised System of Classification and Labelling of Chemicals** (GHS). Developed by a United Nations agency, the GHS provides a uniform way of classifying chemicals internationally. It also uses risk statements and pictograms to inform chemical users about chemical hazards they may be exposed to. The GHS system will have impacts on the current system of classification and labelling of hazardous substances, and sites should review the final program when it becomes available.

Bulk storage vessels should be appropriately labelled or placarded in accordance with ADG7. Hazardous substances that are not dangerous goods should be appropriately identified. The MSDS should be located nearby in a storage container (as discussed in Section 4.1.2).

A full listing of hazchem and dangerous goods placarding requirements can be found in ADG7.

Hazardous substances used and hazardous waste generated on mine and mineral processing sites can include the following:

- *Acids (sulfuric, hydrochloric)*. Contact with strong acid liquids or fumes is a human health hazard and may also cause structural damage in a facility. Releases of acid to the environment may have direct effects on biota but also solubilise and thus mobilise heavy metal toxicants, as described in the *Managing acid and metalliferous drainage* handbook (DITR 2007).
- *Sodium cyanide for gold recovery in large operations*. *Cyanide management* (DRET 2008a) provides extensive information about sodium and calcium cyanides, with particular attention to toxicity in mammals and environmental impacts. Environmental best practice is exemplified by adherence to the International Cyanide Management Code for the Gold Mining Industry, to which major gold mining organisations subscribe.⁸ 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, and for genetic reasons only one person in two is able to detect the odour of hydrogen cyanide.

7 <http://www.safeworkaustralia.gov.au/swa/HealthSafety/HazardousSubstances/Labelling/>

8 <http://www.cyanidecode.org/>

- *Mercury for gold recovery in small/artisanal operations.* In small or artisanal operations, workplace concentrations of mercury should be monitored routinely where exposure is possible, for example from thermal desorption of metallic mercury. This can occur when ores containing trace amounts of mercury (some zinc concentrates, for example) are roasted. *Risk assessment and management* (DRET 2008b) includes a case study of the reduction of mercury pollution from artisanal mining. In that case, assistance from a mining company operating nearby was provided under the United Nations Industrial Development Organization's Global Mercury Project.
- *Metals as ions or complexes from Cu, Pb, Zn, Ni, Fe, As, Hg and Cd sludges or solutions.* Recovery of the metal is usually the object of the mining project, but hazards may arise from the presence of toxic by-products (for example, arsenic and cadmium) or metals released as a result of developing acidification, as described in *Managing acid and metalliferous drainage* (DITR 2007).
- *Thiosulfates and polythionates, also resulting from acid mine water or processing solutions.* Sodium dithionite generates sulfur dioxide in solution and may be stored on mine sites as an alternative to gaseous sulfur dioxide. Accidental wetting of dithionite leads to an exothermic process that may produce sulfur dioxide fumes.
- *Process reagents (acids, alkalis, frothers and collectors, modifiers, flocculants and coagulants) that contain aluminium and iron salts and organic polymers.* Refer to the MSDS for these substances for information necessary for best practice management.
- *Nitrogen compounds from blasting materials.* In enclosed spaces, the combustion products from nitrate explosives (mainly ammonium nitrate and fuel oil at present) need to be dispersed before work can restart in the affected area. Best practice consists of adequate ventilation and monitoring of the workplace atmosphere, rather than the use of personal protective equipment.
- *Oil and fuel used for engines, power plants, and lubrication.* Although hydrocarbon products can cause dermatitis when skin is contacted, fire is the main hazard. Because 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.
- *Suspended soils, mine water, surface drainage and process effluents.* State and territory regulations cover discharges to watersheds and water-bodies, but best practice should go beyond mere compliance and seek opportunities to avoid environmental damage and to improve water quality.
- *Polychlorinated biphenyls (PCBs) from transformers.* Australia's Polychlorinated Biphenyls Management Plan (2003) has been taken up in state and territory regulations.⁹ As a result of earlier efforts to remove PCBs from service,

9 <http://www.environment.gov.au/settlements/publications/chemicals/scheduled-waste/pcbmanagement/index.html>

many transformer oils are actually 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.

- *Asbestos from on-site plants, including asbestos cement sheets in old buildings.* Asbestos lagging is seldom employed on pipework these days, but some old plants may still contain it. State and territory regulations place restrictions on its removal and disposal.
- *Surplus 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. Chemical 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.¹⁰
- *Solvents used in extraction plants.* Hydrocarbon solvents, such as kerosene, are used in solvent extraction plants for separating complexed metal ions. As for petroleum products, there are flammability hazards and security risks.

Atmospheric contaminants can include the following:

- *Dust/particulates.* These can include crystalline silica, lead and nickel.
- *Gases produced by combustion.* These are produced by blasting and industrial combustion engines, and include CO, CO₂, NO_x, SO₂ and diesel particulate.
- *Natural gas.* This includes methane, which is common in coal mines but rare in base metal mines.
- *Chlorofluorocarbons (CFCs) from cooling equipment and fire protection devices.* CFCs can be released with equipment fails. Although they are not toxic, CFCs released into enclosed spaces can displace air and create an asphyxiation hazard. Most CFCs were phased out some years ago because they damage the Earth's ozone layer. They were replaced with hydrochlorofluorocarbons (HCFCs) or hydrofluorocarbons (HFCs), which pose the same asphyxiation hazards but are also flammable. Other hazards may emerge from the reintroduction of sulfur dioxide and ammonia, and possibly supercritical carbon dioxide, as 'new' refrigerants to replace the HCFCs because of HCFCs' global warming potential. The older chemicals have the potential to be risks to human health if handled incorrectly and released.

10 <http://www.drummuster.com.au/>

- *Gross emissions to the atmosphere.* Gross emissions are a special category of hazardous materials. They are discussed in the leading practice handbook *Air contaminants, noise and vibration* (DRET 2009), which covers what are known as the criteria pollutants—SO₂, CO, NO₂, photochemical oxidants reported as ozone, lead, and particulate matter (PM10). Emissions of hydrocarbons must be reported to the National Pollutant Inventory as volatile organic compounds. From 1 July 2009, emissions of greenhouse gases such as carbon dioxide and methane need to be reported to the Greenhouse and Energy Data Officer in the Greenhouse and Energy Reporting Office.¹¹

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 5500–6500 short ton per annum (stpa) 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 cathode copper. Since then, CuSX plants have proliferated world-wide. 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 electrowinning (EW) 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.

(continued)

11 <http://climatechange.gov.au/reporting/>

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. Of four fires since 1969, all were 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 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 two Australian mines—Ranger and Olympic Dam. No solvent fires have been reported at Ranger, but BHP Billiton's 2003 Environment, Health and Safety 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, we incorporated new standards for fire prevention and fire protection as identified in the investigation of the 2001 fire. 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

3.3 Dangerous goods

Dangerous goods should not be confused with hazardous substances – they are classified according to different criteria. Dangerous goods are classified on the basis of immediate physical or chemical effects, such as fire, explosion, corrosion and poisoning affecting property, the environment or people.

3.3.1 What law applies?

Regulations and codes of practice governing the storage and handling of dangerous goods in the workplace can be obtained from state mines departments and workplace authority websites (listed in Section 2.1.2).

The Australian Dangerous Goods code (currently in its seventh edition, ADG7), published by The National Transport Commission, covers the transport of dangerous goods.¹²

3.3.2 What are dangerous goods?

Dangerous goods are usually chemicals with the potential to present an immediate threat to people, property or the environment if they are not properly contained or controlled.

3.3.3 Types of dangerous goods

Substances (including mixtures and solutions) and articles subject to the ADG7 are assigned to one of nine classes according to the hazard or the main hazard they present. The classes are denoted by labels (or diamonds), and some are subdivided into divisions.

The classes and divisions are as follows:

- **Class 1: Explosives**
 - Division 1.1: Substances and articles which have a mass explosion hazard
 - Division 1.2: Substances and articles which have a projection hazard but not a mass explosion hazard
 - Division 1.3: Substances and articles which have a fire hazard and either a minor blast hazard or a minor projection hazard or both, but not a mass explosion hazard
 - Division 1.4: Substances and articles which present no significant hazard
 - Division 1.5: Very insensitive substances which have a mass explosion hazard
 - Division 1.6: Extremely insensitive articles which do not have a mass explosion hazard

12 <http://www.ntc.gov.au/viewpage.aspx?Areald=35&DocumentId=1147>

- **Class 2:** Gases
 - Division 2.1: Flammable gases
 - Division 2.2: Non-flammable, non-toxic gases
 - Division 2.3: Toxic gases
- **Class 3:** Flammable liquids
- **Class 4:** Flammable solids; substances liable to spontaneous combustion; substances which, in contact with water, emit flammable gases
 - Division 4.1: Flammable solids, self-reactive substances and solid desensitised explosives
 - Division 4.2: Substances liable to spontaneous combustion
 - Division 4.3: Substances which in contact with water emit flammable gases
- **Class 5:** Oxidising substances and organic peroxides
 - Division 5.1: Oxidising substances
 - Division 5.2: Organic peroxides
- **Class 6:** Toxic and infectious substances
 - Division 6.1: Toxic substances
 - Division 6.2: Infectious substances
- **Class 7:** Radioactive material
- **Class 8:** Corrosive substances
- **Class 9:** Miscellaneous dangerous substances and articles

The numerical order of the classes and divisions does not denote the degree of danger.

Table 3.2 gives examples of dangerous goods and the places they might be found on a mine site.

