

# Diesel Particulate Matter in Underground Mines

## – Controlling the Risk (an update)

Kevin Hedges<sup>1</sup>, Fritz Djukic<sup>2</sup> and Gavin Irving<sup>3</sup>

1. Senior Principal Occupational Hygienist (North Region)
2. Senior Principal Occupational Hygienist (Central Region)  
(Department of Mines and Energy – Safety and Health)
3. Principal HSE Scientist  
Safety in mines testing and research station (Simtars)

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### Summary

Questionnaires were sent to twelve underground metalliferous mines in Queensland to enquire how these mines control diesel emissions from mobile diesel engines used underground. Where responses or controls were absent, discussion has been provided. A significant finding, concerns secondary ventilation design rates. Some mines were designing ventilation rates to meet the superseded Mines Regulation Act of 1964 which required 0.04 m<sup>3</sup>/s/kW. The current Queensland Mining and Quarrying Safety and Health Regulation (2001) is risk based. In line with other jurisdictions, including NSW and most Provinces in Canada, a minimum ventilation rate of 0.06 m<sup>3</sup>/s/kW is required. However, this design ventilation rate will vary in practice depending on the diesel engines and controls. Dedicated ventilation engineers and technicians should be appointed to evaluate the effectiveness of the ventilation system. Personal exposure monitoring is required to confirm that exposure standards are not being exceeded. The primary control practice should be to reduce the emission at source. This can be ensured by purchasing low emission (Tier 2, Tier 3) equipment. In addition, the use of ultra low sulphur fuel (< 50 ppm) with electronic engine management systems will produce lower diesel particulate matter and lower diesel particulate-related components (Bagley et al 2002). Diesel fuel with a low aromatic content such as Eromanga diesel fuel will also mean employees are exposed to lower levels of polycyclic aromatic hydrocarbons. These controls should be carried out in parallel with good maintenance practices. Preventative maintenance should be programmed and emissions routinely tested, including both gaseous and particulate pollutants and compared against defined criteria. According to McGinn 2002, there are a number of fundamental tools necessary to carry out preventative maintenance (Hedges et al 2007).

These are outlined in maintenance guidelines and best practices for diesel engines in underground mining produced for the Diesel Emissions Evaluation Program (DEEP).

An effective diesel emission management system needs to be fully integrated within the Safety and Health Management System (Hedges et al 2007). Knowing when to carry out a major engine overhaul is important and the authors suggest that 4000 hours and 8000 hours be considered the maximum operating hour time before major overhauls are required for older engines and newer engines respectively. Of course an emission based monitoring program will identify the optimum period for major overhaul.

