

Diesel Emissions Management in Underground Coal Mines

Best Practices and Recommendations

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SUMMARY

Diesel engine powered vehicles are widely utilised in underground coal mines and the engine exhaust emissions must be effectively managed to minimise the risk to coal mine workers' health. In the short term, exposure to high concentrations of diesel engine emissions may cause irritation of the eyes and respiratory tract and in the long term sustained exposure may increase the risk of lung disease including cancer and possibly bladder cancer.

The mines inspectorate has been collecting and reviewing diesel particulate matter data in underground coal mines since the early 2000s. Despite the improvements observed over time, longwall move activities continue to represent the highest risk similar exposure group (SEG) in underground coal mines.

During 2018 the mines inspectorate completed a series of structured inspections focusing on diesel emissions management at all ten operational underground coal mines. Findings and opportunities for improvement are included in this document.

The mines inspectorate expects all underground coal mines to have a diesel emissions management plan which forms part of the mine's Safety and Health Management System (SHMS). Requirements for this plan as well as best practices and recommendations are also outlined in this document.

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PURPOSE OF DOCUMENT

Diesel engine powered vehicles are widely utilised in underground coal mines and the engine exhaust emissions must be effectively managed to minimise the risk to coal mine workers' short and long term health. During 2018 the mines inspectorate completed a series of structured inspections focusing on diesel exhaust emissions management at all operational underground coal mines. Findings and opportunities for improvement are included in this document.

This document also specifies the requirements of diesel exhaust emissions management plans and outlines best practices and recommendations.

BACKGROUND

Diesel engine exhaust emissions contain complex mixtures of gases, vapours, liquid aerosols and particulates including:

- ❖ Nitrogen (N₂)
- ❖ Carbon dioxide (CO₂)
- ❖ Water (H₂O)
- ❖ Carbon monoxide (CO)
- ❖ Nitrogen oxides (NO_x)
- ❖ Sulphur oxides (SO_x)
- ❖ Various hydrocarbons
- ❖ Alcohols, aldehydes, ketones
- ❖ Particulates (soot)
- ❖ Polycyclic aromatic hydrocarbons (PAHs).

In June 2012, the International Agency for Research on Cancer classified diesel engine exhaust as carcinogenic to humans (Group 1), based on sufficient evidence that exposure is associated with an increased risk for lung cancer.

Currently, Safe Work Australia does not specify an occupational exposure standard for diesel particulate matter (DPM), however, the Australian Institute of Occupational Hygiene (AIOH) has set a guideline concentration where worker exposure to DPM levels should be controlled to below 0.1 mg/m³ as an 8 hour time weighted average (TWA) value, measured as submicron elemental carbon. The value has been determined as being a balance of the factors such as primarily minimising eye and respiratory irritation, then secondarily minimising the potential for risk of lung cancer to a level that is not detectable in a practical sense in the work force, and finally on providing a level that is achievable as best practice by industry and government¹. In addition, a TWA value of 0.05 mg/m³ should be applied as an action level which triggers investigation of the sources of exposure and implementation of suitable control strategies. The AIOH strongly encourages the "precautionary principle" approach in the management of diesel emissions.

BHP Billiton commissioned the Institute of Occupational Medicine (IOM) to assess all relevant and related literature and advise whether there is sufficient data available to develop exposure-response

¹ HSEAustralia, viewed on 10 December 2018, <http://www.hseaustralia.com.au/occupational-hygiene/diesel-particulate-matter-dpm/>.

curve(s) for diesel exhaust particulate (DEP) and lung cancer. The summary paper released in 2015 stated that it may be impractical to set a meaningful risk-based limit for workplace exposure, however, the evidence is in the opinion of IOM, strong enough to support recommending controlling exposures to DEP to the lowest level that is technically achievable.

Recently the International Council on Mining and Metals announced the Innovation for Cleaner Safer Vehicles programme. An aim of the programme is to promote operational and technological innovations to minimise the impacts to underground mining operations from emissions of diesel particulate matter by 2025.

QUEENSLAND COAL DPM STEERING COMMITTEE

The Coal Mining Safety and Health Regulation 2017 requires an underground mine's SHMS to provide means for controlling the exposure of persons to an atmosphere at the mine containing internal combustion pollutants. This requires exposure of pollutants to be below specified concentrations and the risks to coal mine workers to be as low as reasonably achievable.