Table 3.2: Dangerous goods and their likely locations on mine sites

Class	Description	Examples	Location in mine
1	Explosives	ANFO	M
2.1	Flammable gases	liquefied petroleum gas (LPG) liquefied natural gas (LNG) acetylene oxygen methane	P P PWS,M P M
2.2	Non-flammable, non-toxic gases	nitrogen carbon dioxide compressed air helium	P P,W,M M,P,WS P
2.3	Toxic gases	anhydrous ammonia hydrogen cyanide sulphur dioxide carbon monoxide	P P, W P, W M, P, WS
3	Flammable liquids	unleaded petrol (ULP) diesel kerosene aviation fuel	M, WS M P
4.2	Substances liable to spontaneous combustion	Pyrite bearing coal Some base metal sulfides in the presence of pyrite	M, W M, W
5.1	Oxidising agents	Caro's acid ammonium nitrate hydrogen peroxide potassium permanganate calcium hypochlorite	P M (explosives) P P P
6.1	Toxic substances	cyanide arsenic compounds cadmium compounds	P P, W P, W
7	Radioactive material	naturally occurring radioactive minerals containing radioactive elements (U, Th Ce etc.) radon gas radium in dust and water measuring instruments using radioactive sources	M, P, WS, W
8	Corrosive substances	nitric acid sulfuric acid hydrochloric acid Caro's acid sodium hydroxide calcium hydroxide calcium oxide lead acid batteries	P P P P P P P W
9	Miscellaneous dangerous goods	asbestos some metal concentrates	W, P, M, WS P

M = mining; P = processing; W = waste; WS = workshop and maintenance

ADG7 was issued in 2009, and included protocols and criteria for aquatic environmental toxicity testing. Those inclusions have impacts on the transport of metal concentrates off site to ports, as there are cases where results for different metal concentrates have been classified as Class 9, UN 3077, Environmentally Hazardous Substances. (UN 3077 relates to mixtures of solids which are not subject to the ADG7.)

Mine sites must test their concentrates before transport to determine whether they are classified as Class 9, UN 3077. Classified concentrates must be stored and handled in compliance with AS 4681 and transported in compliance with the requirements in ADG7.

3.4 Mining wastes and by-products

3.4.1 What are mining waste materials?

Mining waste materials are a class of materials generated through the mining and processing of rock material containing economic quantities of metalliferous or industrial minerals, coal, or oil (shale oil).

3.4.2 Types of mining waste materials

There are several classes of mining waste. Waste rock or overburden is material that is mined from an open cast pit or underground workings in order to gain access to rock material hosting economic grades. The classification of waste is based largely on the market price and the grade of the target commodity. Generally, waste rock contains little or no economic quantities of the mineral or energy commodity. It includes topsoil, weathered and partially weathered overburden, and primary or unweathered waste rock. Topsoil, on the other hand, cannot be regarded as waste since it is a valuable resource for rehabilitation of the mine site upon closure. In many metalliferous and coal mines, low-grade or sub-economic grade ore or coal is stockpiled for later processing when economic circumstances improve and commodity prices rise. Often, low-grade ores are left to weather, are never treated and become classed as high-grade waste rock stockpiles. Stockpiles of low-grade ores—or high-grade waste rock, depending on the economic viewpoint—often contain sulfides that can oxidise when exposed to air and moisture, forming sulfuric acid. The acid is itself hazardous, but also carries dissolved metals that can damage the environment. *Managing acid and metalliferous drainage* (DITR 2007) gives a full account of the hazards and the best practice relating to them.

Tailings are the fine-grained residue remaining after the processing of ore and extraction of the target commodity. Tailings from metalliferous ores contain small quantities (sub-economic grade) of the target metal plus accessory minerals (for example, sulfide minerals, often in high concentrations), metal ions and process chemicals. Processing of coal generates fine- and coarse-grained rejects, which may contain sulphide minerals and metal ions, including aluminosilicates that may be a source of aluminium in acidic mine drainage. Tailings best practice is described in *Tailings management* (DITR 2007).

Heap leaching technology is applied to low-grade ores. 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 sulfuric 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.

The other main waste material is mine water that accumulates within mine structures, such as open pits, underground, or interacts with mine disturbed areas. Further information on tailings can be found in the leading practice handbooks *Tailings management*, *Managing acid and metalliferous drainage*, and *Water management*.

Monitoring the concentrations of hazardous materials discharged into tailings storage facilities of any type—such as a paddock, central discharge tailings (CDT) or pit infill—for environmental effects is part of best practice for the mining industry. For example, the gold mining industry has adopted the voluntary International Cyanide Management Code to minimise the hazardous effect of cyanide on the environment. All operations are expected to comply with the code, compliance is verified by independent auditors, and reports are published on the International Cyanide Management Institute's website.¹³

One site, Anglo Gold Ashanti Australia's Sunrise Dam operation, uses hypersaline groundwater in its gold winning process. While the operation works continuously to reduce the cyanide levels used in the process to minimise the loss to the CDT, the discharge to the CDT is still above the International Cyanide Management Code guideline level of 50 mg/L weak acid-dissociable cyanide. Recent extensive peer-reviewed research¹⁴ provided a novel way to reduce the environmental impact and prevent wildlife death (particularly bird deaths) due to cyanide toxicity by ensuring that discharge to the CDT is above a certain minimum in salinity. The research identified protective mechanisms that prevent birds from drinking from the ponded solution and drains, and produce a faster oxidation rate of the cyanide to less toxic cyanate forms. Even the most salt-tolerant avian species cannot drink water with a salinity above 50,000 mg/L total dissolved solids.

Simple daily salinity determination confirms that the cyanide solutions are above the minimum salinity level. When rain or storms threaten to dilute the salinity below the established 'safe' level, wind, solar and mine-operated groundwater pumps add hypersaline groundwater to the cyanide solutions, thus protecting wildlife and continuing the fast oxidation of the cyanide.

The Cowal gold mine in central New South Wales is a heavily regulated operation because it is in an environmentally sensitive area adjacent to a lake that fills intermittently from overflow of the Lachlan River. The concentration of weak acid-dissociable cyanide discharged to tailings ponds must not exceed 30 ppm and must remain below 20 ppm for 90% of operating time, in order to reduce the hazard posed to birdlife in the area.

13 <http://www.cyanidecode.org/>

14 ACMER research project 58: A Risk Assessment of the Effects of Goldmining Cyanide-Bearing Tailings Solutions on Wildlife.

CASE STUDY: Management of arsenic minerals at the Yerranderie mine site

Yerranderie is a historic abandoned silver-lead mining town southwest of Sydney near the World Heritage listed Blue Mountains National Park. The site is about 12 kilometres 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 occupational health and safety (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 approximately 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.

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Fencing and signage was not a long-term management solution.



Part of the mining heritage at Yerranderie.
Source: NSW Department of Industry and Investment–Minerals and Energy.

3.5 Security risk substances

3.5.1 What law applies?

The basis for security risk substances (SRS) regulations is the COAG agreement of 25 June 2004 relating to counter-terrorism measures. All states and territories have adopted SRS regulations.

States and territories did not need identical or even new specific legislation, but they contribute to national consistency in various ways. For example, Western Australia developed the Dangerous Goods Safety (Security Risk Substances) Regulations 2007, rather than including security risk substances in explosives regulations. This avoids confusion or inconsistencies between safety and security requirements for ammonium nitrate. The regulations contain guidance and definitive statutory requirements. The requirements of the SRS Regulations are in addition to those of other dangerous goods safety regulations.

3.5.2 Types of security risk substances

The following substances, other than Class 1 Dangerous Goods, are SRSs in Western Australia:

- solid mixtures containing more than 45% ammonium nitrate (AN)
- ammonium nitrate emulsions, suspensions or gels.

The latter group does not include single-phase, homogeneous aqueous solutions of AN (as opposed to multiphase, heterogeneous mixtures). Such solutions are classified as Class 5.1, UN 2426 in the ADG7 and are commonly used as fertiliser or as hot, concentrated solutions for making AN emulsion explosives. However, it includes calcium ammonium nitrate (CAN), which is not a dangerous good under the UN classification system.

Consider chemicals a security risk

The Australian minerals industry strongly supports the need for a 'social licence to operate' as a complement to a regulatory licence issued by government. To the industry, a social licence to operate is about operating in a manner that is attuned to community expectations and which acknowledges that businesses have a shared responsibility with government, and society more broadly, to help develop strong and sustainable communities.

All minerals operations receive, store, utilise and dispose of chemical substances. Some of those chemicals can be used to develop materials that can be used to harm people or property. Most minerals operations have security procedures in place related to mitigating OHS, personnel management, environmental performance and asset management risks.

Minerals operations should remain vigilant about the potential for people or organisations to access chemicals used in industry operations and use them in ways for which they are not intended. Such an event would incur significant reputational and direct costs for an operation, the company involved and the broader industry.

Chemicals security risks can be formally considered and managed in existing operational risk management processes. The *Risk assessment and management* leading practice handbook (DRET 2008b), AS/NZS 4360:2004 and the materials stewardship philosophy provide a robust framework for assessing and managing operational risks throughout the value chain. The Standards Australia / Standards New Zealand *Security risk management* handbook (HB 167:2006) provides specific guidance on managing security-related risks.

Incorporating chemicals security into risk registers allows minerals operations managers to understand, identify and manage security risks. The following items could be considered for incorporation into existing risk assessment processes:

- • employability or desirability of the chemical
 - could this substance be of interest for terrorist purposes?
 - if not, it would not require further assessment from a security perspective
- • supply chain vulnerability, for example
 - employee/contractor suitability assessments
 - inventory control measures
 - volumes and packaging transported
 - site/route location and accessibility
 - security awareness training and communication for suppliers

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- on-site vulnerability, for example
 - access controls for chemical store (access onto and within operation)
 - employee/contractor suitability and monitoring
 - time and frequency of chemical storage
 - inventory control, including documentation and auditing
 - training in and awareness of chemicals security concerns
 - procedures for handling, use and disposal.

Leading practice operations in Australia have taken a life-cycle approach to custodianship of all chemicals brought to and used on site, which also extends to chemicals suppliers and waste disposers. They apply risk assessment and management processes, and typically have comprehensive chemicals inventories that document accountabilities, amounts, storage conditions and disposal methods. This is often implemented with dedicated tracking software. At leading practice operations, chemicals management is factored into site risk management through risk registers that are subject to regular and comprehensive audits against company standards.

These existing comprehensive systems can be tailored to include particular issues related to chemicals' security risks.

