QGN 21
Guidance note for management of diesel engine exhaust in metalliferous mines

Mining and Quarrying Safety and Health Act 1999

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Guidance note – QGN 21

Management of diesel engine exhaust in metalliferous mines

This guidance note has been issued by the Mines Inspectorate of the Department of Natural Resources and Mines (DNRM). It is not a Guideline as defined in the *Mining and Quarrying Safety and Health Act 1999* (MQSHA). In some circumstances, compliance with this guidance note may not be sufficient to ensure compliance with the requirements in the legislation. Guidance notes may be updated from time to time. To ensure you have the latest version, check the DNRM website: http://mines.industry.qld.gov.au/safety-and-health/guidance-notes.htm or contact your local Inspector of Mines.

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Glossary

DEEP	Diesel Emission Evaluation Project
DNRM	Department of Natural Resources and Mines
EPA	Environmental Protection Agency
IARC	International Agency for Research on Cancer
MQSHA	Mining and Quarrying Safety and Health Act 1999
MQSHR	Mining and Quarrying Safety and Health Regulation 2001
NIOSH	National Institute of Occupational Safety and Health
NOHSC	National Occupational Health and Safety Commission
OEM	Original Equipment Manufacturer
PPE	Personal Protective Equipment
RPE	Respiratory Protective Equipment
SEG	Similar Exposure Group
SIMTARS	Safety in Mines Testing and Research Station
SSE	Site Senior Executive
STEL	Short Term Exposure Limit
TWA	Time Weighted Average

Units of measure

nm	nanometre
µm	micrometre
mg/m^3	milligrams per cubic metre of air
$m^3/s/kW$	cubic metres of air per second per kilowatt of engine power
ppm	parts per million

Preface

Obligations under Queensland legislative and regulatory requirements

Relevant laws require risk to be eliminated or controlled to an acceptable level.

Obligations exist under the *Mining and Quarrying Safety and Health Act 1999* (MQSHA) to protect the safety and health of persons at mines; and to ensure that the risk of injury or illness to any person resulting from operations is at an acceptable level.

For a risk to a person to be at an acceptable level, operations at a mine must be carried out so that the level of risk from the operation is not only within acceptable limits but also as low as reasonably achievable.

The obligations and legislation provided in this guidance note are not exhaustive, and all obligation holders need to refer to the MQSHA and the Mining and Quarrying Safety and Health Regulation 2001 for the most recent and relevant legislation. This legislation can be found at: http://www.legislation.qld.gov.au/Acts_SLs/Acts_SL.htm

1 Introduction

1.1 Background

The diesel engine was invented over 120 years ago and both ‘on’ and ‘off-road’ diesel engines are now commonly used in mining.

Rudolf Diesel invented the compression-ignition engine in 1893 and since then diesel engines have proliferated in all modes of transport and internal combustion engine applications. Diesel engines are generally more efficient, offer more power, have a longer service life; and due to engine design and the properties of diesel fuel are generally safer to operate than petrol engines. Both ‘on-road’, ‘off-road’ and stationary diesel engines are extensively used in various metalliferous mining applications.

Health concerns about exposure to diesel engine exhaust were first raised in the 1950s.

Questions about the health effects of diesel engine exhaust were first identified by researchers doing animal cancer research in the mid-1950s and then again in the 1970s and 1980s (Davies 2004). Similarly, health studies on workers found possible links between exposure to diesel engine exhaust and lung cancer from the mid-1950s onwards (Davies 2004). In 1988, the International Agency for Research on Cancer (IARC) reviewed the animal research and long-term worker health studies and concluded that diesel engine exhaust was ‘probably carcinogenic to humans’ (IARC1998).

In 2012, IARC found long-term exposure to diesel engine exhaust can cause lung cancer and probably bladder cancer in humans.

In June 2012, an IARC expert panel conducted another assessment of the research that had occurred since1988. Three American cohort health studies were reviewed: Non-metal miners, railway workers and truck drivers in the road transport industry. All three studies found evidence that the number of lung cancers reported increased as the cumulative and average exposure to diesel engine exhaust increased. Other epidemiological studies from America, Canada and Europe supported the same positive exposure-response relationship (IARC 2012a).

Based on this additional information, the IARC revised its classification of diesel engine exhaust. IARC found ‘sufficient evidence’ to conclude that diesel engine exhaust ‘is carcinogenic to humans’ (IARC 2012b).

More research is needed to determine if diesel engine technology and cleaner fuel is improving worker and community health.

It is important to note that in the same 20 year period since IARC initially classified diesel exhaust as probably carcinogenic to humans, diesel engine emission reduction technologies and stricter fuel specifications have been gradually phased in to address both environmental and community health concerns in various countries like Australia, America, Canada and the European Union (IARC 2012a). IARC stated that further research is needed to understand if these changes will yield any health benefits to workers and the wider community (IARC 2012a).

1.2 Purpose of this document

The purpose of this guidance note is to provide information on how to manage risks associated with diesel engine

The purpose of this guidance note is to provide information to metalliferous mining operations on how to systematically manage diesel engine exhaust risks so that obligation holders comply with the legislative framework. It sets out a risk management approach and the minimum requirements for a diesel engine exhaust management plan for inclusion in the overall safety and health management system for a mine.

exhaust in metalliferous mines.

This document is not prescriptive, which means individual operators and sites can develop a risk management plan that is specific to their needs. However, all plans should as a minimum consider and address where appropriate each of the main areas identified in this document.

2 Risk management

2.1 Introduction

Risk management is a continuous four step process: 1) Identify the hazard; 2) analyse and evaluate the risk; 3) identify and implement controls; and 4) monitor the effectiveness of the controls and improve them as necessary.

The mine's risk management practices and procedures should firstly include establishing the risk management context (Standards Australia 2009a). The risk management context includes considering internal and external factors that influence the scope, objectives and key performance indicators for the risk management process (Standards Australia 2009a). Factors that could influence the risk context include:

- workers exposure data
- changes to plant, processes or substances at the mine
- changes to legislation
- new knowledge about hazards or controls.

