Diesel Particulate Matter in Underground Mines—Controlling the Risk

by Kevin Hedges, Fritz Djukic and Gavin Irving

Summary

Questionnaire responses received from twelve underground metalliferous mines revealed that some mines were designing ventilation rates to meet the superseded Mines Regulation Act of 1964 which required 0.04 $m^3/s/kW$. In line with other jurisdictions, including NSW and most Provinces in Canada, a minimum ventilation rate of 0.06 $m^3/s/kW$ is required.

Dedicated ventilation engineers and technicians should be appointed to evaluate the effectiveness of the ventilation system. The primary control practice should be to reduce the emission at source. This can be ensured by purchasing low emission 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.

Preventative maintenance should be programmed and emissions routinely tested, including both gaseous and particulate pollutants and compared against defined criteria.

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.

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^3 measured as submicron elemental carbon (EC). 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.

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.

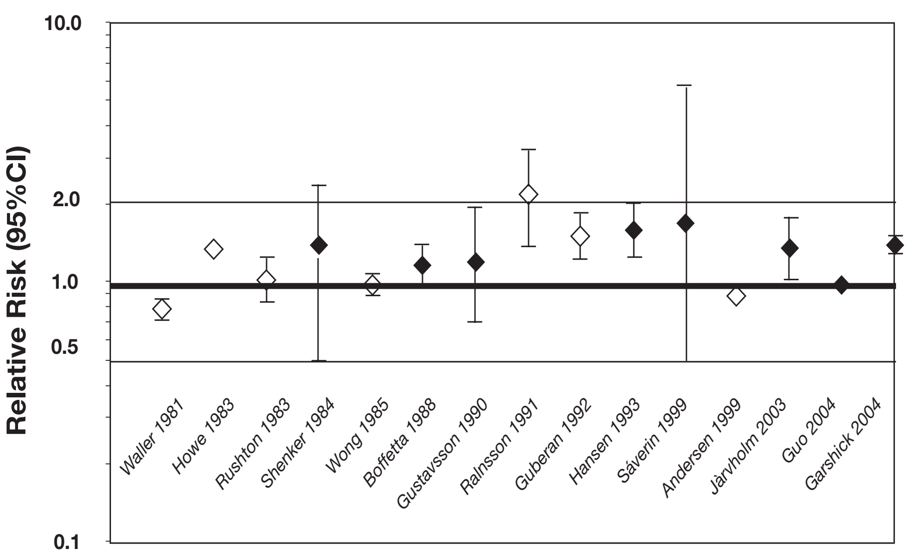

Fig. 1. (Source: Hoffman 2006, page 256.)

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).

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 diesel emission should be kept as low as reasonably achievable (ALARA).

It must be emphasised 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.

What are the current levels of exposure in metalliferous mines?

In 2005, nine underground metalliferous mines participated in a baseline personal exposure monitoring survey carried out Simtars.

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.

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; and
- 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; and
- A purchasing policy that includes the technical specifications (refer to Hedges et al 2006).

Ventilation

The secondary ventilation design rates are also lower than expected.

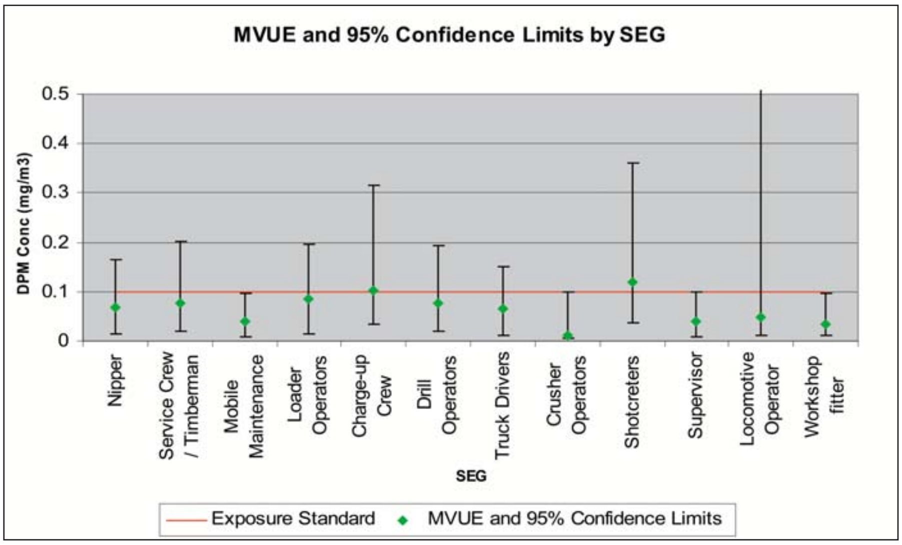

Fig. 2. Baseline monitoring results for metal mines in Queensland. (Source: Irving 2006)

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 $m^3/s/kW$".