Thefts of hazardous material from mine sites can be dangerous. In 2008, German prosecutors brought charges of 'membership in a terrorist organisation' against two men, and a third man was extradited from Turkey to face charges of providing 26 explosive detonators. According to German media reports, the alleged terrorists wanted to blow up US targets in Germany and had stockpiled hundreds of litres of concentrated hydrogen peroxide.¹⁵ The quantities of chemicals were large enough to build bombs that could have been more powerful than those that killed 191 commuters in Madrid in 2004 and 52 commuters in London in 2005.

15 <http://www.welt.de/politik/article2384639/Prozess-gegen-Sauerland-Terroristen-eroeffnet.html>





4.0 RISK MANAGEMENT

Purpose

This section presents risk management strategies that may be implemented at the corporate, mine site or personal level.

Key messages

- Substitution of materials or control measures, such as ventilation and containment, can reduce exposures to hazardous substances.
 - Worker hazard awareness and training is of vital importance.
 - Communication of risks to the community needs to be part of broader communication.
 - Suppliers' stewardship programs can augment mine management practice.¹⁶
-

In July 2009, the International Council on Mining and Metals released *Good practice guidance on health risk assessment (HRA)*, which describes the development of health risk assessments of chemicals at mining sites. This useful document is available on the council's website.

4.1 Worker hazard awareness

4.1.1 Material Safety Data Sheets

Material Safety Data Sheets (MSDS) were established around 30 years ago to fulfil 'worker's right to know' legislation in the United States.

Before the 1990s, Australian legislation controlling OHS information on labels and MSDS was poor, leading to incidents in which workers were not aware of hazards or how to handle chemicals safely. National legislation was introduced to ensure that MSDS and labels meet standards and include required information content.

The key documents, which can be found on the Safe Work Australia website¹⁷, are:

- *National Code of Practice for the Preparation of Material Safety Data Sheets*, 2nd edition [NOHSC: 2011 (2003)]
- *National Code of Practice for the Labelling of Workplace Substances* [NOHSC: 2012 (1994)].

16 <http://www.icmm.com/page/14733/new-guidance-on-health-risk-assessment>

17 <http://www.safeworkaustralia.gov.au/swa/AboutUs/Publications/NationalStandards/IndexofNationalStandardsCodesofPracticeandrelatedGuidanceNotes.htm>

Legislation

The various OHS Acts require that employers provide information, in the form of an MSDS, to allow workers to handle hazardous substances safely. Even when a product is not classified as a hazardous substance or a dangerous good, it is recommended that an MSDS be prepared for the mine site to enable workers and managers to store and handle the product safely. A similar approach should be taken to waste material that needs to be disposed.

Employers' responsibilities

Employers have the following responsibilities:

- They must provide the information needed to allow the safe handling of hazardous substances used at work.
- They must ensure that all employees have ready access to MSDS (either as paper copies or in databases).
- They should encourage employees to read MSDS for the hazardous substances that workers may be exposed to in their work.
- MSDS on site must be dated and current (within five years of the issue date).
- 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.

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).¹⁸ In the case of a mixture or blended product, such as a lubricant, its components must be listed. In addition, the mining company becomes responsible for preparing an MSDS to meet the legal guidelines.

New chemicals coming on site

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

- Procedures must be available to control and assess new products or chemicals being introduced.
- Before a hazardous substance is used at the site, an MSDS must accompany the first supply of the substance.
- A risk assessment must be conducted and signed off by a competent person.
- 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.

Figure 4.1 shows a sample checklist for a risk assessment.

18 <http://www.nicnas.gov.au>

Figure 4.1 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	
1. Eye				
2. Inhalation				
3. Skin				
4. Ingestion				
5. Fire hazard				
6. 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"/> Barricades / Guards		
<input type="checkbox"/> Forced ventilation		<input type="checkbox"/> Fire extinguisher		
<input type="checkbox"/> Atmospheric Monitoring		<input type="checkbox"/> Training		
<input type="checkbox"/> Additional lighting		<input type="checkbox"/> Written procedure		
<input type="checkbox"/> Warning signs		<input type="checkbox"/> other		
5. What special personal protective equipment is required				
<input type="checkbox"/> Splash proof goggles		<input type="checkbox"/> Full Face Respirator		
<input type="checkbox"/> Full face shield		<input type="checkbox"/> Air flow hood / Mask		
<input type="checkbox"/> Standard Rubber gloves		<input type="checkbox"/> Disposable Coveralls		
<input type="checkbox"/> Special Gloves		<input type="checkbox"/> PVC Apron/coveralls		
<input type="checkbox"/> Particulate Mask		<input type="checkbox"/> other		
<input type="checkbox"/> Half Face Respirator				
Environment - (Completed By Environmental Superintendent)				
The product (or components) is reportable under the National Pollutant Inventory?				
Storage containment / bunding required?				
Special waste disposal requirements?				
Spill control procedures are necessary?				
Stores - (Completed By Store Superintendent)				
Storage Compatibility:				
Storage Requirements:				
Recommendations/Actions/Comments				
	Safety	Environment	Warehouse	Technical Expert
Reviewed by				
Signed				
Date				
Department Manager Approval				
Signature:		Date:		

Source: Newcrest Mining Ltd

Waste materials

Waste materials should also be assessed and an appropriate MSDS and label should be prepared to ensure that the workers handling the drums of material on site or off site can do so safely.

Registers

All hazardous materials on site must be on a site register, which is often a computerised MSDS database.

For all hazardous materials, the register must include the product name, the MSDS, the quantity, and the location in which the material is used.

The register should be updated as new hazardous substances are introduced to the workplace and the use or production of existing hazardous substances is discontinued.

Dangerous goods must be recorded in a site manifest that complies with the dangerous goods legislation.

Access to the register

All workers, emergency services and relevant public authorities should have ready access to the site register. The register can either be centrally located or kept in the workplace to which it pertains.

Identification of hazardous substances in enclosed systems

Where a hazardous substance in a workplace is contained in an enclosed system, such as a pipe or piping system or a 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* or AS 1345 *Identification of the contents of piping, conduits and ducts*.

How to read an MSDS

The MSDS is divided into 16 sections:

- **Section 1: Identification of material and supplier** provides the name and supplier of the material, recommended uses, and contact information for the supplier, including an emergency contact.
- **Section 2: Hazards identification** describes the hazards of the material and the appropriate warning information (risk and safety phrases) associated with those hazards, including whether the material is a hazardous substance, a dangerous good, or both.

There is no legal requirement to provide an MSDS for a non-hazardous and non-dangerous material. However, it is good practice to do so, as an MSDS is a well-accepted and effective way to provide workplace information and information required for product liability for the supplier.

- **Section 3: Composition / information on ingredients** identifies the ingredients of the material. This includes CAS (Chemical Abstract Service) registry numbers, which are assigned numbers for chemicals and process streams. CAS numbers can be used to find out more information about the chemical on the Safe Work Australia's Hazardous Substances Information System database.¹⁹
- **Section 4: First aid measures** describes the initial care that can be given without sophisticated equipment and a wide selection of available medications.
- **Section 5: Fire fighting measures** describes the fire and explosive properties of the material and provides advice on how to deal with incidents. It also lists hazardous chemicals produced during fire or by overheating.
- **Section 6: Accidental release measures** recommend the appropriate response to spills, leaks or releases to prevent or minimise adverse effects on people, property and the environment.
- **Section 7: Handling and storage** provides guidance on safe handling practices that minimise potential hazards to people, property and the environment from the material.
- **Section 8: Exposure controls / personal protection** details engineering control measures needed to minimise exposure to and risks associated with the hazards of the material. Occupational exposure standards, if applicable or available, must not be exceeded. Not all substances have occupational exposure standards. Those that do, do not cover the dermal (skin) or oral (mouth) routes of exposure.
- **Section 9: Physical and chemical properties** gives empirical data on the material. The key pieces of information are the boiling point and solubility of the chemical. The closer the boiling point is to 25°C, the higher the risk of exposure to airborne material. The flash point also gives an indication of the flammability of the chemical.
- **Section 10: Stability and reactivity** describes reactivity hazards of the material and provides specific test data for the product as a whole, where available. However, the information may also be based on general data for the class or family of chemical, if such data adequately represent the expected hazard.
- **Section 11: Toxicological information** describes the potential adverse health effects and symptoms associated with exposure to the material and its ingredients or known by-products. This will cover short-term health effects and, in some cases, long-term effects. Routes of exposure to be considered are airborne or skin absorption, if appropriate.

- **Section 12: Ecological information** provides information to evaluate the environmental impact of the material if it is released to the environment. This information can assist in handling spills and evaluating waste treatment practices. The section should clearly indicate species, media, units, test duration and test conditions.
- **Section 13: Disposal considerations** provide information on the disposal, recycling or reclamation of the material and/or its container.
- **Section 14: Transport information** provides basic classification information for the preparation of the material for transport or shipment. If that information is not available or relevant, this should be stated. The core transport information is
 - UN Number
 - UN Proper Shipping Name
 - Class and subsidiary risk(s)
 - Packing Group
 - Special precautions for user
 - Hazchem Code.
- **Section 15: Regulatory information** describes other regulatory information on the material that is not provided elsewhere in the MSDS.
- **Section 16: Other information** provides information relevant to the preparation of the MSDS.

4.1.2 Labelling

All containers of hazardous substances supplied to, used in or handled at the workplace should be appropriately labelled to allow them to be used safely.

Bulk storage vessels should be appropriately labelled or placarded in accordance with ADG7. Hazardous substances that are not dangerous goods should be appropriately identified, and the MSDS should be located nearby in a storage container.

Hazardous substances can be described by a series of risk and safety phrases that allow the user to understand the hazards and required precautions. The phrases are listed in the *National Code of Practice for the Labelling of Workplace Substances* [NOHSC:2012(1994)].²⁰

20 http://www.safeworkaustralia.gov.au/NR/rdonlyres/9A5FFEC7-940E-478A-BB34-07C8A1C9D597/0/LabellingCOPNOHSC_2012_1994.pdf

For example, concentrated sulfuric acid is classified as a corrosive and would require the following risk and safety phrases:

- R35: Causes severe burns
- S23: Do not breathe vapour
- S30: Never add water to this product
- S36: Wear suitable protective clothing
- S37: Wear suitable gloves
- S39: Wear eye/face protection
- S26: In case of contact with eyes, rinse immediately with plenty of water and seek medical advice
- S45: In case of accident or if you feel unwell, seek medical advice immediately (show the label whenever possible).