The legislated risk management process consists of:

1. hazard identification
2. risk analysis
3. risk reduction
4. risk monitoring.

Further guidance about setting the risk management context and the risk management process is provided in *AS/NZS ISO 31000: 2009 Risk management – Principles and guidelines*.

The risk management process must be based on the best available information when assessing the level of risk.

Risk management is based on information which can come from a variety of sources. These sources include:

- the experience of workers and supervisors
- industry historical data
- academic research
- the judgement of experts
- other data, including worker exposure monitoring and health surveillance data.

To be effective the risk management process must be based on the best available information. The limitations of the data and information being relied on must be understood when assessing the level of risk (Standards Australia 2009a).

Workers should be consulted during the risk management process.

Workers need to be made aware of the physical, chemical, biological and psychological hazards at a mine. This includes having an understanding of the hazard and any risk controls relevant to their work and also being able to recognise substandard conditions or practices that can lead to accidents, injuries or illness (Standards Australia 2001).

Workers should be consulted during the risk management process or when changes in internal or external factors occur that alter the risk management context at a mine (Standards Australia 2009a).

2.2 Approach for assessing and managing occupational exposures

The risk management process may require specific risk assessment methods to be used when managing occupational exposures such as dust, chemicals, noise, heat etc.

Assessing and managing risk associated with occupational exposures can be complex. The risk management process may require the use of specific risk assessment techniques (Standards Australia 2009a).

For example, assessing risk from occupational exposures could include measuring workers exposure by sampling the work environment (e.g. collecting personal dust or noise exposure levels) or through worker health surveillance screening (e.g. blood lead levels or hearing tests).

The approach to assessing risk must be established by an appropriately qualified person, such as an occupational hygienist or an appropriately experienced medical practitioner.

The approach outlined in Figure 1 shows the relationship between each of the legislated risk management processes and some of the technical and administrative activities that may be undertaken to achieve an effective outcome.

Further guidance about how to assess and manage occupational exposures is provided in the following references.

- *Simplified occupational hygiene risk management strategies*: *A guidebook for use in the Australian work environment, on how to meet Australian Safety and Compensation Council's requirements for employers to identify, assess and control risks arising from workplace exposures (Firth I, van Zanten D, & Tiernan G, 2006).*
- *A strategy for assessing and managing occupational exposures (Ignacio J, & Bullock W, 2006).*

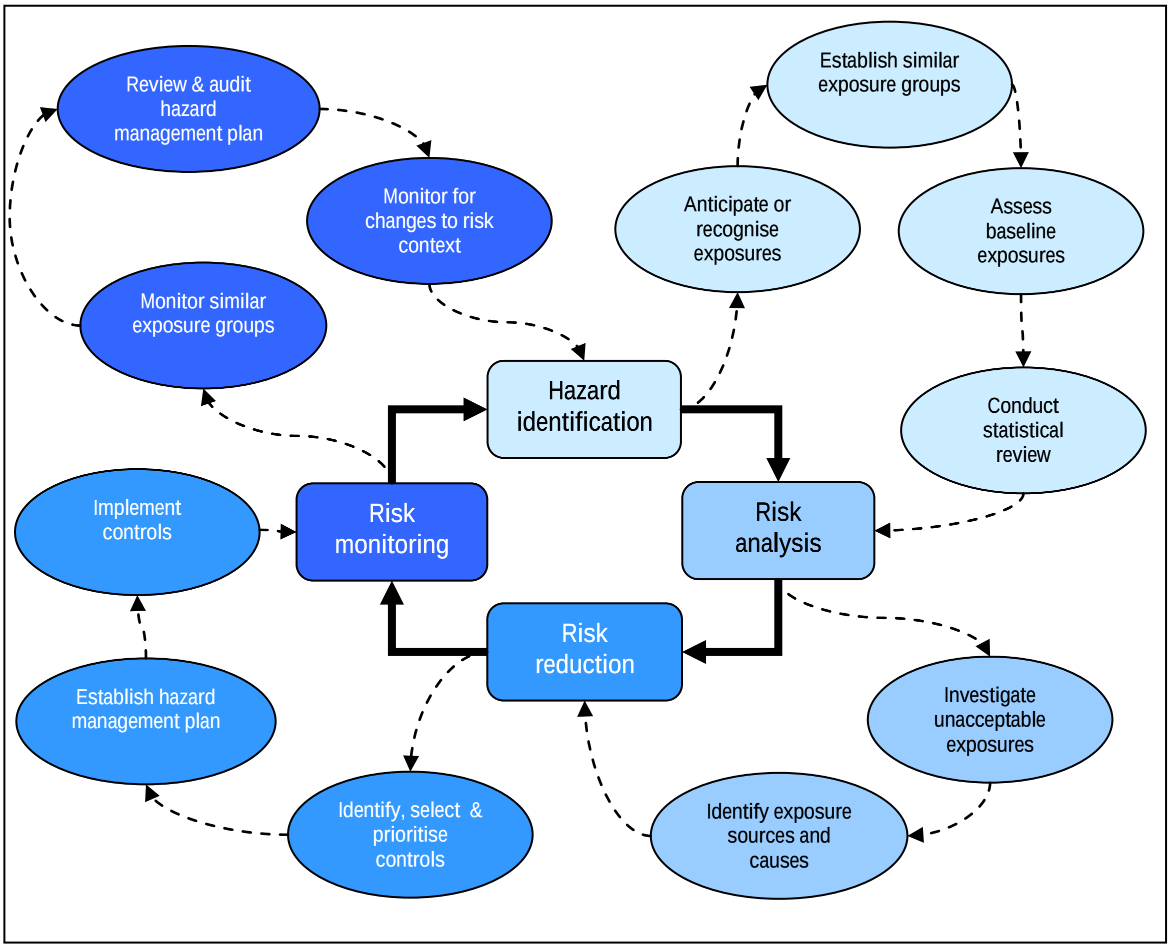

Figure 1 - Approach to assessing and managing occupational exposures. (Grantham 2001; Standards Australia 2001; Ignacio & Bullock 2006)

2.3 Hazard identification

Hazard identification is the process of anticipating or recognising plant, equipment, substances, processes, working arrangements or other environmental factors at a mine that could result in an accident, injury or illness.