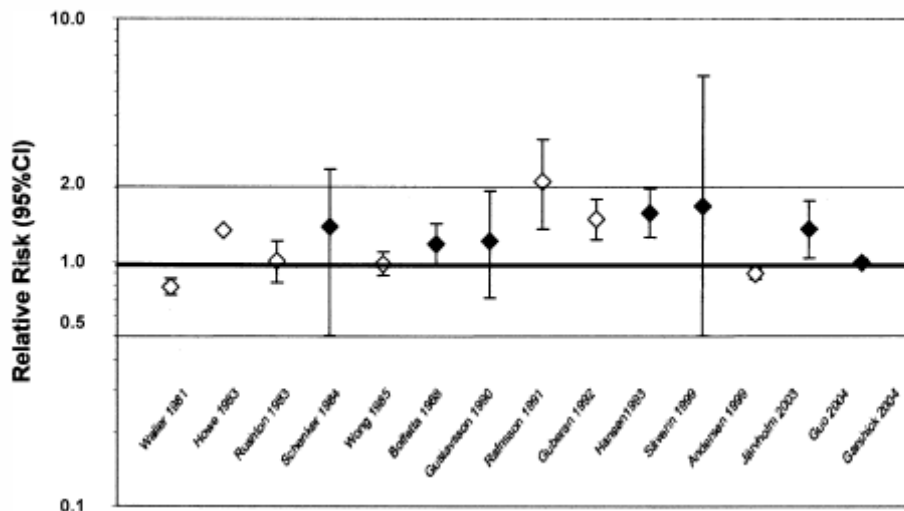
## Background

The Queensland Mines Inspectorate within the Department of Mines and Energy is concerned about the potential health effects from exposure to diesel particulate matter in underground mines. In line with sound risk management practices, this hazard should be risk assessed and the risk controlled to an acceptable industry standard. The currently accepted industry standard is 0.1 mg/m<sup>3</sup> measured as submicron elemental carbon (EC). This industry standard was first proposed by the NSW Minerals Council in 1999 and has now been recommended by the NSW Department of Primary Industries' "Guideline for the Management of Diesel Engine Pollutants in Underground Environments MDG 29 (revised draft July 2007)". BHP Billiton has adopted 0.1 mg/m<sup>3</sup> EC and the Australian Institute of Occupational Hygienists (AIOH) have published "A Guideline for the Evaluation and Control of Diesel Particulate in the Occupational Environment". This guideline refers to the Minerals Council exposure standard of 0.1 mg/m<sup>3</sup> EC. It should be noted, however, that an exposure standard has not been included in Queensland legislation. There is now an industry exposure standard, a method to assess personal exposure to element carbon (NIOSH 5040) and methods to measure the concentration of diesel particulate matter in the raw exhaust. Considerable research in Australia since the 1980s has evaluated control technologies to reduce emission. Based on this research, new technology and guidance material being made available to the mining industry, the Queensland Department of Mines and Energy considers there is now sufficient information for industry to comply with the industry exposure standard of 0.1 mg/m<sup>3</sup> EC (Hedges et al 2007).

## Health Effects

There are a number of epidemiological studies that demonstrate an association between exposure to diesel emission and lung cancer (Hoffman et al 2006). However it is important that the reader acknowledges that the studies were carried out over periods where exposures to diesel emission would have been higher than current day levels. A number of studies also highlight the "healthy worker effect". For example, the following graph (figure 1.0) shows a number of cohort studies on occupational exposure to diesel emission and lung cancer risk since 1981. Open marks indicate cohort studies with external reference group, filled marks represent cohort studies with internal reference group.

**Figure 1.0** (Source: Hoffman 2006, page 256)



A major difficulty in determining whether there is an association between the effects observed in epidemiologic studies and diesel exhaust has been accurately assessing exposure to diesel exhaust (HEI 2003).

Long-term bioassays conducted in rats, mice, and hamsters have been carried out. An increase in lung tumours has only been observed in rats and only at relatively higher levels of exposure. That is at several milligrams of diesel exhaust PM per cubic meter (HEI 2003). This concentration is well above daily averages that are typically encountered currently in mining. Notwithstanding, there is an exposure estimate, dose response study provided by Saverin et al 1999. This was the only study that could be found where quantitative exposure data was available and the incidence of lung cancer was evaluated against exposure estimates. The study assessed diesel exhaust and lung cancer mortality in potash mining. The study was unique in that the cohort followed potash miners from 1970 to 1994 and that diesels were only used in the mine from 1970. The technology had not changed over this period and among the workers there was a sub-cohort of 3,258 miners who worked underground for at least 10 years and held one single job for at least 10 years (Saverin et al 1999). The study demonstrated that the production workers who had an average exposure of 0.39 mg/m<sup>3</sup> measured as total carbon and mean exposure time of 15 years demonstrated a relative risk of 2.17 when compared with the lowest exposed group which was the workshop group who had an average exposure of 0.12 mg/m<sup>3</sup>. This study highlighted the importance of accounting for the "healthy worker effect" by comparing groups within a cohort and not with the general population. The principal finding of the study was a doubling of relative risk of lung cancer over an exposure time of 20 years. This observed elevation however was reported as being non significant even at the 90% level (Saverin et al 1999).

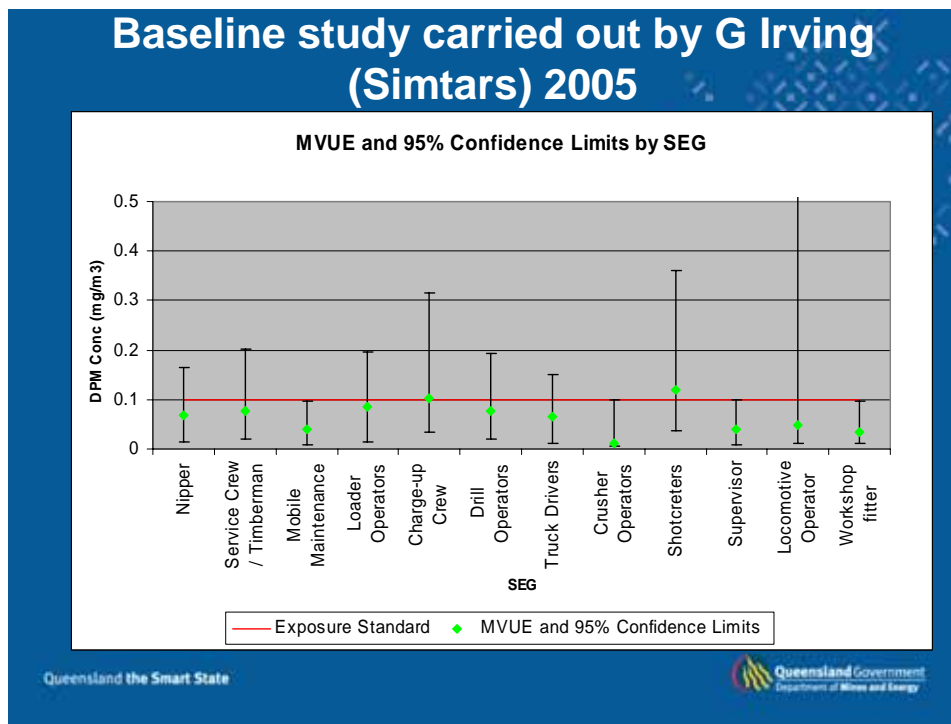
It may be many years before a dose response curve for diesel particulate matter is determined, that is, using real current-day exposure data with statistical power. However, as there is biological evidence for the carcinogenicity of diesel exhaust, supported by the induction of cancer in laboratory animals, the existence of mutagenic compounds and human cancer causing agents in the diesel emission mix and increased levels of DNA adducts in exposed workers (Hoffman 2006), diesel emission should be kept as low as reasonably achievable (ALARA).