From around 2001 Queensland coal mines started to actively monitor personal exposure to DPM. An industry wide DPM steering committee was established in February 2004. Members of the committee included coal company representatives, mines' inspectors and suppliers. DPM committee meetings have provided an opportunity for the sharing of information and learnings related to the management of DPM. The DPM committee has also developed a draft guideline on the management of diesel emissions which is widely referenced in site management plans.

Coal mines have voluntarily provided DPM monitoring data to the mines inspectorate. In 2007 the first industry data report covering monitoring results for 2004-2007 was published. The industry dust database is now also used for the DPM data which is still provided on a voluntary basis by all active underground coal mines on an annual basis.

DPM TRENDS

Personal DPM monitoring data for the Queensland underground coal industry up until the end of 2017 has been compiled and presented at industry forums during 2018. The data is also included in the Queensland Mines and Quarries Safety Performance and Health Report 2017–2018, which is available on the department's website.

Reported data from two high risk similar exposures groups; longwall move and development is discussed:

- ❖ For the longwall move SEG (Figure 1), 60 per cent of mines recorded mean exposures above the shift adjusted exposure guideline in 2016; this reduced to 10 per cent in 2017 where one mine's average exceedance was above the shift adjusted exposure. It must be noted that the data shown in the figures is for average exposure and that the 95% upper confidence limit (UCL) indicating where the true mean may sit is likely to be much higher.

- ❖ For the development SEG (Figure 2), 20 per cent of mines recorded mean exposure above the shift adjusted exposure guideline during 2016. No mines recorded mean exposures above the guideline for development SEG in 2017.

Despite the significant improvements observed in 2017, longwall move activities continue to represent the highest risk SEG in underground coal mines. While this SEG does not operate continuously, some of the coal mine workers within the SEG are contractors who potentially move from mine to mine performing multiple longwall retraction/installations, and may be subject to elevated exposure risk.

FIGURE 1 – MEAN EXPOSURES, DPM, LONGWALL MOVE SEG, 2014-2017

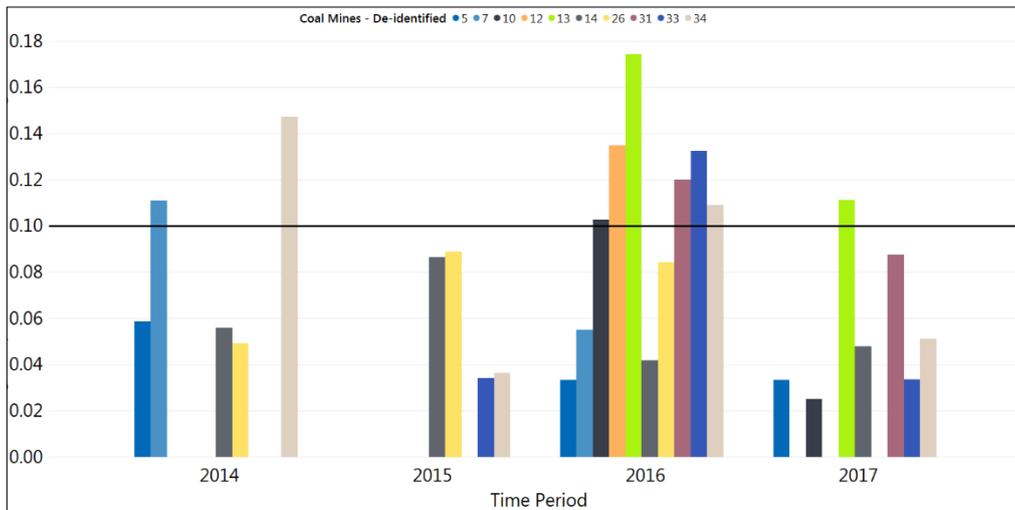
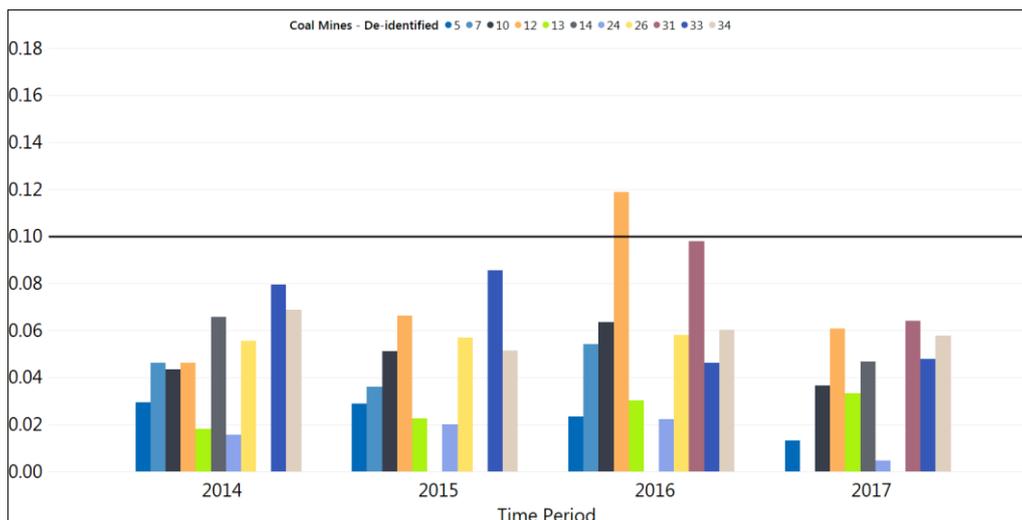