Hazard identification is the process of anticipating and recognising: plant, equipment, substances, processes, working arrangements or other environmental factors at a mine that could result in an accident, injury or illness (Standards Australia 2009a).

The operator must ensure hazard identification is done during the mine's planning and design phases. This is the ideal time for a hazard such as diesel engine exhaust to be anticipated as there is an opportunity for the operator to reduce risk to an acceptable level through the early application of the hierarchy of controls to:

- the mine plan, processing, and infrastructure design, including mine ventilation
- the procurement and selection of diesel powered plant and substances
- working arrangements such as shift and roster design;
- other environmental factors such as prevailing weather conditions and proximity to local communities.

Hazard anticipation by the operator is also particularly important in circumstances where it is planned to extend the mine's life beyond original plans and designs.

The Site Senior Executive (SSE) must ensure hazard identification is done at the start of operations, throughout the mine's lifecycle and when changes occur that can affect the level of risk at the mine.

Persons with an obligation under the Act to manage risk at a mine must also identify hazards in the person's own work and activities at the mine.

To assist with the assessment of occupational exposures, workers with similar exposures can be grouped together for the purpose of statistical analysis. Establishing a similar exposure group (SEG) can be used to reduce the number of samples and therefore the resources required to assess the risk of exposure, particularly for large work groups. The number of samples required for each SEG should be determined by an appropriately qualified person. When a baseline assessment of a SEG is completed it can be statistically analysed and the average exposure of the group compared with an exposure limit to determine if risk is at an acceptable level.

Further guidance about how to identify hazards associated with occupational exposures, establishing SEGs and statistical considerations is provided in the following references.

- *Simplified occupational hygiene risk management strategies*: *A guidebook for use in the Australian work environment, on how to meet Australian Safety and Compensation Council's requirements for employers to identify, assess and control risks arising from workplace exposures (Firth I, van Zanten D, & Tiernan G, 2006).*
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2.3.1 Diesel engine exhaust is an inhalation hazard

Diesel engine exhaust is a toxic mix of gases, soot and ash that can build up in an underground mine's atmosphere or other enclosed spaces and be inhaled by workers.

Toxicologically, diesel engine exhaust is a complex mixture of gases and particles that forms when diesel fuel and air ignites under high pressure and temperature in the combustion chamber of a diesel engine.

The gas fraction of the diesel engine exhaust consists of air and pollutant gases (Davies 2011). Air (i.e. nitrogen, oxygen, argon, carbon dioxide and water vapour) makes up approximately 99 per cent of the mixture, with the one percent being the pollutant gases from the combustion reaction (i.e. carbon monoxide, nitrogen dioxide, nitric oxide, and sulphur dioxide) (Davies 2011).

The particle fraction of the exhaust consists of very small, sub-micron particles (i.e. 15 – 30 nm) that clump together to form chains of particles which are less than 1 µm in size (Davies 2011). The 'nanoparticles' are so small that they act more like a gas than a typical solid dust particle and can remain airborne for long periods before gravitational settling occurs (Bugarski et al 2011). The particles are the by-products from the combustion of fuel and lubricants; and also from the wear of engine parts (Bugarski et al 2011). The particles that are formed in the exhaust are a complex mixture of chemical compounds such as elemental carbon (soot), organic carbon compounds, sulphates and trace levels of metallic compounds (ash) (Bugarski et al 2011).

The physical properties of diesel engine exhaust mean that it can accumulate in an underground mine's atmosphere or other enclosed spaces such as surface maintenance workshops where there is an insufficient rate or quality of ventilating air.

Exposure to the pollutant gases in diesel exhaust can cause sleepiness, breathing difficulty and asphyxiation; irritation and chronic disease of the lungs and heart may also occur.

Exposure at concentrations exceeding the exposure limits of pollutant gases such as carbon monoxide, carbon dioxide and nitric oxide can cause narcosis and breathing difficulties. Exposure to these gases at very high concentrations can cause simple asphyxiation (displacement of breathable air) or a more complex form of asphyxiation where the pollutant gas, after entering into the blood stream, impairs the oxygen carrying capacity of the red blood cells.

Exposures exceeding the exposure limit for nitrogen dioxide and sulphur dioxide can cause acute irritation of the nose, throat and lungs.

Long-term exposure exceeding the exposure limits to nitrogen dioxide can result in heart and chronic lung disease.

Exposure to the particulates in diesel exhaust can cause irritation to the eyes, nose, throat and lungs; heart disease, chronic lung disease and lung cancer may also occur with long-term exposure to diesel particulates.

Exposure to the particulates in diesel exhaust can cause irritation to the eyes and lungs (Australian Institute of Occupational Hygienists 2013). The main cause of irritation is contact of the very small diesel particles with mucous membranes. At high concentrations this can cause a stinging sensation, 'watery eyes', coughing and breathlessness.

Long-term exposure to the particulates in diesel exhaust can result in heart disease, chronic lung disease and lung cancer (IARC 2012a).

2.4 Risk analysis and evaluation

Risk analysis and evaluation are the processes that determine the level of risk of injury or illness associated with a hazard and decide which risks need controls.

Risk analysis is the process that determines the level of risk of injury or illness associated with a hazard. It involves investigating unacceptable exposures and then understanding the sources and cause of the hazard and consequences; and the likelihood those consequences can occur (Standards Australia 2009a).