Under the Globally Harmonized System of Classification and Labelling of Chemicals, some changes will be made to terminology.

Risk and safety phrases can vary between similar products, as it is up to the manufacturer or supplier to nominate the phrases from the Safe Work Australia list.

4.1.3 Training

Mining companies have a duty to make the workforce aware of the problems and dangers associated with hazardous materials and of safer handling requirements. It is up to the company to provide adequate training and enforce the implementation of its procedures.

Workforce training

All workers and personnel working regularly on the mine site who might come into contact with or into the vicinity of hazardous substances or dangerous goods must be trained on the inherent hazards. The training should include:

- recognition of the material as hazardous at the operation
- adequate information about the health or environmental effects of the material
- symptoms of overexposure to the material
- first aid and emergency procedures
- safe handling procedures and personal protective equipment requirements.
- environmental clean-up procedures
- firefighting requirements.

MSDS 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 records of that training should be kept.

Each worker is responsible for abiding by the health, safety and environmental components of the training. The training requirements for each job should be identified in the training materials. Personnel in particular positions (including those involved in unloading and storing the materials, plant operators, tailings storage facility operators, maintenance and environmental personnel, and management staff) should be trained in the relevant procedures by appropriately qualified personnel, who may be external experts and/or regulators.

Emergency drills simulating worker exposure and environmental releases 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.

Visitor and contractor management

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

They should be inducted according to the locations they are likely visit. The induction should be:

- at a basic level for visitors who are being accompanied; for example, to the site office
- at operational levels for contractors, according to the requirements of the relevant sections of the plant.

Education on hazardous materials

The education of site personnel may be carried out through internal specialised training courses or through attendance at conferences, workshops or courses provided by external providers.

Education of the community and stakeholders may be through public forums or meetings, newsletters, and the distribution of educational and informational documents through local councils, libraries or other means.

4.2 Community awareness

4.2.1 Communication

Appropriate operational and environmental information on the management of hazardous or dangerous goods should be made available to stakeholders, including the community. The stakeholders should be kept informed about how the operation manages hazardous substances in relation to health and safety and the environment. This information may be communicated through public meetings, newsletters, the internet and other means.

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 community have been working 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.

Port Pirie is an integrated multi-metal smelter and refinery, with 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 human bodies through ingestion (eating and swallowing) of lead-contaminated food, water, soil, dust or paint chips and through inhalation (breathing in) of lead dust particles. A common way of absorbing lead, particularly for young children, is through contaminated hand-to-mouth movements.

Blood lead levels above 10 µg/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 approximately 50% because lead resembles calcium and children's gastrointestinal tracts take up calcium at greater rates than adults. Nutritional deficiencies of iron and calcium can also lead to greater absorption, exacerbating the toxic effects of lead.

The Tenby10 project has 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 has made running improvements each year since it began.

This result was achieved through substantial investment by Nyrstar in on-site emission control measures and environmental programs. In addition, extensive community education and awareness programs have 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.

Further information on community engagement is available from the:

- *Community consultation and communication guidelines: The Dangerous Goods Safety Management Act 2001*, Chemical Hazards and Emergency Management (CHEM) Unit, Queensland Department of Emergency Services, March 2002²¹
- Leading practice *Community engagement and development* handbook (DITR 2006).

4.3 Controls

Worker exposure to hazardous materials should always be minimised, and exposure minimisation relies on control regimes.²²

Control regimes involve a hierarchy of controls:

1. Elimination/substitution
2. Engineering controls
3. Administrative controls
4. Personal protective equipment (PPE).

Which regime is appropriate depends on the nature of the job. For example, engineering controls are appropriate for normal operations or tasks that continue for long periods. Short-term or intermediate tasks, such as maintenance, rely more on controls at the lower end of the hierarchy.

While PPE is important, action higher up the hierarchy should be considered first. Long-term use of PPE may not be the safest or most cost-effective control.

4.3.1 Elimination/substitution

The definitive way to reduce the risk from a process or substance in the workplace is to completely remove that process or substance. However, more often substitution is used to prevent health problems; for example, by replacing asbestos with safer synthetic substitutes, such as glass foam, rock and glass wool.

In some industrial processes where a less hazardous material cannot be used, the risk in handling hazardous materials can be reduced by changing the process. For example, an operation might:

- use a pelletised form of the hazardous substance, rather than a powdered form
- vacuum or use an industrial sweeper to clean up concentrate dusts, rather than manually sweeping them up.

4.3.2 Engineering controls

A range of engineering controls is possible, including various types of containment and ventilation systems.

21 <http://www.ret.gov.au/resources/sdmining>

22 Parts of the control strategies in this section have been extracted from *Principles of occupation health and hygiene: an introduction* (AIOH 2007), published by the Australian Institute of Occupational Hygienists.

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 the 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 NSW 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, and that no new cases have been detected since 1988. 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 1970–1973. 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 NSW 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 exceedances. The committee also conducts research into relevant industry issues (such as diesel particulate and inhalable dust) and better methods of dust suppression and workplace monitoring.

An untiring focus over more than 50 years has eliminated this debilitating disease from the NSW coal industry, but the same cannot be said for overseas coal industries. Several years ago, cases of pneumoconiosis occurred in young coal miners in the United States. As a result, the American National Institute for Occupational Safety and Health and the Mine Safety and Health Authority set up the Enhanced Coal Workers' Health Surveillance Program. At that time, the program detected 37 cases of coal miners with dusted lungs. Notably, all 37 miners had worked underground for at least 10 years without having had a chest X-ray, 22 had worked for 20 years without an X-ray, and 2 had worked for over 30 years without radiology.

The importance of principles of effective control backed by vigilant monitoring cannot be overstated. A problem might be under control, but it can easily re-emerge if control and monitoring procedures are discarded.

Source: Coal Services Pty Ltd.

Isolation

If the worker can be isolated completely from the hazard, the risk to health is removed. Isolation may be by a physical or a distance barrier. Time is also a barrier, although time may equally be considered an administrative control. Isolation controls include:

- remote storage of hazardous materials (for example, explosives, fuel tank farms)
- the separation of materials that could create hazards by coming into contact with each other by accident (for example, oxidants and fuels).

Occasionally, it is possible to use timed sequences to conduct hazardous operations when fewer workers are present. For example, if a workplace is to be painted, the painting should obviously be done outside normal working hours to prevent unnecessary exposure to solvent vapours.

Containment

Once dust, fumes or vapours have escaped from the source, they become far more difficult to control. A better strategy is to maximise containment by engineering controls, for example by:

- totally enclosing the whole process and using an exhaust extraction system
- enclosing noisy machinery in sound-proofed structures.

The design of structures to enclose or contain processes must allow for maintenance activities. Poorly designed enclosures can create a safety risk for maintenance workers or put their health at risk from an unpredictable exposure.

Care should be taken when locating potentially hazardous storage or operational tasks in remote locations, because that remoteness might cause new risks if there are difficulties or breakdowns.

Potentially hazardous materials or processes should not be located near frequently used thoroughfares and buildings.

Ventilation

Ventilation is the engineering control of contaminants by dilution or local exhaust ventilation. It is one of the main methods of control of airborne chemical hazards, particularly contaminants in underground mines.

Strict regulatory controls on respirable dust and respirable crystalline silica have achieved dramatic reductions in the incidence of pneumoconiosis and silicosis in underground miners.

4.3.3 Administrative controls

In some situations, the higher level control mechanisms do not work, or they cannot be made to work well enough to completely eliminate the hazard. In such cases, administrative controls may be needed.

Administrative controls include worker rotation and schedules to remove workers from exposure. An extreme form of work-schedule change would be to rotate tasks within a workgroup to spread the exposure across a larger number of staff.

In many circumstances, exposure to hazardous substances or a hazardous environment cannot be avoided. If any workers are exposed to the maximum permissible level, they may have to be removed from that task. Two examples are as follows:

- In lead mines, workers may be removed from the area of exposure if their blood lead levels exceed a certain level, and kept away from further lead exposure until their blood lead falls to an acceptable level. The causes of the exposure should be investigated immediately, with a view to eliminating it.
- In uranium mines, workers are permitted a maximum radiation dose over a specified period.

To be able to use administrative controls properly, workers have to be adequately trained so that they know:

- why the administrative control is being used
- the exact procedures and guidelines to be followed
- the limitations of the administrative control
- the consequences of ignoring the administrative control.

In other words, worker involvement, participation, training and education are critical to success.

Housekeeping and labelling are two administrative control processes that limit inadvertent (especially skin) exposure to workplace hazards. The importance of maintaining high standards of housekeeping cannot be overstated. Dirty and untidy workplaces increase the likelihood of secondary exposures. For example, lead concentrate dust raised by draughts and wind, or inadvertent skin contact on dirty surfaces and equipment, may cause extra exposures not identified in the risk assessment. Poor housekeeping also sends a message to site workers, contractors and employees that poor work habits are acceptable.

4.3.4 Personal protective equipment

PPE is used when other means of exposure control cannot be employed. Use of any PPE places restrictions upon workers; it reduces the flexibility of a worker's operation, may contribute to heat load on the worker's body, and affects the worker's ability to do the task safely.

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. For example, a welder doing structural work inside a mine storage shed may be working at heights in a hot environment and trying to protect against welding fumes as well as metal fumes from metal concentrates.