FIGURE 2 – MEAN EXPOSURES, DPM, DEVELOPMENT SEG, 2014-2017

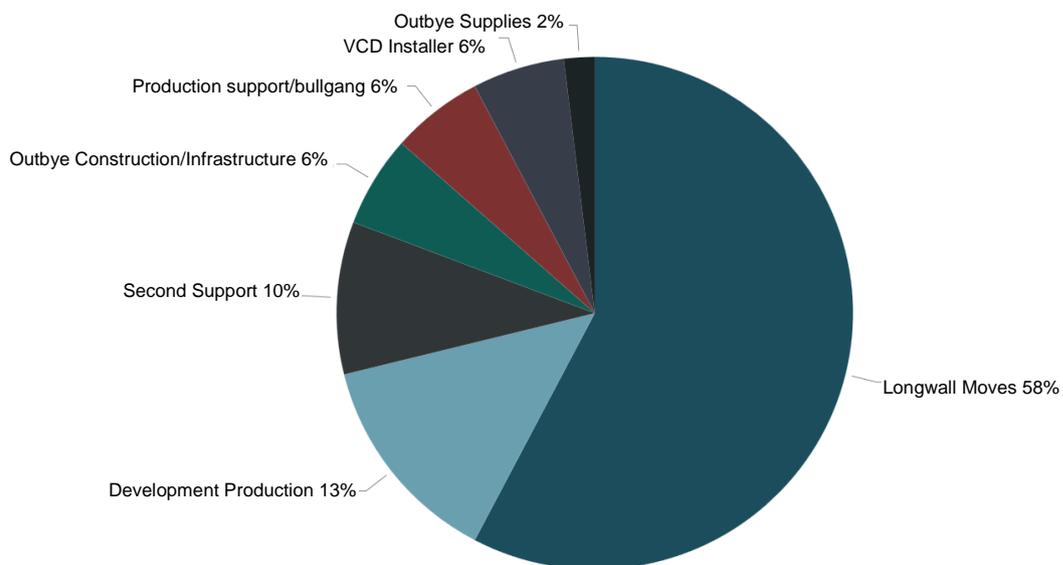


Single exceedances – DPM 2017

In 2017, there were noticeable improvements in the single sample exceedance rates for DPM for longwall move and development SEGs. Over the period of 2015-16 the single sample exceedance rate for DPM for these groups demonstrated an increasing trend, before reducing by more than half in the year 2017.

A total of 1339 valid DPM samples were reported in 2017 of which 52 exceeded the sites' shift adjusted exposure guideline. It is not surprising that the majority of exceedances occurred in the longwall and development SEGs (Figure 3) with 30 occurring during the longwall move sampling and 7 occurring in the development areas. It is noted that one mine contributed to 50% of the single longwall exceedances where 5 of these exceedances occurred on the same day and all were nearly double the occupational exposure limit. Exposure data for 2018 will be requested from sites in early 2019 and will be analysed for exposure trending and assessment of the effectiveness of controls.