Although the focus has been on diesel emission and lung cancer, it must be emphasized that short-term exposure to diesel exhaust particles on the respiratory and immune systems, particularly in individuals with asthma and other allergic diseases, may also be a concern. Taken together, human and animal studies suggest that diesel exhaust and other particles may induce markers of non-specific inflammation in healthy and asthmatic participants, increase symptoms of asthma rhinitis, and act as an adjuvant to increase the specific immune response to an allergen (HEI 2003).

### **What are the current levels of exposure in metalliferous mines?**

In 2005, nine underground metalliferous mines participated in a baseline exposure monitoring survey carried out by the Safety in mines testing and research station (Simtars). The survey involved measuring baseline concentrations of diesel particulate matter (EC) using personal exposure monitoring (NIOSH method 5040 2003). When the Simtars data was pooled, the upper confidence limit (Lands Exact) exceeded the recommended guideline limit of 0.1 mg/m<sup>3</sup> (EC). To qualify these findings, only small pools of samples were collected from each mine. As the samples were taken over three consecutive days, the results may not be statistically representative of longer term exposure. Albeit, as most mines found that a significant percentage of samples taken exceeded the limit, it was unlikely that more representative sampling data would fall within the limit (Hedges et al 2007).

**Figure 2.0** Baseline monitoring results for metal mines in Queensland.



Source (Irving 2006)

#### Recommendations provided by Simtars

From the monitoring results, Simtars recommended the following:

- Data limitations highlight the need for including monitoring diesel particulate matter in existing monitoring programs for dusts, noise, etc
- Facilitate collection of more exposure data
- Better define the extent of exposures in the industry
- Increase awareness of the issue
- Low sulphur fuel
- Driver education
- Targeted engine maintenance and regular testing
- After-market exhaust treatment, if necessary.

#### Recommendations provided by the Mines Inspectorate.

- A Safety and Health Management System that includes a policy to control and monitor all underground atmospheric contaminants, through mine design, purchasing, maintenance and management follow-up.
- A purchasing policy that includes the technical specifications and requirements for:
  - Compliance with legislation and if applicable, say for Toyota personnel carriers, compliance with Australian Design Rules
  - Use of ultra low sulphur automotive diesel fuel that complies with the *Fuel Quality Standards Act 2000*
  - Tier 2 or 3 rated diesel engines for off highway engines used underground
  - Exhaust treatment devices
  - Enclosed cabins on vehicles that supply pressurised and filtered air to the vehicle operator, and passengers

- A maintenance scheme that controls and monitors engine emissions through workshop schedules and routines that include:
  - Regular engine tuning, including routine cleaning or replacement of air filters to ensure optimum air/fuel ratios
  - Measuring and recording the treated engine emissions under established load/flight criteria at each routine service or when other engine work is performed
  - Monitor and record backpressure on exhaust treatment devices at each routine service and clean or service in accordance with manufacturers specifications
  - Replacement of engines based on established wear or emission criteria.
- In development and production environments, a mine ventilation design that ensures, *measures are taken to ensure the ventilating air in a place where a person may be present at the mine is of a sufficient volume, velocity and quality to achieve a healthy atmosphere (Mining and Quarrying Safety and Health Regulation 2001 section 48).*

The size and complexity of the diesel exhaust emissions controls will be dependant on the size and complexity of the underground mine and whether other environmental factors such as temperature, dust and noise are included in the integrated management plan.

Catalytic converters are effective in reducing emission while water scrubbers are used primarily as spark arrestors (Hedges et al 2006).

### Questionnaire Responses.

Responses to a questionnaire issued to underground mines were tabulated and analysed (*refer to Table 1.0*). This was carried out to assess whether responses to all questionnaires were consistent and to determine if, in fact, a system existed that covered specific practices. All of the responses were pooled and assessed to identify the main gaps. These main gaps have been presented as follows:

**Table 1.0**

*Main gaps from questionnaire responses.*

Parameter:	Sulphur in fuel	Ventilation	Maintenance	
Mine Id	Nominal sulphur (ppm)	Secondary ventilation design rate (m3/s/kW)	Exhaust back pressure monitored.	Procedure to diagnose after exhaust treatment.
8	45	0.05	No	Yes
7	45	0.05	No	Yes
6	45	0.05	No	Yes
5	500	0.06	No	No
4	500	0.06	No	Yes
12	<500	0.05	Yes	Yes
10	500	0.04	No	Yes
1	100	0.04	No	No
9	320	0.04	No	No
11	Not reported	0.05	Yes	Yes
3	200	0.04	Yes	No