Gloves

Most people use their hands all the time at work, and hand injuries are consequently very common. Such injuries can be physical trauma or chemically induced damage, such as dermatitis. Good practice when selecting gloves involves a risk assessment of the hazard and consulting the workers (as dexterity and 'feel' are important for worker 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. Polyvinyl chloride (PVC) gloves are often worn when workers are handling oils and corrosives (acids and alkalis), but may offer little protection against many organic 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 the 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 appropriate type of RPE, with the appropriate protection factor
- workers' acceptance of the RPE
- medical assessment of respirator use for some RPE users
- training in RPE use, including the correct fit of respirators
- 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* (Standards Australia 2009)
- *AS/NZS 1716 Respiratory protective devices* (Standards Australia 2003).

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)—particles (metal fumes) generated by high-temperature operations such as welding, soldering, brazing and smelting
- Class P3 for 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 this (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.

Gases and vapours

Gas/vapour respirators contain a specialised absorbent to trap those contaminants (for example, activated charcoal is used to trap organic vapours). AS/NZS 1715 has a number of gas and vapour classifications. Each filter type is designated by a letter or chemical abbreviation that indicates the substance or group or substances that it is intended to protect against. Table 4.1 and Table 4.2 list filter classes and types.

Table 4.1: Gas/vapour filter classes

Class	Description
Class AUS	Low absorption capacity filters
Class 1	Low to medium absorption capacity filters
Class 2	Medium absorption capacity filters
Class 3	High absorption capacity filters

Source: AS/NZS 1716 (Standards Australia 2003).

Table 4.2: Gas/vapour filter types

Type	Use
A	For use against certain organic gases and vapours as specified
B	For use against certain inorganic gases and vapours as specified, excluding carbon monoxide
E	For use against sulphur dioxide and other acid gases and vapours as specified
G	For use against certain organic compounds with vapour pressures less than 1.3 Pa (0.01 mm Hg) at 25°C as specified. These filters shall have an integral particulate filter with an efficiency at least equivalent to that of a P1 filter.
K	For use against ammonia and organic ammonia derivatives as specified by the manufacturer
AX	For use against low boiling point organic compounds as specified by the manufacturer (boiling point less than 65°C)
NO	For use against oxides of nitrogen
Hg	For use against metallic mercury
MB	For use against methyl bromide

Source: AS/NZS 1716 (Standards Australia 2003).

All instructions and warnings about product use, fit and limitations must be followed for the product to work properly and provide adequate protection.

Facial hair that impedes the seal of a respirator greatly reduces its effectiveness and should be discouraged if respirator use is a part of normal daily work.

Fit testing should be considered before a worker uses a reusable respirator for the first time. Some people may be unable to achieve a satisfactory fit.

Supplied-air and air-purifying respirators

Various types of RPE rely on either supplied fresh air or on purifying air with filters (see Table 4.3). They have been developed for different applications and vary in protection factors. Guidance from the supplier or an occupational hygienist is required.

Table 4.3: Supplied-air and air-purifying respirators

Type	Description
Air purifying, powered type	Supplied air, self-contained powered air purifying respirator (PAPR) uses a battery-driven fan to force air through a filter assembly and deliver cleaned air to a helmet, hood or face mask.
Air purifying, replaceable filter type	A facepiece (full face or half face) to which a replaceable filter assembly is connected. The user's lung power is used to draw the air through the filter.
Air purifying, disposable	A respirator with the filter as an integral part of the facepiece and the filter is not replaceable. When exhausted the whole assembly is discarded.
Supplied air, air hose	The respirator facepiece is connected by a wide diameter hose that is located outside the contaminated zone. The user's lung power draws air to the facepiece (can be low pressure fan assisted). The critical factor in air hose systems is they supply air at or near atmospheric pressure
Supplied air, compressed air-line	Air for respiration is supplied by a small-bore line that is connected to a compressed air source. This may be a compressor, or compressed air cylinders located a distance from the work location. There are specifications in AS 1716 regarding the purity of air supplied systems and SCBA systems.
Supplied air, self contained	The respirator facepiece is connected by a breathing tube to a cylinder of breathable gas that is carried by the wearer. Often referred to as SCBA.

Source: AS/NZS 1716 (Standards Australia 2003).

Protection factors

Inexperienced and untrained personnel should not attempt to select correct RPE. Some regulations or codes of practice (for example, the National Occupational Health and Safety Commission's *Code of Practice for the Management and Control of Asbestos in Workplaces*) spells out the minimum RPE for situations where it is required.²³ AS/NZS 1715 should be consulted to select the most appropriate RPE.

23 <http://www.safeworkaustralia.gov.au/NR/rdonlyres/DB7C0238-F1D3-4EDE-B444-F7B751CE83FE/0/ManagementCode.pdf>

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 these data, it is possible to calculate the required minimum protection factor expected from particular RPE using the formula:

$$\text{Required minimum PF} = \text{concentration in workplace} / \text{Workplace Exposure Standard (or other target)}$$

Concentration and the workplace exposure standard should be in the same units (ppm or mg/m³).

AS/NZS 1715 also 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 and 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 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 the 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 some 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 are 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; 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.

Inspection, maintenance and repair

The employer must provide all the PPE required for any operation involving hazardous substances, and most mines keep the bulk of the PPE 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 shift 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 non-disposable PPE, such as respirators and gloves, 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

PPE must be used when required and worn correctly to be of value. An employee training program is required whenever there is a likelihood that PPE may be required. Training should be interactive and demonstrate the use of the PPE. The following program format addressing respiratory protection is from AS 1715:2009, but can be modified for most forms of PPE:

- Identification of the hazard
- Reasons for respirators
- Respirator selection
- Use and proper fitting of respirators
- Wear time
- Limitations of respirators
- Maintenance and storage.

With the exception of disposable-filter respirators, the use of RPE requires a constant program of inspection, maintenance and repair. Maintenance includes washing, cleaning, disinfecting where necessary, inspection for wear, checking for leaks, replacement of worn components and replacement of filter components.

It is essential to have 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.

Where possible, each wearer should be provided with their own individual RPE.

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 the air quality.

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 airways disease.

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

4.4 Suppliers

Manufacturers, importing suppliers and other suppliers have specific duties in relation to hazardous substances used at workplaces.

A manufacturer or importing supplier must:

- determine whether the substance is hazardous
- prepare an MSDS
- review and revise the MSDS every five years
- label containers of the hazardous substance
- disclose a chemical name to a registered medical practitioner in certain circumstances.

Importers, manufacturers and suppliers of hazardous substances and dangerous goods are required to label those chemicals correctly, according to labelling guidelines.

Suppliers must not supply carcinogenic substances to anyone who does not hold a licence to use them.

Manufacturers, importing suppliers and suppliers of a hazardous substance for use at a workplace must ensure that a current MSDS for the substance is provided when a person:

- purchases the substance from the supplier for the first time
- purchases the substance from the supplier at a later time and requests an MSDS

or

- purchases the substance from a retailer who originally obtained it from the supplier and requests an MSDS.

The NSW Hazardous Materials (Hazmat) Register of Suppliers contains information about providers that offer resources, equipment, products and advice to minimise the environmental effects of hazardous materials incidents.²⁴

24 <http://www.environment.nsw.gov.au/hazmat/register.htm>

4.4.1 Transport codes

The *Australian Code for the Transport of Dangerous Goods by Road and Rail* (7th edition) provides procedures and protocols for the transport of dangerous goods. The code provides detailed technical specifications, requirements and recommendations, and includes rules and recommendations covering:

- the definition, classification, packaging, marking and labelling of substances and articles that meet the United Nations classification criteria for dangerous goods or are prescribed as dangerous goods by the competent authority
- the consigning of dangerous goods for transport, including loading, stowage, load detention and segregation
- the provision of transport documentation describing the dangerous goods being transported, and appropriate emergency information for those goods
- the unloading, receipt and transfer of dangerous goods
- the transport of dangerous goods, including the use of vehicles, containers and equipment, and the provision of safety equipment.

Part 3 of the code incorporates a comprehensive listing of dangerous goods of all classes.

The third edition of the Australian Explosives Transport Code²⁵ was prepared by the Australian Forum of Explosives Regulators and was endorsed by the Workplace Relations Ministerial Council in April 2009. This code is the primary reference for explosives and has been designed to complement and be consistent with the 7th edition of the Australian Code for the Transport of Dangerous Goods by Road and Rail.²⁶

The code adopts the classification, packaging and labelling system for explosives detailed in the United Nations' Recommendations on the Transport of Dangerous Goods—Model Regulations (16th revised edition)²⁷ and is designed to complement the International Maritime Dangerous Goods Code.

While the Transport of Dangerous Goods Code provides guidance in the transport of hazardous materials, some substances are singled out for further management controls. One example is ammonium nitrate, which is used in mining and related activities as an explosive component but is also widely used as a fertiliser. Security is the overriding consideration, to prevent access to this material by potential terrorists.

25 <http://www.safeworkaustralia.gov.au/swa/IndustryInformation/AFER/>

26 <http://www.ntc.gov.au/filemedia/Publications/ADG7Volume1Introduction.pdf>

27 http://www.unece.org/trans/publications/dg_recommend.html

CASE STUDY: Ammonium nitrate transport

The Council of Australian Governments (COAG) agreed in 2004 to a national licensing system for security-sensitive ammonium nitrate (SSAN), and legislation has been introduced in each state and territory to give effect to the system. Transport of SSAN must also meet the safety requirements of the Australian Dangerous Goods Code or jurisdictional occupational health and safety requirements. Additional requirements of the licensing system mean that transport of this hazardous substance within Australia is arguably world's best practice.

Included in the SSAN designation are ammonium nitrate, ammonium nitrate emulsions and mixtures containing greater than 45% ammonium nitrate, although there are certain exclusions (for example, Class 1 explosives and fertilisers such as calcium ammonium nitrate). Class 1 explosives are gunpowder and other explosives that have a mass explosion hazard (that is, if part of the load detonates, the entire load will explode). Class 1.1 and Class 1.2 include most of the common blasting explosives, such as packaged emulsions and water gels, detonating cords, boosters, detonators and certain types of Commonwealth munitions.