Risk evaluation is the process of comparing the level of risk determined during the risk analysis process with risk criteria identified when establishing the risk management context. Risk evaluation permits decisions about which risks require reduction and the priority for risk reduction controls to be implemented (Standards Australia 2009a).

Persons with an obligation under the Act to manage risk at a mine must analyse risk in the person's own work and activities at the mine to decide whether the risk is at an acceptable level.

For a health hazard such as diesel engine exhaust, the risk is analysed using a combination of the consequence of exposure to the hazard and the likelihood the measured level or workers' exposure will result in an adverse health effect (Firth, van Zanten & Tiernan 2006).

Information gathered from air monitoring data can be used during the risk analysis process to identify the sources and causes of exposure, analyse the likelihood of exposure and make judgements to the effectiveness and efficiency of existing controls.

During risk evaluation, air monitoring data can be used to evaluate a worker's or SEG exposure by comparison with an exposure limit (i.e. setting the exposure limit or half the exposure limit as the risk criteria can be useful when evaluating airborne contaminants). The risk criteria can also be used to determine the need for risk reduction controls and the priorities for risk reduction.

For example, implementing controls for workers' exposures above the exposure limit should have priority over implementing controls for exposures already below the exposure limit. When all exposures are below the exposure limit consideration should be given to re-establishing the risk management context and lowering the risk criteria levels to 'as low as reasonably achievable'.

Further guidance about how to analyse and evaluate the risk associated with occupational exposures is provided in the following references.

- *Simplified occupational hygiene risk management strategies*: *A guidebook for use in the Australian work environment, on how to meet Australian Safety and Compensation Council's requirements for employers to identify, assess and control risks arising from workplace exposures (Firth I, van Zanten D, & Tiernan G, 2006).*
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2.4.1 Exposure limits for diesel engine exhaust

Diesel engine exhaust exposure limits.

Health Hazard	Exposure Limit
Carbon monoxide Carbon dioxide Nitric oxide Nitrogen dioxide Sulphur dioxide	• Eight hour time weighted average (TWA) and short term exposure limit (STEL) as stated in Safe Work Australia's document - *Workplace Exposure Standards for Air Contaminants*.
Carbon monoxide	• Limits for short-term excursions above the eight hour TWA exposure limit for carbon monoxide as stated in Safe Work Australia's document - *Guidance on the Interpretation of Workplace Exposure Standards for Airborne Contaminants.*
Diesel particulate (measured as sub-micron elemental carbon using NIOSH Method 5040)	• 0.1 mg/m^3 as recommended by the Australian Institute of Occupational Hygienists' document – *Position Paper on Diesel Particulate*. A STEL has not been proposed.

Table 1 - Exposure limits for diesel engine exhaust

2.4.2 Complying with exposure limits

Complying with exposure limits protects most people from the health effects of a particular substance.

Safe Work Australia (2012) states the following about complying with exposure limits:

"Exposure limits represent the airborne concentration of a particular substance or mixture that must not be exceeded. Exposure limits are based on the airborne concentrations of individual substances which, according to current knowledge, should not cause adverse health effects nor cause undue discomfort to nearly all workers. Exposure limits do not represent a fine dividing line between a healthy and unhealthy work environment. Natural biological variation and the range of individual susceptibilities mean that a small number of people might experience adverse health effects even below the exposure standard."

In practice this means if monitoring of a worker's exposure to a hazard indicates airborne concentrations are below the exposure limit, every effort should still be made to continue to reduce the worker's exposure to as low as reasonably achievable, because for some workers health effects can still occur below the exposure limit.

Further guidance about how to comply with exposure limits is provided in the following references.

- *Guidance on the Interpretation of Workplace Exposure Standards for Airborne Contaminants (Safe Work Australia, 2013).*
- *Simplified monitoring strategies: A guidebook on how to apply NOHSC's exposure standards for atmospheric contaminants in the occupational environment to Australian hazardous substance legislation (Grantham D, 2001).*

2.4.3 Adjusting exposure limits for non-standard work schedules

Adjusting exposure limits for airborne hazards like diesel engine exhaust should be considered when a shift is longer than 8 hours and the working week is greater than 40 hours.

The eight hour time weighted average (TWA) exposure limits have been established based on the assumption that exposure occurs over the course of an eight hour working day, during a five day working week, and there are two days without exposure in every seven days. Because many mining work schedules do not conform to this assumption, the TWA exposure limit may need to be adjusted[1] to compensate for the greater exposure during a longer work shift and where there is decreased recovery time between shifts.

The rationale for adjusting an exposure limit must be established by an appropriately qualified person such as an occupational hygienist, whom has a sound understanding of the toxicology of the substance and the reasoning behind the specified exposure limit.

Further guidance about how to adjust exposure limits is provided in the following references.

- *Guidance on the Interpretation of Workplace Exposure Standards for Airborne Contaminants (Safe Work Australia, 2013).*
- *Adjustment of occupational exposure limits for unusual work schedules (SIMTARS, 2003).*

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[1] Adjustments must never be made to the measured airborne concentration of a substance to account for non-standard work schedules.

- *Simplified monitoring strategies: A guidebook on how to apply NOHSC's exposure standards for atmospheric contaminants in the occupational environment to Australian hazardous substance legislation (Grantham D, 2001).*

2.5 Risk reduction

Risk reduction is the process of eliminating a hazard or minimising the likelihood of injury or illness occurring.

Risk reduction is the process of eliminating a hazard or minimising the likelihood of injury or illness occurring (Standards Australia 2009a).

To be successful, a 'whole of mine' approach is required to control exposure to diesel engine exhaust. This will require the co-ordination of expertise and require a high level of process discipline in many functions including:

- mine operations
- maintenance
- mine engineering and ventilation
- safety and health
- training
- supply and procurement.

Controls that should be considered to reduce worker exposure to diesel engine exhaust include:

- electrically powered plant and equipment
- advanced diesel engine technology
- fuel quality control
- ventilation
- emissions-based maintenance strategies
- work practices
- enclosed cabins
- education and training
- personal protective equipment.