*Source (Hedges et al 2006)*

### Sulphur in diesel fuel.

When responses were received in early 2005, all mines were meeting the requirements specified in AS3570 (amended 1999), automotive fuel standard, which specified a limit for sulphur of 500 ppm and Fuel Quality Standards Act 2000 which also specified 500 ppm. However, according to [Fuel Quality Standards Act 2000](#) as of 1<sup>st</sup> January 2006 the specification (limit) has been reduced to 50 ppm (Hedges et al 2007).

**Table 2.0 Sulphur specifications.**

<b>Year</b>	<b>Sulphur Content (ppm)</b>
Pre 2003	1300 – 5000
2003 – 2005	300 – 500
2006	50
2009 – 2010	10

(Source: Fuel Quality Standards Act 2000).

When interpreting the *Fuel Quality Standards Act 2000*, other parameters including aromatic content must be considered. Although Eromanga fuel has a typical sulphur content of 100 ppm, the lower aromatic content should ensure that employees are exposed to significantly lower levels of poly-cyclic hydrocarbons (PAH) (BHP Billiton 2005). Albeit, personal exposure monitoring is required to verify that the industry exposure standard of 0.1 mg/m<sup>3</sup> EC is not being exceeded.

[Bagley et al \(2002\)](#), notes that the use of low sulphur diesel fuels reduces the sulphate fraction of diesel particulate matter (DPM) emission, reduces objectionable odours associated with diesel use and allows oxidation catalysts to operate properly. A further benefit in the use of low sulphur fuel is reduced engine wear and maintenance costs. During research carried out by Bagley et al (2002) it was found that:

*“Electronically controlled modern diesel engines, with ultra low sulphur fuel (34.2 ppm), in an underground mine under study resulted in large reductions in diesel particulate matter and all diesel particulate-related components. The measured potentially health related components showed similar reductions”.*

[Schnakenberg et al 2002](#), notes that, *“during fuel combustion, the sulphur oxidizes to produce sulphur dioxide (SO<sub>2</sub>), a fraction (<5%) of which can be further oxidized to sulphur trioxide, SO<sub>3</sub>, which combines with water to form a sulphuric acid aerosol Studies with low-sulphur fuel revealed that the number of relatively large particles (>0.040 µm) remains unaffected when fuel with ultra low sulphur content is used.*

*In contrast, low sulphur content is found to reduce the concentration of nano-particles (<0.040 µm) by several orders of magnitude, revealing that most particles of this size are sulphur-related”.* This is an important point as health professionals are both concerned and uncertain about the health effects of nano-particles (Hedges et al 2007).

### **Ventilation**

The secondary ventilation design rates are also lower than expected. It is stated in the Diesel Emissions Management Guideline (BHP Billiton, 2005) that: “Generally the ventilation flow requirement in underground mines in Australia ranges from 0.06 to 0.1 m<sup>3</sup>/s/kW”.

### **Queensland**

There are no statutory prescribed ventilation rates to dilute internal combustion engine pollutants in the Queensland Mining and Quarrying Regulation 2001, nor are there in the Coal Mining Safety and Health Regulation 2001. The Mining and Quarrying Safety and Health Regulation 2001, instead applies a risk management approach in section 48, where:

*A person who has an obligation under the Act to manage risk in relation to ventilation at a mine must ensure that appropriate measures are taken to ensure the ventilating air in place where a person may be present in the mine is of sufficient volume, velocity and quality to achieve a healthy atmosphere.*

## **New South Wales**

The recently promulgated NSW Coal Mine Health and Safety Regulation 2006 has kept the section on special ventilation required at certain places (section 114); where

*The volume of air in each place where a diesel engine operates must be such that a ventilating current of not less than:*

*0.06 cubic metres per second for each kilowatt of maximum output capability of the engine, or*

*3.5 cubic metres per second, whichever is greater, is directed along the airway in which the engine operates.*

*If more than one diesel engine is being operated in the same ventilating current, the engine kilowatts must be added and the minimum ventilation requirement is 0.06 cubic metres per second per kilowatt or 3.5 cubic metres per second, whichever is greater.*

## **Western Australia**

The WA *Mines Safety and Inspection Regulations 1995, Part 10 Division 4, 10.52 (5)* notes the following:

*The airflow in any workplace in which a diesel unit is operated must be not less than 2.5 cubic metres per second. A sufficient volume flow of air must be maintained in each workplace in which a diesel unit is operated to dilute the engine exhaust gases to the lowest practicable levels, and this volume flow must not in any case be less than the minimum ventilation flow specified in this regulation.*