A transport licence is not required for less than 20 kilograms of SSAN and there are exemptions for up to 5 tonnes for agricultural use, but all others planning to move SSAN must submit a security plan as outlined in the transport guidance note accessible at the Australian National Security website.²⁸

The SSAN must be transported in a locked or sealed container or be under constant surveillance by an authorised person who has undergone police and PMV (politically motivated violence) checks and is identified by the 100-point identification system generally used by financial institutions.²⁹ The authorised person must be clearly identified in the security plan. Transport must be from one secure location to another, both of which must be identified in the security plan, and the SSAN must never be left unattended in an unsecured location. Strict record-keeping is required, both for inventory purposes (and any discrepancies reported to authorities) and to demonstrate that the SSAN has been obtained from an authorised person and supplied to an authorised person.

Diversion of hazardous substances to illicit uses that may pose dangers to employees or the public is a serious risk, and best practice is required if the risk is to be minimised or eliminated.

(continued)

28 <http://www.nationalsecurity.gov.au/agd/www.nationalsecurity.nsf/D2801B61EABE80A2CA256809001328BA/8FCA7A705B40263ACA25701B00155D7A>

29 http://www.aussiemigrant.com/your_finances/f.htm



Transporting hazardous substances



Source: CSBP Limited.

4.4.2 Handling and storage

The handling and storage of hazardous materials requires the same care as is taken for active involvement with those substances in the workplace, including training of personnel. Storage of high-risk hazardous materials, such as cyanide and explosives, needs to be organised so that access is only available to authorised staff, there is strict inventory control and there are regular inspections.

All mine sites should have their existing dangerous goods storage licensed and registered with the regulating authority.

When the states and territories introduced their dangerous goods regulations, the regulations were retrospective. Existing storage was approved where the licensee could demonstrate that the storage provided a level of safety equal to that required in the regulations. All new installations for licensable quantities of dangerous goods and significant alterations to existing facilities are required to comply fully with the regulations. An application for a licence to store dangerous goods must be received and approved before the construction of new facilities is permitted. Among the requirements for licensing of a bulk storage facility is documentation of tank approval. This is certification that the storage tank has been constructed to a suitable standard and is in good condition at the time of installation.

Spills and leaks may occur during storage and handling of hazardous materials and need to be dealt with safely and expeditiously. The following Australian Standards provide guidance in relation to spills management for dangerous goods and combustible liquids:

AS 1894-1997	The storage and handling of non-flammable cryogenic and refrigerated liquids
AS 1940-1993	Storage and handling of flammable and combustible liquids
AS 4326-1995	The storage and handling of oxidizing agents
AS 2507-1984	The storage and handling of pesticides
AS 3780-1994	The storage and handling of corrosive substances
AS 3833-1995	The storage and handling of mixed classes of dangerous goods in packages and intermediate containers
AS 3846-1998	The handling and transport of dangerous cargoes in port areas
AS 2243.10-1993	Safety in laboratories Part 10—storage of chemicals
AS 4681-2000	The storage and handling of Class 9 (Miscellaneous) Dangerous Goods Articles

More detail of the legislative requirements is in Section 2.1.2 of this handbook.

Storage of incompatible dangerous goods

This section is adapted from Queensland's Safe Storage and Handling of Dangerous Goods: Guidelines for Industry.³⁰

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 onsite
- recognise goods or other materials that are incompatible.

The compatibility and segregation tool developed by the Queensland Government can be used to determine whether each combination of dangerous goods and combustible liquids is likely to be compatible.³¹ The tool is only a guide and not meant to replace an MSDS or a risk assessment.

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

Factors to consider when determining incompatibility

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 spilt 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).

30 http://www.emergency.qld.gov.au/chem/publications/pdf/Guidelines_for_Industry_version1A_SW2Draft.pdf

31 <http://www.deir.qld.gov.au/workplace/subjects/hazardousmaterials/incompatible/isolation/index.htm>

4.4.3 Chemical supplier stewardship through the mine cycle

The supplier is part of the stewardship chain. All entities in that chain need to work together and be aware of constraints and opportunities at every stage. This is the preferred approach to stewardship as set out in the *Stewardship* handbook (DITR 2006): a shared approach that attempts to build engagement through the life cycle, with particular emphasis on cooperation and partnership. This approach is most evident in the supply and use of cyanide³² and ammonium nitrate, which are among the most hazardous materials used on mine sites, but elements of best practice involving suppliers may be found in connection with other materials as well.

4.5 Environment

There are times during mining when hazardous materials can affect the environment by becoming bioavailable to downstream ecosystems. The most common pathway is from mine wastes, ore stockpiles and mine operations into surface water or groundwater. Spills during the mineral processing circuit are another potential pathway, but are less common.

If hazardous materials used in the mining industry are mismanaged, they can poison humans, animals, plants and aquatic ecosystems, disrupt their reproductive processes or their habitat, or sometimes generate fires or explosions. They can cause considerable harm if allowed to leach into sensitive water resources. Many hazardous materials are highly mobile, do not degrade or are not attenuated in soils or waterbodies. Some are harmful at very low concentrations (in the parts per billion range). Once hazardous materials enter soil or water resources, they may go undetected for long periods, cause extended loss of values and be very costly to remedy.

The Western Australian Department of Water's *Toxic and hazardous substances—storage and use*³³ provides guidance on how impacts on the environment may stem from:

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

The impact on the environment from hazardous materials used and generated by mining is discussed in other handbooks in the leading practice series, including *Acid and metalliferous drainage*, *Cyanide management*, *Water management* and *Tailings management*.

32 International Cyanide Management Code, <http://www.cyanidecode.org>.

33 http://portal.water.wa.gov.au/portal/page/portal/WaterQuality/Publications/WaterQualityProtectionNotes/Content/WQPN_65.pdf





5.0 PERFORMANCE MANAGEMENT

Purpose

This section considers techniques, such as monitoring, reporting and auditing, that provide information about use of and exposure to hazardous materials.

Key messages

- Procedures for monitoring are based on identified hazards and take into account regulatory requirements.
 - Reporting against targets is important for demonstrating compliance.
 - Auditing by second or third parties can provide oversight of performance.
-

5.1 Health and environmental monitoring

Each site should have in place a monitoring program that is based on 'due diligence'. Due diligence is not 'taking general precautions', but a mindset concentrating on likely or potentially likely risks.

The risks from hazardous substances and dangerous goods must be incorporated into the site's specific monitoring program to ensure that potential exposure to the environment, workers on site and the community is minimised throughout the site's life cycle.

Procedures for risk assessment and management are described in the *Risk assessment and management* handbook (DRET 2008b). Section 3.2.1 of that handbook discusses workplace health and safety, noting that the consequences of an unsafe workplace are unacceptable to employees, their families, communities, government health authorities and mining companies. Best practice involves the application of robust standardised risk management processes to protect the health and safety of people. Similarly, hazardous materials released to the environment during mining operations can affect community health and damage ecosystems, both of which can be avoided by using best practice. The principles of best practice apply to the closure of mines, as well as to the period of active mining.

Hazardous substances and dangerous goods can only be monitored for any real or perceived effects if they have been identified, registered and thoroughly assessed according to their potential risk to the environment, as well as to the health of staff and people likely to come into contact with the substances.

Exposure standards and/or guidelines for many substances have been established in Australia or internationally. Based on those standards and guidelines, monitoring programs must be established to specifically address each identified high-risk or medium-risk substance. A program may involve one or all of electronic area or personnel monitoring, the taking of samples for assays, and observations by trained and accredited personnel, such as occupational hygienists and qualified environmental technologists.

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.

Independent auditors should review and validate the monitoring program, in addition to routine reviews by management-appointed personnel.

Site-specific plans must monitor the environment—that is, the potential exposure of humans, livestock, wildlife and other biota through the release of the identified hazardous substances and dangerous goods to the air (vapours), soil (spillages) and surface or groundwater.

The monitoring plan may include specific advice for various types of emission that may result from hazardous material, because the effects of substances can vary according to the receiving environment (air, water and biota). To assess the quantitative and qualitative effect, relevant standards, guidelines and procedures need to be consulted, such as:

- *Australian drinking water guidelines* (NHMRC 2004)
- *Guidelines for assessing human health risks from environmental hazards* (en-Health 2004)³⁴
- the National Pollutant Inventory's emission estimation technique manuals (NPI 1999)
- Safe Work Australia national exposure standards.

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

All electronic monitors must be regularly calibrated as directed by the manufacturer and against certified standards.

5.1.1 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. The results from air sampling can be compared against exposure standards and can be 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 limits' (OELs) or '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 with better datasets. For many chemicals, there seems to be a 'threshold dose' below which no significant adverse effect will occur in most people. Epidemiological and toxicological studies, coupled with occupational hygiene measurements, help to identify that threshold.

34 <http://enhealth.nphp.gov.au/council/pubs/pdf/envhazards.pdf>

Occupational exposure standards are developed by Safe Work Australia and regulated through state legislation. 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.

National Exposure Standards have been established for chemicals and hazardous materials that are known to cause long-term health effects (such as cancer, or respiratory diseases such as silicosis, pneumoconiosis and asbestosis).

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 undue discomfort. The exposure standard can be in one of three forms:

- **time-weighted average (TWA)** is an 8-hour time-weighted average work day and a 40-hour work week
- **short-term exposure limit (STEL)** is a 15-minute TWA exposure that should not be exceeded at any time during the work day, 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 (biologic action) and unbearable odours. Examples of such factors include:

- **Irritants** (for example, hydrochloric acid fumes, ammonia)—ability to cause inflammation of mucous membranes that they come into contact with
- **Asphyxiants** (for example, simple asphyxiants such as nitrogen, carbon dioxide and helium; and chemical asphyxiants such as carbon monoxide and cyanides)—ability to deprive the tissue of oxygen
- **Anaesthetics** (for example, ether and chloroform)—depressant action on the central nervous system, particularly the brain
- **Carcinogens** (for example, asbestos, crystalline silica)—cause cancers
- **Unbearable odour** (for example, mercaptans)
- **Toxic effect** (for example, lead).

Where such exposure standards exist, it is best practice and in many cases a statutory requirement to maintain workplace exposures below those 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.