The key measure of success of risk reduction will be the level of diesel engine exhaust compared to the risk criteria after the selected controls have been implemented.

2.5.1 The hierarchy of controls

Examples of the hierarchy of control for diesel engine exhaust.

Persons with an obligation under the Act to manage risk at a mine must, as far as reasonably practicable, apply hazard controls using the hierarchy of controls.

The hierarchy of controls should be applied to ensure that workers' exposure to diesel engine exhaust does not exceed the exposure limit; and exposure is as low as reasonably achievable.

Examples of the use of the hierarchy of control for diesel engine exhaust are provided in Table 1.

Elimination of the hazard	• Replace all diesel powered plant and equipment with electrically powered plant and equipment

Substitution with a lesser hazard	• Replace high emission fuel with lower emission fuel • Replace high emission diesel engines with low emission engine technology
Separation of persons from the hazard	• Enclosed operator cabins
Engineering controls	• Rebuild older diesel engines with low emission engine technology • Add engine exhaust treatment and filtration systems to older diesel engines • Establish mine ventilation that removes and/or dilutes emissions • Install local exhaust ventilation in mobile equipment workshops or engine emission testing bays
Administrative controls	• Emission-based engine maintenance strategies • Operating practices and rules (e.g. diesel tag board system) • Worker education and training
Personal Protective Equipment	• Respiratory protection

Table 2 - Examples of controls for diesel engine exhaust

2.5.2 Fuel specification and quality

Fuel specification and quality can reduce the type and amount of diesel engine exhaust.

Fuel specification and quality can directly affect the type and amount of diesel engine exhaust produced.

Research has shown that low sulphur (<500 ppm) and ultra-low sulphur (<50 ppm) fuels can significantly lower sulphur dioxide gas and sulphate particles in diesel engine exhaust. Sulphate particles make up a significant proportion of the total particulate matter present in diesel engine exhaust.

Diesel fuel specification is regulated in Australia by the Fuel Quality Standards legislation. The specifications for petroleum diesel and biodiesel are contained in the National Fuel Standard (Automotive Diesel) Determination and National Fuel Standard (Biodiesel) Determination respectively. From 1 January 2009 both standards specified 10 ppm as the maximum concentration permitted for sulphur in diesel fuel.

Fuel quality can be diminished through poor transport, storage and handling practices. The integrity of the fuel supply-chain is an important consideration in reducing diesel engine exhaust. Increases in the emission of oxides of nitrogen, particulate matter and hydrocarbons can occur when fuel is contaminated with water, dirt, biological growth, rust and other sediment. Efforts should be made to monitor and reduce contamination at each stage in the supply-chain.

2.5.3 Engine technology

Engine technology can reduce the type and amount of diesel engine exhaust.

Engine technology can directly affect the type and amount of diesel engine exhaust produced.

Over the last 20 years or more, the amount and type of diesel engine exhaust has been significantly reduced through ‘in-cylinder’ and exhaust treatment and filtration technologies. Regulatory standards mandating greater diesel engine emissions control have been gradually phased in for both ‘on-road’ and ‘off-road’ vehicles by various countries.

It is recommended that European Union and American Environmental Protection Agency (EPA) Emission standards for ‘off-road’ vehicles are considered when purchasing new equipment. Consideration should always be given to specifying the most advanced diesel engines where practical.

Furthermore, it may be possible for the mine’s maintenance function to work with original equipment manufacturers (OEM) and suppliers to upgrade the less advanced diesel engines in the mine’s fleet and ancillary equipment to reduce diesel engine exhaust.

2.5.4 Enclosed operator cabins

Enclosed Cabs provide protection to operators inside the cabin from diesel engine exhaust but not to people working close by.

Enclosed cabins on plant and equipment do not alter the type or amount of diesel engine exhaust produced.

Enclosed cabins can only separate the operator from the hazard. When designed to exclude diesel engine exhaust; and are maintained and used as intended, enclosed cabins can provide good protection to the operator[2].

However, consideration must also be given to workers without the same level of protection required to work in close proximity to diesel powered plant and equipment or working in the same ventilation circuit.

2.5.5 Ventilation

Ventilation can be used to remove or dilute the amount of diesel engine exhaust.

Ventilation does not alter the type or amount of diesel engine exhaust produced.

Ventilation can only remove or dilute the amount of diesel engine exhaust to an acceptable level before it enters the breathing zone of a worker.

An estimate of the total quantity of diesel engine exhaust produced and the location of workers in a ventilation circuit must be taken into account when establishing and maintaining mine ventilation. It is recommended that a minimum mine ventilation rate of >0.06 m^3/s/kW

[2] Enclosed cabins do not provide protection from carbon monoxide.

is achieved to remove diesel engine exhaust from a place where a person may be present at the mine. However, the quality of the ventilating air supplied also needs to be considered for effective dilution of diesel engine exhaust to occur.

To achieve a healthy atmosphere, other factors such as radiant heat produced by diesel powered equipment may require higher ventilation rates to be established to maintain thermal comfort.

Consideration must also be given to the ventilation of other enclosed spaces at the mine such as surface maintenance workshops where diesel exhaust is able to accumulate and workers can be exposed. Where general dilution ventilation is not effective, local exhaust ventilation may be required in mobile equipment workshops or engine emission testing bays.

2.5.6 Maintenance strategy

An effective maintenance strategy can reduce the type and amount of diesel engine exhaust.

Maintenance strategies can indirectly affect the type and amount of diesel engine exhaust produced.

The diesel emission evaluation project (DEEP) found that, depending on engine technology and condition, reductions in diesel engine exhaust (both gaseous and particulate) of over 50 per cent were possible using diesel engine exhaust-based maintenance strategies. Research indicates that to control diesel engine exhaust there are a number of key engine systems that should be the focus of preventative maintenance. These include the:

- air-intake system
- exhaust treatment and filtration system
- fuel injection system
- cooling system
- fuel delivery and filtration system
- lubrication system.