*The minimum ventilation volume rate of air required for each diesel unit is:*

*If the maximum exhaust gas emissions of the engine in a diesel unit contain less than 1 000 ppm of oxides of nitrogen and less than 1 500 ppm of carbon monoxide, the diesel unit must have a ventilation volume rate of not less than 0.05 cubic metres per second per kilowatt.*

*If the maximum exhaust gas emissions of the engine of a diesel unit contain not less than 1 000 ppm oxides of nitrogen or not less than 1 500 ppm of carbon monoxide, the diesel unit must have a ventilation volume rate of not less than 0.06 cubic metres per second per kilowatt.*

**Table 3.0** In Canada, Diesel Engine Certification Requirements are as follows:

CANMET Mining and Minerals Sciences Laboratories			
Diesel Engine Certification / Ventilation Requirements			
<u>Engine Certification</u>			
Province / Territory	CSA	MSHA	Ventilation notes
New Brunswick	Yes	Yes	Certification required for engines above 75kW. Minimum ventilation of 0.067m <sup>3</sup> /s/kW.
Nova Scotia	Yes	Yes	A Certificate that machine exceeds better level of safety is also acceptable.
Newfoundland and Labrador	-	-	Requires diesel machine specifications and written approval from the Chief Inspector of Mines. Minimum ventilation of 0.047 m <sup>3</sup> /s/kW.
Northwest Territories and Nunavut	-	-	Requires a permit from the Chief Inspector. Minimum ventilation of 0.06 m <sup>3</sup> /s/kW.
Yukon	Yes	-	Other similar approvals may also be accepted by the Chief Inspector of Mines. Minimum ventilation of 0.06 m <sup>3</sup> /s/kW.
British Columbia	Yes	-	Ventilation as per CSA standard. Minimum ventilation of 0.06 m <sup>3</sup> /s/kW.
Alberta	Yes	-	Ventilation as per CSA standard. Minimum velocity of 1.9 m <sup>3</sup> /s at active headings.
Saskatchewan	See notes	-	Ventilation as per CANMET engine approval, or a minimum of 0.063 /m <sup>3</sup> /s/kW
Manitoba	Yes	Yes	Ventilation as per CANMET or MSHA approval. Minimum of 0.092 m <sup>3</sup> /s/kW for non-approved engine. For multi-engines, ventilation using 100/75/50 rule and minimum ventilation of 0.045 m <sup>3</sup> /s/kW.
Ontario	-	-	Minimum ventilation of 0.06 m <sup>3</sup> /s/kW.
Quebec	Yes	See notes	Ventilation as per CANMET or Part 31/32 of MSHA (not the current part 7). Minimum of 0.092 m <sup>3</sup> /s/kW for non-approved engines. For MSHA engines, ventilation using 100/75/50 rule and minimum ventilation of 0.045 m <sup>3</sup> /s/kW.

(Source: Canadian Underground Mining Regulations for Diesel Engines 12<sup>th</sup> Annual MDEC Conference)

From the above the minimum ventilation requirement for the majority of Canada's Provinces / Territories is at least 0.06 m<sup>3</sup>/s/kW (Hedges et al 2007).



## Maintenance

As indicated in *table 1.0*, responses indicated that mines generally did not:

- Monitor exhaust back pressures and some mines did not carry out preventative maintenance of exhaust after treatment systems (catalytic converters).

[According to the Maintenance Guidelines and Best Practices for Diesel Engines in Underground Mines](#) produced for the Diesel Emissions Evaluation Program (DEEP):

- Air intake restrictions and leaks and exhaust back pressure should be regularly monitored.
- In addition, exhaust aftertreatment systems also should be maintained and problems diagnosed and treated.

In Canada, the Diesel Emissions Evaluation Program (DEEP) developed a technical committee to develop guidance material for diesel engines used in underground mining. The material was developed based on research and good maintenance practices primarily in the metalliferous mining industry which has direct relevance to the underground mines of Northern Queensland.

The Canadian guidance material provided for a three-year mandate to produce a toolbox of technologies and information on control and reduction of diesel particulate matter in the underground mining environment.

From the above, six engine systems have been targeted for improved engine maintenance:

- intake system
- exhaust system
- fuel injection system
- cooling system
- fuel quality and handling
- lubrication system.

Further information is available on the Diesel Emissions Evaluation Program (DEEP) website <http://www.deep.org/> and specifically in the following documents:

- [The relationship between diesel engine maintenance and exhaust emissions.](#)
- [Maintenance guidelines and best practices for diesel engines in underground mining.](#)
- [Diesel engine maintenance audit plan.](#)
- [Diesel emissions mechanics maintenance manual.](#)
- [Diesel emissions instructors guide.](#)

The above guides can be used as platforms to further develop and improve diesel engine maintenance programs in the Queensland underground metalliferous mining industry (Hedges et al 2007).