The national exposure standards are based on 8-hour shifts, and must be adjusted when workers are working 12-hour shifts. Some mining authorities have special formulas that take into account 12-hour shifts as well as the mining roster, particularly for fly-in, fly-out ('FIFO') operations.

5.1.2 Health surveillance

Recognition of health hazards in the workplace is fundamental to their proper control. Occupational disease still occurs because employers and their workers are often unaware of the hazardous nature of materials or processes in particular workplaces. Health hazards often arise from unexpected sources, as well as from well-documented sources.

Understanding the particular industrial process and the sources of exposure is the key to providing a healthy workplace. Determining the health risk requires knowledge of the work practices, the chemicals or materials, and the potential routes of exposure (inhalation, skin absorption, skin contamination, poor personal hygiene, smoking).

Because the long latency period of many diseases makes direct health indicators less useful, it is obviously not a good strategy to wait until workers become ill. It is best to manage the potential risks to workers through a well-designed surveillance strategy.

Some hazards can be seen, most cannot, but all need evaluating. It may be difficult to recognise some operations as dangerous to health if few workers complain of ill health and most are prepared to tolerate the dust, fumes and noise.

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 special controls for this hazard?
- How much control is needed?
- What is the most effective control mechanism for this process?

In many situations, evaluation of the risks will 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 occupational hygienist a decade or so of experience to be able to make such judgments, using instrumental verification as back-up. The eye cannot judge a concentration of 0.1 mg/m³ of quartz dust particles it cannot see; the nose cannot judge 0.02 mg/m³ of isocyanates vapour it cannot smell, or the concentrations of various organic vapours in a mixture; the ear cannot judge the integrated noise dose of intermittent or impulse sounds. There is often no substitute for proper instrumental evaluation, which should be performed only by someone with the appropriate skills.

In some situations, usually defined by statutory authorities, medical surveillance will be required. Medical surveillance should be conducted under the guidance of an occupational physician.

It is recommended that miners and contractors 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 a mine site. Mine owners' and mining industries' current practice for regular medical examinations is variable. The most well-established system is that in NSW for coal miners, who have a five-yearly full medical examination.

Monitoring of occupational exposures to respirable dust, respirable silica or particular hazardous substances 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.

Health surveillance can be extended to include other high-risk hazardous substances where the potential for sources of exposure other than airborne dusts is important. Blood lead monitoring of workers in smelters and certain mining activities (including maintenance workers) highlights the importance of personal hygiene habits in preventing exposures and damage to workers' health. In some lead mine sites, workers are not allowed to smoke on site, as skin contamination is an important source of exposure.

Biological monitoring can be considered for workers, particularly those involved in smelting, to reassure them that they have not been exposed to levels of heavy metals that might cause adverse health effects.

Summaries of biological monitoring and health surveillance techniques can be found in:

- *Health surveillance and biological monitoring* on the Western Australian Department of Mines and Petroleum website³⁵
- *Guidelines for health surveillance* on the Safe Work Australia website.³⁶

5.1.3 Monitoring procedures

Operations must develop site-specific monitoring procedures that include separate, specific procedures for each of identified substance. The procedures should cover all operations on the site in which identified materials are handled, received, used or produced as product, by-product or waste, and all storage areas.

Occupational hygiene monitoring and assessment of worker exposure can be complex because of the variability of workers' activities during a shift. A useful reference source is *Simplified monitoring strategies*, published by the Australian Institute of Occupational Hygienists (AIOH 2001).

35 <http://www.dmp.wa.gov.au/6747.aspx>

36 <http://www.safeworkaustralia.gov.au/NR/rdonlyres/481CF3F5-8C4B-4BCC-AF65-3FDBA031D43B/0/HealthSurveillance.pdf>

Health, safety and environmental components are intrinsic to monitoring procedures and need to be addressed individually.

5.2 Auditing

An audit is a systematic investigation or appraisal of documented procedures, systems or operations to determine whether they conform to prescribed procedures, guidelines, standards or regulations. The audit is based on verifiable information, records or statements of fact.

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, which should 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 major customer, usually at no cost to the auditee. 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 specific customer's work. Second-party audits should be objective but may be distorted by the customer-supplier relationship.
- A **third-party audit** is an external audit carried out by an independent organisation, usually a certification body. All fees and costs are paid by the auditee. The audit may be a full, partial, phased, follow-up or surveillance audit and should examine the whole of the system covered by the certification. The use of skilled and independent auditors should ensure objectivity.

5.2.1 Environmental

An environmental audit will investigate the impact of the 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* handbook (DRET 2009) covers in detail the reasons for environmental auditing and the methodology.

There are several types of environmental auditing:

- An **environmental performance audit** is directed at verifying a mine's environmental status against specific, predetermined audit criteria. The audit program objectives should articulate senior management's and/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 a mining 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 mine or that part of it selected for the EMS audit. An EMS audit may assess conformance with a standard, such as ISO 14001 or a mining company's specific EMS criteria (which might or might not be based on ISO 14001).

Other types of audit, possibly mandatory under prevailing legislation, share many of the features of these two types.

5.2.2 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 the EMS, or whether a specific licence is in accordance with the relevant legislation or code. It will also include observed performance according to the documented management system. The audit report will state whether the operation is fully compliant with the relevant legislation or codes, is compliant subject to the rectification of listed non-conformances, or is not compliant.

Where non-conformances relate to compliance with licence conditions, the operation may have a specified time in which to rectify them. Failure to do so may result in prosecution and potential closure of the operation by the relevant regulator.

5.2.3 Performance

Under the company's management plan, it is obliged to carry out regular assessments of key areas of the operation. The assessment determines whether each operation complies with performance requirements for output and obligations under safety and environmental guidelines and regulations. Assessment is usually through first-party or second-party audits. Underperformance or non-performance will activate a corrective action request to the personnel in charge of the section found lacking.

Hazardous materials performance monitoring can also be included through key performance indicators established in the management business plan for close-out of audit findings, especially where legislative limits are exceeded.





GLOSSARY AND ABBREVIATIONS LIST

Acid	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.
Acute exposure	Short-term exposure, usually occurring at high concentration.
Acute health effect	An effect that develops either immediately or a short time after exposure.
ADG7	Australian Dangerous Goods Code
Alkali	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.
AMD	acid and metalliferous drainage
Analysis	A process used to identify the kinds or quantities of ingredients in a substance.
ANFO	ammonium nitrate - fuel oil
Asbestosis	A chronic lung disease caused by inhaling asbestos fibres.
Asphyxiant	A vapour or gas that can cause unconsciousness or death by suffocation (lack of oxygen).
Asthma	A disease caused by spasmodic contraction of the bronchioles in the lungs.
Biological monitoring	The measurement and evaluation of hazardous substances or their metabolites in the body tissues, fluids or exhaled air of a person.
Boiling point	The temperature at which a liquid changes from a liquid to a gas at normal atmospheric pressure.
Carcinogens	Agents/compounds that can induce cancer in humans.
CAS Registry Number	A number assigned to a chemical substance by the Chemical Abstracts Service (CAS) of the American Chemical Society as a unique identifier.
Chemical formula	A formula that indicates the elements that make up a compound; sometimes called the molecular formula.
Chemical name	The proper scientific name of the active ingredient in a product.
Combustible liquid	A liquid that has a flash point above 37.8°C.

Compressed gas	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.
Condensation	The process of reducing a substance from one form to another, denser form, such as steam to water.
Container	Anything in or by which substances are or have been wholly or partly encased, covered, enclosed, contained or packed (whether empty, partially full or completely full), but not including a bulk container: <ul style="list-style-type: none"> ▪ in the case of a container designed to hold gas—a container that has a capacity of more than 500 litres ▪ in the case of a container designed to hold either solids or liquids—a container that has either a net mass of more than 400 kilograms or a capacity of more than 450 litres.
Density	The weight of a material in a given volume, usually given in grams per millilitre (g/mL).
Dermal	Used on or applied to the skin.
Dermatitis	Inflammation of the skin.
Dose	The amount of an agent that has entered the body through the various routes of entry.
Dust	Solid particles formed by mechanical action and suspended in air.
Emphysema	An irreversible lung disease resulting in an excessive loss of lung capacity.
Exposure	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 substances by ingestion, inhalation or through the skin (dermal absorption) or mucous membrane.

Exposure limits	<p>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:</p> <ul style="list-style-type: none"> ■ TWAEV: time-weighted average exposure value. The average airborne concentration of a biological or chemical agent to which a worker may be exposed in a work day or a work week ■ STEV: short-term exposure value. The maximum airborne concentration of a chemical or biological agent to which a worker may be exposed in any 15-minute period, provided that the TWAEV is not exceeded ■ CEV: ceiling exposure value. The maximum airborne concentration of a biological or chemical agent to which a worker may be exposed 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, 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. <p>Other exposure limits include permissible exposure limits (PELs), which are legal exposure limits in the United States.</p>
Flash point	<p>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.</p>
Fume	<p>An airborne dispersion consisting of minute solid particles arising from the heating of a solid.</p>

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.
Health surveillance	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.
Ignition temperature	The lowest temperature at which a combustible material will catch on fire in air and continue to burn independently of the source of heat.
Ingestion	Taking a material into the body by eating it.
Inhalation	Taking a material into the body by breathing it in.
International Council on Mining and Metals (ICMM)	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.
Irritant	A material that irritates whatever tissue it comes into contact with.
Key performance indicators (KPIs)	Predetermined targets that help an organisation define and measure progress towards organisational goals.
Leading Practice Sustainable Development Program for the Mining Industry	A program that integrates the environmental, social and economic aspects of 14 key themes across all phases of the mining industry, from exploration, construction and operation, through to mine closure and rehabilitation.
Mist	Suspended liquid droplets in air caused by condensation or spraying.
MSDS	Material Safety Data Sheet
Mutagen	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.
Neutralise	To return pH to the neutral level of 7 by adding an acid to a base or a base to an acid.
NIOSH	National Institute of Occupational Health and Safety
NOHSC	National Occupational Health and Safety Commission
Odour threshold	The airborne concentration, usually in parts per million, at which an odour becomes noticeable.
Parts per million (ppm)	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.