FIGURE 3 – SINGLE SAMPLE EXCEEDANCES, DPM, 2017



DIESEL EMISSIONS MANAGEMENT PLAN

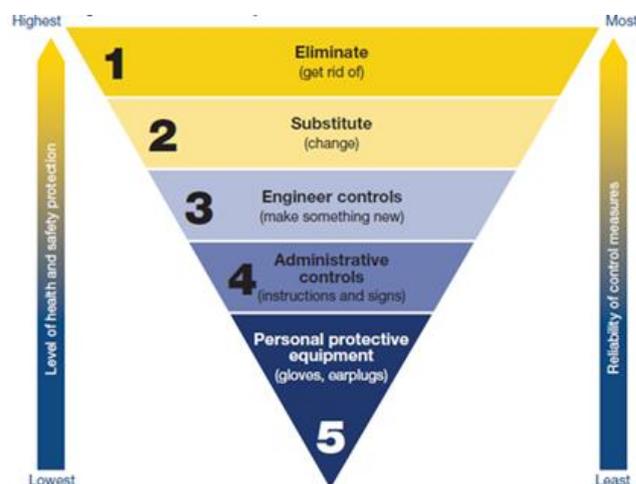
The mines inspectorate expects all underground coal mines to have a diesel emissions management plan which forms part of the mine's Safety and Health Management System (SHMS). An integrated approach that involves relevant disciplines such as engineering, mine design and ventilation, hygienist, training and supervision is required.

Key elements of the plan would include:

- ❖ Roles and responsibilities
- ❖ Sources of diesel emissions
- ❖ Health risk assessment
- ❖ Emission controls
 - Equipment design and specification
 - Fuel management
 - Emission reduction devices
 - Maintenance strategies
- ❖ Transmission controls (ventilation)
 - Ventilation design
 - Traffic management plan (e.g. routine and non-routine, longwall move periods)
 - Ventilation performance
- ❖ Exposure controls
 - Training and education
 - Personal protective equipment
- ❖ Auditing, monitoring and review
 - Performance indicators
 - Review criteria
 - Corrective actions
 - Audit requirements
- ❖ Communications
- ❖ Change management
- ❖ Records

The application of the hierarchy of controls in managing diesel emissions is a key element of the plan.

FIGURE 4 – HIERARCHY OF CONTROLS



DNRME STRUCTURED INSPECTIONS

During 2018 the mines inspectorate completed a series of structured inspections focusing on diesel emissions management at all ten operational underground coal mines. Mines in care and maintenance were not included. At the time of the structured inspections there were 490 diesel powered vehicles operating in Queensland underground coal mines. On average each mine has 20 load haul dump loaders and 21 personnel transporters in service. It is noted that one mine which was undertaking a longwall relocation had 89 diesel powered vehicles on site.

Diesel emissions management plan

Findings:

- ❖ All mines have a diesel emissions management plan.

Opportunities exist for some mines to:

- ❖ update and communicate roles and responsibilities
- ❖ review performance indicators
- ❖ define lower raw gas DPM trigger points based on actual engine package performance.

SHMS requirements

Findings:

- ❖ All mines refer to exhaust gas emissions.

Opportunities exist for all mines to:

- ❖ detail pollutants to be targeted and establish exposure limits (e.g. consider carbon dioxide / carbon monoxide / nitrogen dioxide / nitric oxide / water vapour / nanoparticles / oil mists / PAHs / aldehydes / particulates / heat / noise / vibration).

Roles and responsibilities

Findings:

- ❖ Most mines have most roles and responsibilities documented.

Opportunities exist for some mines to:

- ❖ ensure senior management provide active leadership in setting and driving improvements in diesel exhaust emissions management
- ❖ review and document who is responsible for diesel emissions management within the management structure
- ❖ review and ensure all roles and responsibilities are documented
- ❖ communicate the roles and responsibilities to their owners.

Risk assessments

Findings:

- ❖ All mines have conducted a diesel emissions risk assessment.

Opportunities exist for some mines to:

- ❖ consider and review risks associated with exposure to all diesel emissions including nanoparticles
- ❖ conduct a gap analysis of diesel emission controls and identify additional controls
- ❖ re-evaluate controls for effectiveness through monitoring and measurements.

Emissions measurement

Findings:

- ❖ All mines monitor diesel engine emissions as part of the maintenance programme.