In addition to the above THE US Mine Safety and Health Administration has issued a Public Information Bulletin to disseminate its evaluation technique to determine the maximum total exhaust system backpressure for diesel-powered underground machines. The information can be accessed via the following link:

<https://lakegovprod1.msha.gov/ReportView.aspx?ReportCategory=EngineAppNumbers>

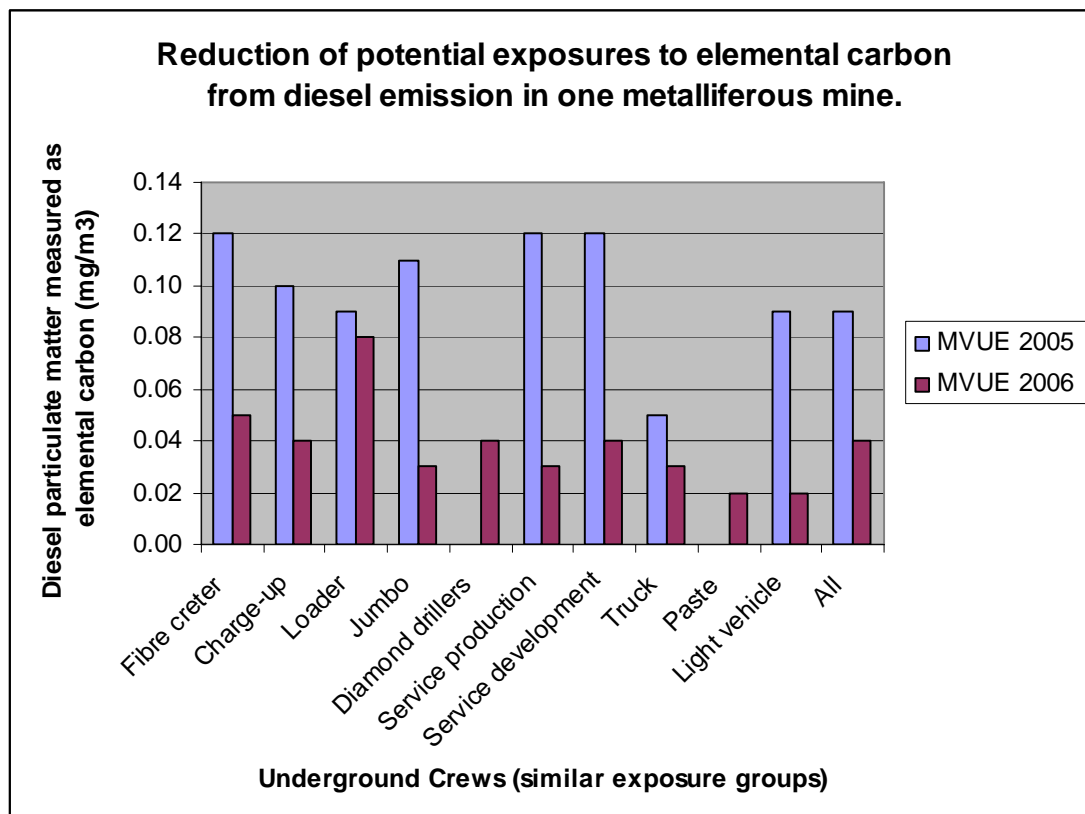
### **Current status in Queensland underground metalliferous mines.**

Mines that participated in the initial baseline monitoring and survey have been requested, in writing, to identify what progress has been made to reduce potential exposures. Responses revealed that, since the survey, poor performing had engines been fitted with new injectors and in some situations removed from service and replaced with new engines. At one mine larger machines were replaced with smaller units.

The same mine reported extensive improvements were made to the underground ventilation systems and active reporting of emission issues as part of the pre-start protocol. Monthly exhaust gas emission tests are being conducted and weekly maintenance schedules include checks on air-conditioning systems and seals on cabins. Education of the workforce has been carried out to reinforce ventilation standards and emphasize the importance of keeping cabin doors and windows closed. Work horizons have also been extended to additional ore bodies to reduce the number of vehicles working on a single ore body.

In one particular mine a rule was introduced which stated “where diesel units have no air-conditioning they will not be operated”. Preventative maintenance practices are generally in place including raw exhaust gas testing. However, it was noted by at least one mine that there is no scheduled maintenance of catalytic converters and that work is only performed when a problem is identified. Some mines are still designing minimum ventilation rates to meet the superseded Mines Regulation Act of 1964 which required 0.04 m<sup>3</sup>/s/kW. As discussed previously, industry good practice generally requires a minimum of 0.06 m<sup>3</sup>/s/kW. At this stage, ongoing diesel particulate exposure monitoring is not being carried out by all metalliferous mines, nor is this monitoring integrated into an overall exposure monitoring program. There were exceptions. One mine provided 88 elemental carbon sample results for monitoring carried out since the initial survey. *Figures 1.0 and 2.0* demonstrate a major reduction in both the estimated average exposures and percentage of exposures above 0.1mg/m<sup>3</sup> EC. The mine represented in *figures 1.0 and 2.0* reported carrying out a complete engine midlife service including replacement of injectors, turbo-chargers and water pumps. They also noted that performance tests were carried out every 2000 hours and that the air filters were routinely replaced and catalytic converters were inspected and tested at 250 hr intervals. Since 2005, two full time dedicated personnel had also been assigned to monitor and improve the ventilation.