pH	A measure of the acidity or basicity (alkalinity) of a material when dissolved in water.
Pneumoconiosis	A respiratory tract and lung condition caused by the inhalation of mineral or metallic particles.
Polymer	A natural or human-made material formed by combining units, called monomers, into long chains.
PPE	Personal protective equipment (devices or clothing worn to help isolate a worker from direct exposure to hazardous substances)
Research	Systematic investigative or experimental activities that are carried out for the purpose of: <ul style="list-style-type: none"> ▪ acquiring new knowledge (whether or not that knowledge will have a specific practical application) ▪ creating new or improved materials, products, devices, processes or services ▪ improving systems.
Risk to health	In relation to a substance, the likelihood that the substance will cause harm to health in the circumstances of its use.
RPE	respiratory protective equipment
Silicosis	A condition characterised by shortness of breath, caused by exposure to silica dusts.
Solubility	The ability of a material to dissolve in water or another liquid.
Solvent	A material that is capable of dissolving another chemical.
SSAN	security sensitive ammonium nitrate
Stability	The ability of a material to remain unchanged in the presence of heat, moisture or air.
Substance	A natural or artificial entity, composite material, mixture or formulation, other than an article.
Supplier	An importer, manufacturer, wholesaler or distributor of workplace substances, but not a retailer.
Teratogens	Agents or compounds that a pregnant woman takes into her body and that generate defects in the foetus.
TLV	see Exposure limits.
Toxicity	The ability of a substance to cause harmful effects.

Type I ingredient	<p>An ingredient present in a particular hazardous substance in a quantity that exceeds the lowest relevant concentration cut-off level specified for the hazard classification of the substance in <i>Approved criteria for classifying hazardous substances</i> [NOHSC: 1008 (1999)], published by the NOHS Commission, being an ingredient that:</p> <ul style="list-style-type: none"> ■ is a substance that is, according to that document, carcinogenic, mutagenic or teratogenic; a skin or respiratory sensitiser; corrosive, toxic or very toxic; a harmful substance that can cause irreversible effects after acute exposure; a harmful substance that can cause serious damage to health after repeated or prolonged exposure; toxic to reproduction, or ■ is a substance for which an exposure standard is listed in Adopted National Exposure Standards for atmospheric contaminants in occupational environments [NOHSC: 1003], published by the NOHS Commission, as in force from time to time.
Type II ingredient	<p>An ingredient present in a particular hazardous substance in a quantity that exceeds the lowest relevant concentration cut-off level specified for the hazard classification of the substance in <i>Approved criteria for classifying hazardous substances</i> [NOHSC: 1008 (1999)], published by the NOHS Commission, being an ingredient that:</p> <ul style="list-style-type: none"> ■ is a harmful substance according to that document, and ■ is not a Type I ingredient.
Type III ingredient	An ingredient present in a particular hazardous substance that is not a Type I ingredient or a Type II ingredient.
UN (United Nations) Number	A four-digit number assigned to a potentially hazardous material or class of materials. UN numbers are internationally recognised and are used by fire fighters and other emergency response personnel to identify materials during transportation emergencies.
Use of a substance	The use, production, handling, storage, transport or disposal of the substance.
Vapour	A gaseous form of a material that is normally solid or liquid at room temperature and pressure.
Vapour pressure	The pressure of a vapour in equilibrium with its liquid or solid form.
Ventilation	The provision of fresh air to provide a safe work environment.



REFERENCES AND FURTHER READING

The human health risks posed by hazardous materials have long been recognised. As a result, there is a large body of legislation covering the production (deliberate or inadvertent), handling, storage, use and disposal of hazardous materials. The literature on hazardous materials is also extensive, and a number of professional associations have published useful guidelines and templates.

Changes in mining, in the types of minerals encountered and in mineral processing technology mean that companies need to remain vigilant. Known hazards that have not previously been encountered at a particular mine may pose new risks, while advances in health science will from time to time lead to reassessments of risks. The coverage in this handbook will equip mine operators to understand the materials they work with and encounter today and provide a basis for responding to new risks.

There is less legislation and fewer ancillary publications on the impact of hazardous materials on the environment than in the human health field, but environmental documents require serious attention from mine operators.

Readers and users of this handbook are encouraged to explore the literature listed below. Like the handbook, the list is not exhaustive, but it includes resource documents used to compile the handbook.

AIOH—see Australian Institute of Occupational Hygienists.

Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand 2000, *Australian and New Zealand guidelines for fresh and marine water quality*, ARMCANZ, Canberra.

Australian Institute of Occupational Hygienists 2001, *Simplified monitoring strategies*, 1st edn, ed. D Grantham, AIOH.

—2007, *Principles of occupational health and hygiene: an introduction*, ed. C Tillman, AIOH.

Australian Dangerous Goods Code, 7th edn.

Brown, DJA & Sadler, K 1989, 'Fish survival in acid waters', In: *Acid toxicity and aquatic animals*, eds. R Morris et al, Society for Experimental Biology Seminar Series: 34, Cambridge University Press, pp. 31–44.

Department of Environment 1997, *Acid mine drainage in Australia*, Supervising Scientist Report 125.

—2006, *Community engagement and development*, Leading Practice Sustainable Development Program for the Mining Industry, Department of Industry, Tourism and Resources.

—2007, *Managing acid and metalliferous drainage*, Leading Practice Sustainable Development Program for the Mining Industry, Department of Industry, Tourism and Resources.

–2006, *Stewardship*, Leading Practice Sustainable Development Program for the Mining Industry, Department of Industry, Tourism and Resources.

–2007, *Tailings management*, Leading Practice Sustainable Development Program for the Mining Industry, Department of Industry, Tourism and Resources.

–2008a, *Cyanide management*, Leading Practice Sustainable Development Program for the Mining Industry, Department of Resources, Energy and Tourism.

–2008b, *Risk assessment and management*, Leading Practice Sustainable Development Program for the Mining Industry, Department of Resources, Energy and Tourism.

DITR—see Department of Industry, Tourism and Resources.

DRET—see Department of Resources, Energy and Tourism.

Earle, J & Callaghan, T 1998, 'Effects of mine drainage on aquatic life, water uses, and man-made structures', In: *Coal mine drainage prediction and pollution prevention Pennsylvania*, eds. KBC Brady, MW Smith & J Schueck, Pennsylvania Department of Environmental Protection.

en-Health (Department of Health and Aged Care) 2004, *Guidelines for assessing human health risks from environmental hazards*.

Environment Australia 1997, *Best practice environmental management in mining—hazardous materials management, storage and disposal*.

Hedges, K & Djukic, F 2008, 'Managing silica dust', Safety and Health Seminar presentation, Department of Mines and Energy Safety and Health, Bardon, Queensland.

Hedges, K, Reed, SG & Djukic, F 2007, 'Airborne crystalline silica (RCS) in Queensland quarrying processes, particle size and potency', 25th Annual Conference Proceedings, Australian Institute of Occupational Hygienists, Melbourne.

–2008a, 'Occupational exposure to respirable crystalline silica in Queensland quarries, exploration sites and small mines', Queensland Mining Industry Safety and Health Conference, Townsville.

–2008b, 'Airborne crystalline silica (RCS) in Queensland quarries, small mines and exploration sites', 26th Annual Conference Proceedings, Australian Institute of Occupational Hygienists, Perth.

Hem, JD 1970, *Study and interpretation of the chemical characteristics of natural waters*, 2nd edn, United States Geological Survey Water Supply Paper No. 2254.

Hoehn, RC & Sizemore, DR 1977, 'Acid mine drainage (AMD) and its impact on a small Virginia stream', *Water Resources Bulletin*, vol. 13, pp. 153–160.

Hustrulid, WA 1982, *Underground mining methods handbook*, American Institute of Mining and Metallurgy and Petroleum Engineers, New York.

ICMM—see International Council on Mining and Metals.

International Council on Mining and Metals 2009, *Good practice guidance on occupational health risk assessment*, ICMM, London.

International Cyanide Management Code for the Gold Mining Industry, International Cyanide Management Institute, August 2008, <http://www.cyanidecode.org>.

Jennings, SR, Neuman, DR & Blicher, PS 2008, *Acid mine drainage and effects on fish health and ecology: a review*, Reclamation Research Group, Bozeman, Montana.

Karmis, M 2001, *Mine health and safety management*, SME.

National Health and Medical Research Council 2004, *National Water Quality Management Strategy: Australian drinking water guidelines*, NHMRC, Canberra, www.nhmrc.gov.au/publications/synopses/eh19syn.htm.

National Pollutant Inventory 1999, Emission estimation technique manuals, http://www.npi.gov.au/handbooks/approved_handbooks/eetmanuals.html.

NHMRC—see National Health and Medical Research Council.

Nordstrom, DK & Southam, G 1997, 'Geomicrobiology—interactions between microbes and minerals', *Mineralogical Society of America*, vol. 35, pp. 261–390.

NPI—see National Pollutant Inventory.

Office of the Queensland Parliamentary Counsel 2001, *Dangerous Goods Safety Management Act 2001: Dangerous Goods Safety Management Regulation 2001*, Reprinted 1 September 2008; Reprint No. 1B.

Smith, K 2007, 'Strategies to predict metal mobility in surficial mining environments', In: *Understanding and responding to hazardous substances at mine sites in the western United States*, ed. JV DeGraff, The Geological Society of America, Reviews in Engineering Geology, vol. XVII.

Standards Australia 2004, AS/NZS 4360:2004 *Risk management*, Standards Australia.

Western Australian Department of Consumer and Employment Protection 2008a, *Safe storage of solid ammonium nitrate: code of practice*.

—2008b, *Storage and handling of dangerous goods: code of practice*.

Western Australian Department of Mines and Petroleum 2009a, *Dangerous goods safety information sheet: overview of SRS regulations*.

—2009b, *Dangerous goods safety information sheet: overview of transport regulations*.

Western Australian Department of Water 2006, *Toxic and hazardous substances—storage and use*, Water Quality Protection Note no. 65.