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.

Canada

The majority of Canada's Provinces/Territories are at least 0.06 $m^3/s/kW$ (Hedges et al 2007).

Maintenance

Questionnaire responses, received from underground metalliferous mines in 2005, 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) http://www.deep.org/:

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

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.

Education of the workforce has been carried out to reinforce ventilation standards and emphasise 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."

As part of their exposure monitoring program, one mine provided 88 elemental carbon sample results for monitoring carried out since the initial survey. The results demonstrated a major reduction in both the estimated average exposures and percentage of exposures above 0.1mg/m^3 EC. This mine also reported carrying out a complete engine midlife service including replacement of injectors, turbo-chargers and water pumps. Since 2005, two full time dedicated personnel had also been assigned to monitor and improve the ventilation.

Current status in Queensland underground coal mines

The majority of underground coal mines in Queensland now include DPM in their routine atmospheric personal monitoring programs.

The underground coal mining industry established a steering committee was in February 2004 with representatives from the Inspectorate, industry and the Construction, Forestry, Mining and Energy Union (CFMEU). Fourteen quarterly meetings have been held to date. 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 provided an invaluable opportunity for mines to discuss maintenance techniques that reduce DPM emissions (Hedges et al 2007).

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 (i.e. 1000 hours).

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. Preliminary trials on the benefits of bio-diesel are currently being explored. 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.

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).

We have demonstrated that meeting the nominal industry occupational exposure standard (0.1 mg/m^3) 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. Meeting the abovementioned industry standard will reduce exposures and the level of risk to as low as reasonably achievable (ALARA).

The original paper titled “Diesel Particulate Matter in Underground Mines – Controlling the Risk” K Hedges, F Djukic, G Irving and T Fisher was presented at the ***The AusIMM New Leaders’ Conference 2-3 May 2007*** *and sections of this paper have been reproduced with permission.*

References

Standards Australia AS3570 – 1998, *Automotive Diesel Fuel*, 1998 (Amended 1999).

Standards Australia AS4801 – 2001, *Occupational health and safety management systems – specification with guidance for use.*

Diesel Emissions Evaluation Program (DEEP). http://www.deep.org/

Diesel Emissions Mechanics Maintenance Manual. DEEP Technology Transfer. http://www.deep.org/techtrans.html

Diesel Emissions Instructors Guide. DEEP Technology Transfer. http://www.deep.org/techtrans.html

HEI Program Summary Research on Diesel Exhaust and Other Particles Health Effects Institute © 2003 Charlestown Navy Yard, 120 Second Avenue, Boston MA 02129-4533 USA http://www.healtheffects.org/Pubs/DieselProgrSumm2003.pdf

Hoffman B, Jockel K (2006); Diesel exhaust and coal mine dust. Lung cancer in occupational settings. Ann. N.Y. Acad. Sci. 1076: 253-265 (2006). Institute of Medical Informatics, Biometry and Epidemiology, University Clinics of Essen, 45122 Essen, Germany.

IARC (International Agency for Research on Cancer) Monographs on the Evaluation ofthe Carcinogenic Risk of Chemicals to Humans: Diesel and Gasoline Engine Exhausts and Some Nitroarenes, Vol. 46, IARC, World Health Organization, Lyon, France. 1989.

Hedges K, Djukic F, Irving G, Fisher T (2007) *Diesel Particulate Matter in Underground Coal Mines – Controlling the Risk*. Paper presented to the Australian Institute of Mining and Metallurgy (AusIMM) New Leaders Conference Brisbane Queensland, 2 – 3 May 2007.

Irving G (2006) *Diesel Particulate Matter in Queensland’s underground metal mines*. Paper presented to the Queensland mining industry health and safety conference 2006 coping with growth.

NIOSH (2003), NIOSH Analytical Method 5040 – Diesel Particulate Matter (as Elemental Carbon), NIOSH Manual of Analytical Methods.

Queensland The Mines Regulation Act of 1989. The Mines Regulation Act of 1964 Amended by Mines Regulation Act Amendment Act 1989, No. 101 (Superseded).

Queensland Mining and Quarrying Safety and Health Regulation (2001). ■