**Figure 3.0.**



**Note:** n = ≥ 5 samples for each similar exposure group.

Follow-up to determine why a higher result obtained from the loader operator in 2006 of 0.46 mg/m<sup>3</sup> (EC) revealed that the heading where the loader was being operated remotely was inadequately ventilated. This single result has skewed the similar exposure group (SEG) which resulted in a higher average. It is interesting to note that this mine reported using diesel fuel with a typical sulphur content of 100ppm and that this specification had not changed (Hedges et al 2007).

### Current status in Queensland underground coal mines.

In 2001, underground coal mines in Central Queensland began to actively monitor personal exposures to DPM. The majority of underground coal mines in Queensland now include DPM in their routine atmospheric personal monitoring programs. In the Queensland underground coal mining industry a steering committee was established in February 2004 with representatives from the Inspectorate, industry and the Construction, Forestry, Mining and Energy Union (CFMEU). Thirteen (13) quarterly meetings have been held to date. The committee's objectives are to overview the development and introduction of management plans to minimise the exposure of coal miners to diesel exhaust pollutants including diesel particulate matter. Initially, the meetings were chaired by the Mines Inspectorate. The last few meetings, have, however, been chaired by representatives from industry which demonstrates that there has been a shift in ownership and accountability towards industry. These meetings have also provided an invaluable opportunity for mines to discuss maintenance techniques that reduce DPM emissions (Hedges et al 2007). A recent initiative of the committee has been to produce an industry report that provides statistically valid information on the state of personal DPM exposures in QLD underground coal mines for the period 2004 – 2007. All personal monitoring results have been provided to the Department of Mines and Energy who are facilitating this project through the steering committee. The majority of underground mines have included diesel emission testing as part of their routine maintenance program. Some of these mines have conducted extensive baseline monitoring and established diesel particulate limits for their diesel fleet (Figure 4.0). Vehicles exceeding or approaching these maximum limits are removed from service and subject to maintenance. These limits are continuously being reviewed and adjusted as reductions in DPM are achieved through best practice maintenance procedures.

**Table 4.0** Tail pipe limits established by a Central QLD Coal Mine for their Diesel Fleet.

Equipment	Engine	Maximum DPM Limit (mg/m <sup>3</sup> )	Maximum Average DPM Limit (mg/m <sup>3</sup> )
Eimco 913	Cat 3304	80	40
Eimco 975	Cat 3304	80	40
Eimco trencher	Cat 3304	80	40
Grader	Cat 3304	80	40
Eimco EJC130	Cat 3306	120	60
Eimco ED10	Cat 3126DITA	100	55
Eimco 913-6	Cat 3306	120	60
Eimco chock carrier	Cat 3306	120	60
SMV Drifrunner	Perkins 1000/6	120	50
SMV Ranger	Perkins 1000/4	80	40
Bobcat	Perkins 1000/4	80	40
Juganaut	Hino	40	25

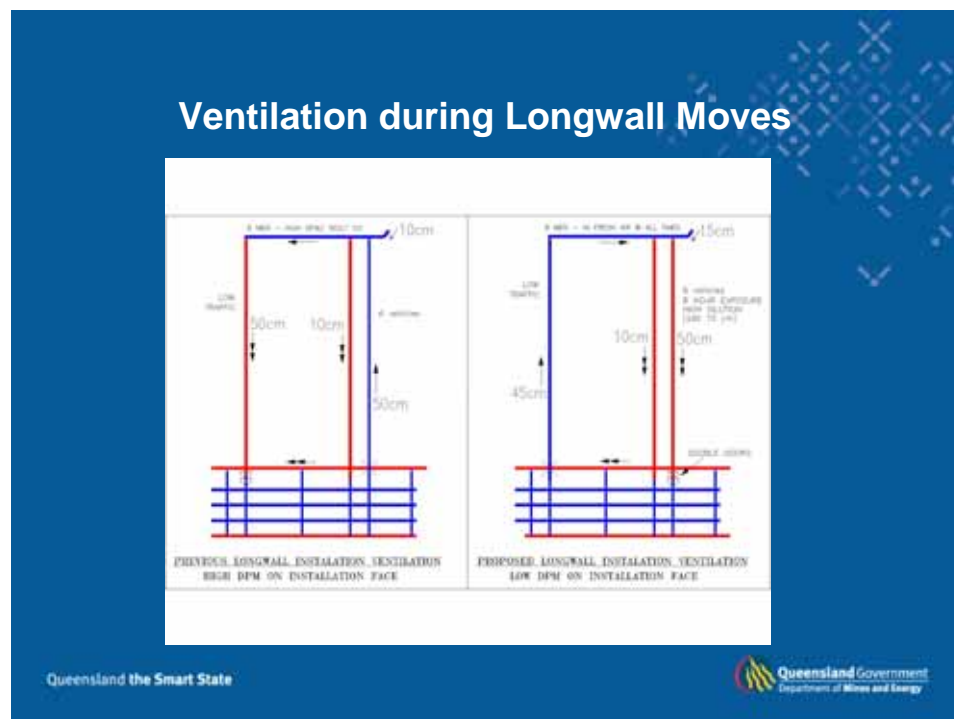
One mine has demonstrated that significant reductions in DPM can be achieved through relatively simple procedures such as adjusting valve clearances back to manufactures specifications and by replacing/rebuilding injectors at regular intervals (ie. 1000 hours). Another mine is using results from exhaust testing as a diagnostic tool to trigger specific maintenance procedures related to engine tune. Not only does high diesel exhaust impact on workers exposure to DPM, it is also an indication of poor engine performance. Engine life has been extended through vigilant exhaust testing and by early response to elevated levels. In addition, the extensive gathering of raw exhaust results has been invaluable for establishing maintenance regimes.