The aims of a diesel engine maintenance strategy should be the monitoring and maintenance of ‘in-cylinder’ and exhaust treatment and filtration technology to the original equipment manufacturer (OEM) specifications.

It is recommended the maintenance strategy includes the establishment of a ‘baseline signature’ of ‘raw’ (without exhaust filtration) and ‘undiluted’ (with exhaust filtration) diesel engine exhaust when the diesel engine system is in an ‘as new’ condition. Over the course of the engine’s lifecycle preventative and corrective maintenance is determined by comparison of monthly testing results and trend analysis with the baseline exhaust signature.

Accurate knowledge about the diesel equipment fleet’s ‘diesel exhaust signature’ can be used when planning/scheduling vehicle usage in a specific mine ventilation circuit. This demonstrates the value of co-ordinating the transfer of information between the mining, maintenance and mine engineering and ventilation functions at a mine.

Further guidance about diesel engine exhaust emissions monitoring and establishing preventative diesel engine maintenance practices is provided in the following references.

- AS/NZS 3584.3: 2012 Diesel engine systems for underground coal mines. Part 3: Maintenance. (See section 3.3 and Appendix D)
- Diesel emissions evaluation program – maintenance guidelines and best practice for diesel engines in underground mining
- MDG29 Guideline for the management of diesel engine pollutants in underground environments

2.5.7 Work practices

Work practices and attitudes can reduce the type and amount of diesel engine exhaust.

Work practices can indirectly affect the type and amount of diesel engine exhaust produced.

Work practices are considered to be lower order controls and require considerable process discipline to be effective. Education, training and supervision can be used to modify work practices and attitudes that contribute to the production of diesel engine exhaust.

Senior positions in the management structure can reinforce the importance of work practices by observing them 'in the field' and coaching supervisors and workers when they are sub-standard.

Work practices that can reduce diesel engine exhaust include:

- promoting the practice of engine 'warm-up' and 'cool-down'
- driving to conditions
- limiting engine idling or 'over-revving'
- limiting the total kilowatts of diesel engine power permitted in a ventilation circuit at any one time
- preventing ingress of water, dirt and other contaminants during refuelling
- promoting good road design and maintenance
- reporting 'blue' or 'black' smoke in diesel engine exhaust
- allowing only qualified mechanics to make diesel engine adjustments
- using clean and organised work areas to perform diesel engine maintenance (when practical), particularly when it relates to the key engine systems that directly affect diesel engine exhaust
- capturing maintenance history completely and accurately
- promoting co-operation between the mining and maintenance functions, particularly between line-management
- reinforcing the importance of the management plan with supervisors and workers, by senior positions in the management structure.

2.5.8 Education and training

Education and training can reduce the type and amount of diesel engine exhaust.

Education and training can indirectly affect the type and amount of diesel engine exhaust produced.

Successful management of diesel engine exhaust will require the co-ordination of many areas of technical expertise and disciplined action at the mine. The key to success is effective communication, education and training.

Basic education must be provided to all workers who may be exposed to diesel engine exhaust. Topics that should be covered include:

- description and nature of diesel engine exhaust
- health effects
- exposure limits
- sources and causes of emissions
- outcome of risk analysis and evaluation for the operation
- outline of the risk management plan including goals and the role of supervision and workers
- controls used to manage diesel engine exhaust
- risk monitoring activities
- process for reporting substandard practices and conditions to control owners.

Training and competency requirements for supervision, workers, and risk and control owners must be developed and documented. This should include requirements to have a more detailed understanding of diesel engine exhaust, the risk controls relevant to their work and the ability to recognise substandard conditions or practices relevant to diesel engine exhaust.

2.5.9 Respiratory protection

Respiratory Protection when properly selected, fitted and used can provide some protection to people from diesel engine exhaust.

Personal protective equipment (PPE) does not alter the type or amount of diesel engine exhaust produced.

PPE is the lowest order control in the hierarchy of control and relies heavily on worker compliance and enforcement by supervision to be effective. Failure to wear suitable, correctly fitted PPE, when required can result in a worker being directly exposed to a hazard.

It is recommended that the use of respiratory protective equipment (RPE) to prevent exposure to diesel engine exhaust is only used as a temporary or interim control. Every effort should be made to reduce diesel engine exhaust to levels that do not require the mandatory use of respiratory protection.

Because diesel engine exhaust particles are so small careful consideration should be given to the selection of RPE, particularly air purifying respiratory protection (Standard Australia 2009b). Recent research has found that the filter efficiency of FFP2 and FFP3 dust masks is lower for submicron diesel engine exhaust (Penconek et al 2012).

Further guidance about the selection, use and maintenance of respiratory protection is provided in AS/NZS 1715: 2009 Selection, use and maintenance of respiratory protective equipment.

2.6 Risk monitoring

Risk monitoring is the process of ensuring risk controls are

Risk monitoring is the process of monitoring and reviewing all parts of the risk management process and can be a periodic or unplanned activity (Standards Australia 2009a).

The site senior executive (SSE) must ensure that the mine and local

effective; gathering further information to improve risk analysis; and indentifying changes in the risk management context and emerging risks.

environment is monitored throughout the lifecycle of operations at the mine and when changes occur that can affect the level of risk at the mine.

Persons with an obligation under the Act to manage risk at a mine must monitor risk in the person's own work and activities at the mine.

The aims of risk monitoring are to:

- review progress with the implementation of controls
- ensure controls are working as designed;
- incorporate new research, trends or industry data into risk management processes
- obtain additional information to improve the risk analysis process
- review whether the risk management context and risk management processes are based on 'best available information', including emerging risks, advances in technology, new research, or industry trends.

2.6.1 Risk communication

All persons have an obligation to pass on information to other persons so they can do their job and to also ensure that other persons are not exposed to an unacceptable level of risk.