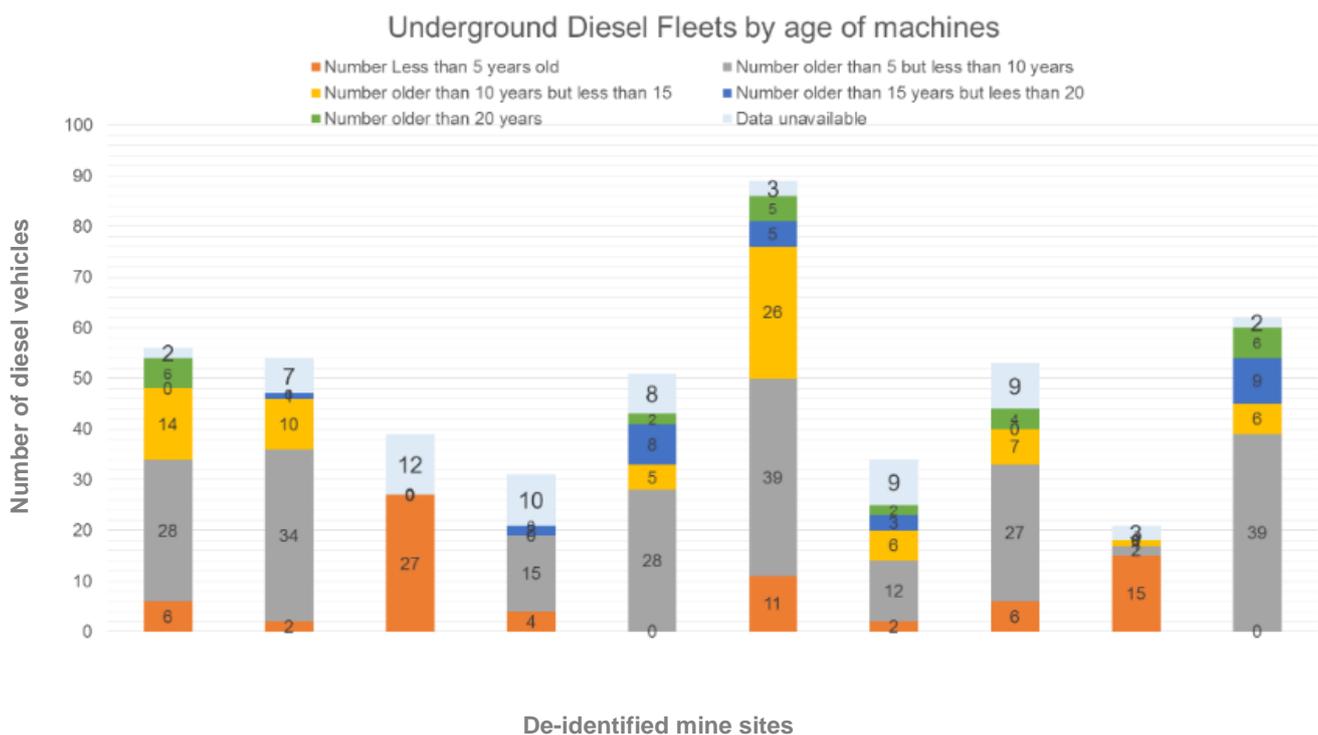
Opportunities exist in some operations to:

- ❖ use periodic external monitoring to validate site data
- ❖ better utilise gas monitoring data for diesel engine maintenance and assessing DPM filter effectiveness.

Existing and older vehicles

Based on the data provided at the time of the structured inspections more than 25% of the operating fleet was older than 10 years. Opportunities exist to actively consider replacement strategies and technologies, including the active participation in the development of lower emission vehicles including electrically powered vehicles.

FIGURE 5 – DIESEL FLEET AGE



Fuels and lubricants

Findings:

- ❖ All mines use ultra-low sulphur fuel that meets the national fuel quality standard.

There are opportunities for some mines to:

- ❖ compare fuel supplied against the contracted specification
- ❖ conduct fuel sampling of on-site fuel storage facilities
- ❖ share the results of alternate cleaner fuel tests, recently conducted at some sites
- ❖ investigate cleaner fuel alternatives.

Emission reduction devices

Findings:

- ❖ All mines use DPM filters during longwall moves and most mines use DPM filters routinely.

There are opportunities for:

- ❖ some mines to use DPM filters during normal routine operation
- ❖ most mines to conduct tests to prove that DPM filters are seated and working correctly.

Maintenance strategies

Findings:

- ❖ All mines have a maintenance strategy for testing diesel emissions. Some mines have set lower raw gas DPM limits than 40 mg/m³ based on actual engine package performance.