A diesel emissions database has been created by Simtars through funding from industry. This database enables mines to record measured emissions from diesel mining equipment and link them to the engine serial numbers. This will provide particular benefits for tracking the operating history of contractor and hire vehicles. Popularity of this database is increasing and recent improvements to the system have made it more user-friendly.

Preliminary trials on the benefits of bio-diesel are currently being explored through a joint effort of two central Queensland coal mines. A drift runner and a PJB will be switched to bio-diesel and mounted on a chassis dynamometer. Monitoring and observation will be conducted to investigate parameters such as diesel particulates and raw gas produced, engine performance, engine power and fuel consumption.

One mine in central Queensland has demonstrated that by changing the ventilation splits around the panel during a long wall installation, worker exposures to DPM on the face can be significantly reduced. The tailgate road was converted to an intake airway and both main-gate roadways carried return air. All tramming of equipment is performed up the main-gate roadway which ensures that the majority of DPM is exhausted down the return prior to reaching the face where the majority of personnel occupy.

**Figure 4.0** Changes to ventilation split during long-wall installation.



An audit tool has been drafted and made available to coal mines in the central region. To date, four mines have been audited against this tool and more audits are being scheduled to include all underground coal mines in Queensland.

### **Current status in NSW in underground coal mines.**

The NSW coal industry has over many years, introduced controls to both monitor and control diesel emission. More recently Coal Mine Technical Services (CMTS) have provided an elemental carbon testing service. Illawarra Coal has developed a system by which the raw exhaust elemental carbon levels can be measured using a R&P Inc Series 5100 diesel particulate matter analyser mounted in a trailer. In addition, two portable units – the SKC diesel detective and TSI Dust TRAC with moisture removal system – have been evaluated for accuracy and repeatability. In NSW a committee has been revising MDG 29 Guidelines for Diesel and Operator Environment Testing in Underground Coal Mines (July 1995). The draft guideline nominates three-monthly testing, including diesel particulate matter, of all registered diesel engines and submission of the results to the NSW Department of Primary Industries (DPI). Each engine will be given a profile and a tolerance of + 15% will be applied as a limit. The final guideline will support existing NSW Legislation. A guidance note will be developed following the same consultative process under the *Queensland Mining and Quarrying Safety and Health Act 1999*, which is expected to dovetail with MDG 29.

### **Conclusion**

Through the NSW Department of Primary Industries, the guideline for the Management of Diesel Engine Pollutants in Underground Environments (MDG 29) has been revised. BHP Billiton has established guidelines to assist in the development of a strategy to reduce emissions. The Queensland coal industry has a well established and progressive steering committee which has continued to have good representation from the Construction, Forestry, Mining and Energy Union (CFMEU), industry, Simtars and the Queensland Mines Inspectorate. The guidelines provided through DEEP (<http://www.deep.org/>) can be used as platforms to further develop and improve diesel engine maintenance programs in the Queensland underground mining industry. Some underground metalliferous mines in Queensland should be aware of the rationale behind the design of ventilation rates. The mine ventilation design should *ensure the ventilating air in a place where a person may be present at the mine is of a sufficient volume, velocity and quality to achieve a healthy atmosphere (Mining and Quarrying Safety and Health Regulation 2001)*.

Monitoring results from one underground metalliferous mine in the northern region of Queensland has demonstrated that meeting the nominal industry occupational exposure standard (0.1 mg/m<sup>3</sup>) of diesel particulate matter (measured as elemental carbon EC) is achievable.

The increased risk of lung cancer, from exposure to DPM is the subject of ongoing research. Until a dose response curve is determined, that is, using real current-day exposure with statistical power there will be uncertainty. Notwithstanding, the irritant properties of exposure to DPM should not be ignored. Meeting the abovementioned industry standard will reduce irritant effects.

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