All persons have a general obligation to pass on information to other persons with an obligation under the Act to manage risk at a mine.

The SSE must also ensure there is a formal opportunity to pass on information for adequate planning and control of operations in relation to any incidents that have occurred and the level of hazards present in the mine's work environment.

For example, accurate information about the status of the diesel equipment fleet's 'diesel exhaust signature' can be used when planning/scheduling production activity in a specific mine ventilation circuit. This may include co-ordinating the transfer of information between the maintenance representative and the mine operations and mine engineering and ventilation representatives at the weekly mine planning meeting.

2.6.2 Health surveillance

Health surveillance is a type of risk monitoring that can be used to detect the effects of exposure to a person from a hazard.

Health surveillance is a risk monitoring activity used to assess that controls are working as designed or to identify trends and emerging risks to workers' health. Respiratory health surveillance should be considered for workers who are exposed to diesel engine exhaust.

It is recommended workers' exposure monitoring results be discussed with an experienced medical practitioner to determine if a health surveillance program is appropriate.

2.6.3 Monitoring workers' exposure

Air monitoring must meet certain requirements for it to be valid.

Air monitoring is required to be performed when a hazard such as diesel engine exhaust has the potential to exceed exposure limits; or the level of risk from the hazard may vary.

Where air samples are used to estimate workers' or SEG exposure for comparison with an exposure limit, the monitoring must be collected in the breathing zone of the person and unless otherwise stated, must be sampled and analysed using a relevant Australian or National Standard for monitoring and analysis.

Air samples collected at ‘fixed’ or ‘static’ locations in the working environment cannot provide personal exposure information and should never be used to demonstrate compliance with an exposure limit. ‘Pre-control’ and ‘post-control’ static air samples may be useful particularly when a control is being established or a control has the capability of being adjusted within its design parameters to increase its effectiveness or efficiency. However, real-time or direct sampling of air contaminants may be a better option when assessing or adjusting controls.

An air monitoring program can be used to assess if a workers’ exposure to diesel engine exhaust is at an acceptable level.

The approach to implementing an air monitoring program must be established by an appropriately qualified person, such as an occupational hygienist.

Exposure assessment requires a sound understanding of the:

- work environment
- workforce
- work processes and equipment
- nature of the hazard
- establishment of a SEG
- strategies for assessing exposure
- methods of sampling and analysis
- relevant statistical techniques, and
- interpretation of results.

The air monitoring program should be documented and state the exposure assessment goals and strategy. The program should be incorporated into the diesel engine exhaust management plan.

Further guidance about how to establish an air monitoring program is provided in the following references.

- *Simplified monitoring strategies: A guidebook on how to apply NOHSC’s exposure standards for atmospheric contaminants in the occupational environment to Australian hazardous substance legislation (Grantham D, 2001).*
- *A strategy for assessing and managing occupational exposures (Ignacio J, & Bullock W, 2006).*

Changes to plant, processes or substances and the results of previous diesel engine exhaust exposure assessments can be used to determine how often worker exposure should be reassessed.

Reassessment of worker exposure is required throughout the lifecycle of operations at a mine and when changes occur that can significantly alter the level of risk at a mine. Change management practices and procedures should require reassessment of worker exposure when there has been change to plant, processes or substances at the mine.

Management of change is not the only reason to conduct risk monitoring. Reassessment of worker exposure can also be used to verify the effectiveness of newly implemented risk controls and also to detect subtle deterioration of these risk reduction measures over time.

The frequency and purpose of reassessment required for each SEG should be determined by an appropriately qualified person. However, due to the expense and time required, exposure reassessment should not be conducted for its own sake.

Methods for determining the frequency of reassessment propose that the frequency of exposure assessment should be determined by the results of previous monitoring. In some cases monitoring may be infrequent or not recommended. For example, one method recommends that where the previous average exposure of the SEG is very low, for example, <10 per cent of the exposure standard, reassessment is not warranted, unless a significant change occurs. Similarly, where the average SEG exposure is many times higher than the exposure standard, reassessment is not justified until risk reduction measures have been implemented. It should be noted, however, where SEG exposure is many times higher than the exposure standard some form of risk monitoring may still be required to determine if the protection factor of respiratory protective equipment continues to remain adequate for the level of exposure.

Further guidance about how to establish the frequency of risk monitoring and exposure reassessment is provided in the following references.

- *Simplified monitoring strategies: A guidebook on how to apply NOHSC's exposure standards for atmospheric contaminants in the occupational environment to Australian hazardous substance legislation (Grantham D, 2001).*
- *A strategy for assessing and managing occupational exposures (Ignacio J, & Bullock W, 2006).*

3 Diesel engine exhaust management plan

Where diesel engine exhaust is a hazard at a mine, a diesel engine exhaust management plan should be developed and documented in consultation with mine workers.

It is recommended a documented and auditable hazard management plan is established if it is identified that diesel powered plant or equipment are present or likely to be present in an underground mine; or diesel engine exhaust can accumulate in an enclosed or partially enclosed place at a mine where workers may be exposed.

The management plan should:

- align with the goals and objectives of the mine's safety and health policy and management system;
- be established in consultation with mine workers and the mine's risk management practices and procedures;
- address all relevant operations at the mine; and
- be integrated and compatible with the mine's safety and health management system.

To be effective, the diesel engine exhaust management plan should cover some minimum requirements such as the scope of the plan, the aim of the plan, responsibilities for the plan and outline the risk management process.

The purpose of a management plan is to consolidate information about the hazard, document controls and to provide references to existing elements of the mine's safety and health management system.