There are opportunities for most mines to:

- ❖ drive the DPM limits to be as low as practically achievable by engine type.

There are opportunities for some mines to:

- ❖ improve available engine diagnostic and tuning skills
- ❖ update testing tools to the latest software version
- ❖ utilise technical expertise to maintain optimal engine tuning.

Off-site workshops

Findings:

- ❖ All mines use and inspect off-site workshops from time to time.
- ❖ All mines inspect these workshops when their machines are in for repair.
- ❖ Some mines use only workshops which hold a NSW ExDES (RSF) license.
- ❖ Some mines conduct formal workshop audits.

There are opportunities for some mines to formally audit these workshops to ensure they have:

- ❖ a quality system
- ❖ workshop workforce is suitably qualified and holds the recognised competencies to work on diesel engine systems (DES).

Ventilation design

Findings:

- ❖ All mines have a designed ventilation system.
- ❖ Most mines use tag boards to control diesels in panels.
- ❖ All mines are basing diesel ventilation requirements on Mining Design Guideline (MDG) 29 (greater of $0.06 \text{ m}^3/\text{s/kW}$ or $3.5 \text{ m}^3/\text{s}$).

There are opportunities for:

- ❖ most mines to consider the total DPM for the mine (e.g. surface tag board)
- ❖ some mines to consider appointing tag board controllers during periods of high intensity (e.g. LW moves and conveyor installations)
- ❖ most mines to calculate ventilation requirements based on actual exhaust DPM output (with and without filters).

Personal exposure and workplace atmospheric monitoring

Findings:

- ❖ All mines conduct exposure and workplace atmospheric monitoring.
- ❖ All mines are supplying appropriate personal protective gear (PPE).
- ❖ Most mines are reviewing their diesel emissions management plans 5 yearly.

There are opportunities for most mines to:

- ❖ consider real time static monitoring
- ❖ consider short term exposure limits and investigate other health monitoring such as nanoparticle counts and blood testing.

There is an opportunity for some mines to:

- ❖ review exposure monitoring strategies when using large slow diesels.

BEST PRACTICES AND RECOMMENDATIONS

Leadership	<ul style="list-style-type: none"> ❖ Active Chief Executive Officer commitment and leadership to drive strategies to reduce diesel emissions standards, ensuring adequate resources are available.
Strategy	<ul style="list-style-type: none"> ❖ Develop, document and communicate near term and long term strategies for reduction in diesel emissions. ❖ Consider strategies to cater for occupational exposure limit (OEL) guidelines reduced to: <ul style="list-style-type: none"> ➢ 0.05 mg/m³ or ➢ 0.03 mg/m³ for example. ❖ Apply the hierarchy of controls to strategy: <ul style="list-style-type: none"> ➢ replace diesels with alternate power source (e.g. battery) ➢ invest in future machine development ➢ efficient machine use to minimise diesel use ➢ revise ventilation strategies.
Emissions targets	<ul style="list-style-type: none"> ❖ Set mine site OEL targets lower than the current AIOH recommended limit and drive strategies to reduce exposure. ❖ Truly adopt an ALARA approach.
Roles and responsibilities	<ul style="list-style-type: none"> ❖ Define who the site champion is, their responsibilities, authorities and resources.
Health risk assessment	<ul style="list-style-type: none"> ❖ Consider additional health assessments including blood testing, biomarkers and exposure to nanoparticles.
Equipment design and specification	<ul style="list-style-type: none"> ❖ Document strategies for new buy, rebuild, overhauls, and repowering machines with lower emission engine packages.
Fuel management	<ul style="list-style-type: none"> ❖ Utilise cleanest available fuels.
Operations	<ul style="list-style-type: none"> ❖ Develop and implement plans to limit the number of diesel engine vehicles essential for efficient mine operation.
Traffic management plan (e.g. routine and non-routine, longwall move periods)	<ul style="list-style-type: none"> ❖ Include traffic management and short term control as a key management activity at high exposure times such as longwall moves.
Exposure controls	<ul style="list-style-type: none"> ❖ Use DPM filters all the time. ❖ Targeted use of static real time DPM monitors (e.g. when working in stubs, longwall moves and main travel roads).
Training and education	<ul style="list-style-type: none"> ❖ Active training in use of diesels (e.g. limit idle periods, PPE, etc.)
Auditing, monitoring & review	<ul style="list-style-type: none"> ❖ Review strategy on an annual basis.