The diesel engine exhaust management plan should include or make reference to the following minimum requirements:

- facility description, that describes the source and magnitude of the hazard
- objectives, targets and performance indicators, including achievement timeframes
- statement designating responsibility for achievement of objectives and targets referenced to the mine's management structure
- demonstrated access to competencies in:
  - workers' exposure monitoring and analysis
  - ventilation planning and design
  - diesel engine exhaust emissions monitoring
  - diesel engine maintenance
  - health surveillance
- risk identification and analysis outcomes
- risk reduction controls to limit worker's exposure including:
  - diesel engine and exhaust treatment technology
  - ventilation
  - diesel engine maintenance strategy
  - mine planning and other operational practices
  - induction, education and training requirements
  - using PPE
- risk monitoring requirements including:
  - mine ventilation
  - worker's exposure
  - diesel engine exhaust (raw and undiluted)
  - fuel quality
  - health surveillance
- record keeping requirements
- process for communicating and reporting sub-standard practices/conditions; and the occurrence of incidents or ill health
- provision for periodic review and improvement of the plan.

The effectiveness of the diesel engine exhaust management plan must be reviewed and audited by the Operator of the mine.

The operator of the mine is required to review and audit the effectiveness of the Mine's Safety and Health Management System including subsystems such as the diesel engine exhaust management plan to ensure risk to persons from operations is at an acceptable level.

Further guidance about how to review the effectiveness of the diesel engine exhaust management system is provided in the following reference.

- Guidance Note QGN09 – Reviewing the effectiveness of safety and health management systems

4 References

Australian Institute of Occupational Hygienists, 2013, AIOH position paper - Diesel particulate and occupational health issues, AIOH, Victoria

Australian Government, 2009, Fuel standard (automotive diesel) determination 2001, Office of Legislative Drafting and Publishing, Australian Capital Territory.

Australian Government, 2009, Fuel standard (biodiesel) determination 2001, Office of Legislative Drafting and Publishing, Australian Capital Territory.

Australian Radiation Protection and Nuclear Safety Agency, 2005, Code of practice & safety guide: Radiation protection and radioactive waster management in mining and mineral processing, Radiation protection series No. 9, Commonwealth of Australia, Australian Capital Territory.

Bugarski A, Janisko S, Cauda E, Noll J, & Mischler S, 2011, NIOSH Report of Investigation 9687 - Diesel aerosols and gases in underground mines: Guide to exposure assessment and control, National Institute for Occupational Safety and Health, DHHS Publication No. 2012-101.

Davies B, 2004, The control of diesel particulates in underground coal mines, Victoria University of Technology, Victoria.

Davies B, 2011, Diesel particulate – where are we? - cited 31/01/2013 http://www.resources.nsw.gov.au/__data/assets/pdf_file/0017/412226/Diesel-Particulate-Brian-Davies.pdf.

Firth I, van Zanten D, & Tiernan G, 2006, Simplified occupational hygiene risk management strategies: A guidebook for use in the Australian work environment, on how to meet Australian Safety and Compensation Council's requirements for employers to identify, assess and control risks arising from workplace exposures, AIOH, Victoria.

Grantham D, 2001, Simplified monitoring strategies: A guidebook on how to apply NOHSC's exposure standards for atmospheric contaminants in the occupational environment to Australian hazardous substance legislation AIOH, Victoria.

Ignacio J, & Bullock W, 2006, A strategy for assessing and managing occupational exposures, 3rd edition, AIHA, Virginia.

International Agency for Research on Cancer, 1998, IARC monographs on the evaluation of carcinogenic risks to humans – Diesel and gasoline engine exhausts and nitroarenes, World Health Organisation, vol. 46, pp.41-46.

International Agency for Research on Cancer, 2012a, Carcinogenicity of diesel-engine and gasoline-engine exhausts and some nitroarenes, cited 08/02/2013 <www.thelancet.com/oncology Vol 13 July 2012>.

International Agency for Research on Cancer, 2012b, IARC: Diesel engine exhaust carcinogenic, World Health Organisation, Press Release No. 213.

National Institute of Occupational Safety and Health, 2003, NIOSH Method 5040 Diesel particulate matter (as elemental carbon), Centers for Diease Control and Prevention, fourth edition.

NSW Department of Primary Industries, 2008, MDG29 Guideline for the management of diesel engine pollutants in underground environments, Mine Safety Operations Division, April, 2008.

Penconek A, Drazyk P & Moskal A, 2012, Penetration of diesel exhaust particles through commercially available dust half masks, Ann Occup Hyg. 2013 Apr; 57(3):360-73.

Queensland Department of Natural Resources and Mines, 2008, QGN09 Reviewing the effectiveness of safety and health management systems, Mines, Safety and Health, 2008.

Queensland Government, 2012, Mining and Quarrying Safety and Health Act 1999, Office of the Parliamentary Counsel, Queensland.

Queensland Government, 2012, Mining and Quarrying Safety and Health Regulation 2001, Office of the Parliamentary Counsel, Queensland.

Safe Work Australia, 2011, Workplace exposure standards for airborne contaminants. Safe Work Australia, Australian Capital Territory.

Safe Work Australia, 2012, Guidance on the interpretation of workplace exposure standards for airborne contaminants. Safe Work Australia, Australian Capital Territory.

Safe Work Australia, 2013, Guidance on the interpretation of workplace exposure standards for airborne contaminants. Safe Work Australia, Australian Capital Territory.

Safe Work Australia, 2013, Workplace exposure standards for airborne contaminants. Safe Work Australia, Australian Capital Territory.SIMTARS, 2003, Adjustment of occupational exposure limits for unusual work schedules, SIMTARS, Queensland.

Standards Australia, 2001, AS/NZS 4804:2001 – Occupational health and safety management systems: General guidelines on principles, systems and supporting techniques, Standards Australia, New South Wales.

Standards Australia, 2009a, AS/NZS ISO 31000:2009 – Risk management: Principles and guidelines, Standards Australia, New South Wales.

Standards Australia, 2009b, AS/NZS 1715:2009 - Selection, use and maintenance of respiratory protective equipment, Standards Australia, New South Wales.

Standards Australia, 2012, AS/NZS 3584.3:2012 - Diesel engine systems for underground coal mines: Maintenance, Standards Australia, New South Wales.

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