PERSONAL EXPOSURE TO DIESEL PARTICULATES

Ken Cram, Joint Coal Board
Brian Davies, AEHS Pty Ltd
Alan Rogers, OH & S Pty Ltd

SUMMARY

Diesel vehicles have been part of the Australian coal Mining industry for approximately 50 years. During that time concern has risen within the Industry as to possible adverse health effects from exposure to engine exhaust fumes. More recently MSHA has moved to legislate for the reduction of diesel particulate exposures by 95% in USA coal mines on the basis of an increased risk of lung cancer. While the scientific community debates the issue of lung cancer risk, considerable anxiety will arise within the mining community, which will need to be addressed.

Considerable research has occurred throughout the world as to the health effects of diesel emissions, appropriate monitoring methods and control strategies. Unfortunately, much of this research is difficult to access and thus a complete picture of this very complex topic is difficult to establish. If the Australian coal industry is to address this issue all stakeholders need to be made aware as to the situation with diesel emissions future research, exposure standards, risk management to achieve operational benefits.

INTRODUCTION

Diesel engines are widely used in mining operations because of their high power output and their increased mobility. Traditionally many mine operators have preferred diesel-powered machines because they have been more powerful than most battery-powered equipment and less restrictive than electrical trailing cable machines.

Diesel powered equipment has been extensively used in Australian underground mines for many years. In Australian underground coal mines, there is nearly 2,000 diesel powered vehicles and this is increasing. Similar trends overseas the USA underground industry has over 10,000 diesel machines with 3,000 in underground coal mines (MSHA 1997).

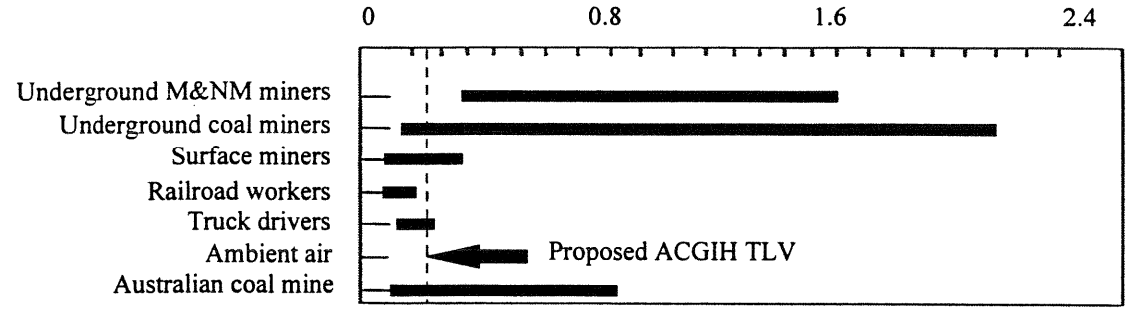
In the environment of underground mines there is a downside to the use of diesel equipment. The problem is the potential acute and long term health effects of exposure to various constituents of diesel exhaust, which consists of noxious gases and very small particulates. The gases in the diesel emissions are well known and understood. The gases have specific limits which are regularly measured and monitored in industry. The particles in the diesel emissions are known as >diesel particulate= (DP). DP from the exhaust consists of tiny particles, which are small enough to be inhaled and retained in the lungs. The particles have hundreds of chemicals from the exhaust absorbed/attached onto their surfaces. The mining community is very familiar with the specific hazards long associated with other particulates of respirable dimensions - like coal mine dust and dust containing silica.

Control of diesel exhaust levels in NSW & Qld is partly determined by monitoring the gaseous components such as the NO_X and CO in raw exhaust (CMRA, 1982)

DIESEL PARTICULATE EXPOSURE

Over the last 10 years diesel particulate has been the centre of increasing scientific interest due to the growing concerns being expressed as to the potential for adverse health effects from occupational exposure. Regulatory authorities and concerned groups in countries such as the USA, Germany, Switzerland and Canada are translating this concern into workplace exposure standards. Currently the American Conference of Governmental Industrial Hygienists (ACGIH) has proposed a general exposure standard for DP of 0.15mg/m; (elemental carbon) and a similar exposure standard for the USA mining industry is imminent.

Many non-mining workplaces where diesel equipment is used have levels of DP well below the recommended ACGIH exposure standard. In contrast studies conducted by various scientific researchers demonstrate that exposures to DP in mining environments can be significantly higher than exposures in the ambient air or in other workplaces as shown in Graph 1. (Davies 1997).



GRAPH 1

USA Data – Personal Exposures Diesel Particulate mg/m³

OVERSEAS RESEARCH

Considerable research has been conducted in various parts of the world by bodies such as the US Bureau of Mines, British Coal, CANMET, on the subject of diesel aerosol particulates. Unfortunately, little published data exists of individual workers personal exposure and that which has been published is difficult to compare because of different operational conditions between Australia and overseas countries.

It is also important to understand how overseas data has been collected as serious errors can arise if comparisons are not made based on the same sampling technique. Having recognised these limitations, some US data is provided in Table 1 (ACARP 1995)

LOCATION	mg/m; DAP
Mine 1	0.25-0.9
Mine 2	0.1 -1.0
Mine 3	0.1 -0.7
Mine 4	0.05-1.0
Mine 5	0.05-3.5
Mine 6	0.4-6.4

TABLE 1

Diesel Aerosol Particulates in US Underground Coal Mines (From US Bureau of Mines & American Mining Congress)

In 1995 the US Mine Safety and Health Administration (MSHA) established an internal working group to explore measures to reduce miners= exposure to DP. This group organised a series of workshops to solicit input from the mining community. The experience of the mining community appears to support several conclusions.

- The levels of exposure to DP in mines depends upon engine exhaust emissions, the use and efficiency of exhaust after treatment technology. In underground mines ventilation rate and system design is important.
- Engine emissions are governed by engine design, work practices, duty cycle, fuel quality and maintenance. Reducing engine emissions will decrease the amount of DP that needs to be controlled by other means and will reduce the exposure of miners.
- There is no single emission control strategy that is a panacea for all problems.
- Monitoring is necessary to evaluate a DP control programme.

AUSTRALIAN RESEARCH

In the early 1990's BHP Coal Illawarra Collieries conducted research into employee exposure to diesel exhaust emissions at Tower Colliery. As a result of that preliminary research an ACARP Project No C3080 was developed to evaluate four possible control measures evaluated for effectiveness, suitability and practicality during 1994/95. Exposure data was also collected at 8 other NSW underground coal mines (ACARP 1995).

All samples collected were on a full shift personal basis with a minimum of four hours sampling duration. In all, a total of 134 personal samples were collected at the eight collieries. A summary of these results is reported in Table 2.

MINE	COALFIELD	DAP mg/m;
A	Northern	0.14-0.56
B	Western	0.15-0.31
C	Southern	0.03-0.17
D	Southern	0.06-0.47
E	Southern	0.04-1.65
F	Western	0.13-0.32
G	Northern	0.06-0.62
H	Southern	0.10-0.25

TABLE 2

Summary of Personal Monitoring for DAP at Eight NSW Coal Mines

A detailed breakdown of the exposures of various machine operators is provided in Table 3.

Machine Operator	DAP mg/m;
Shearer Transporter	1.7
Chock Transporter	0.3-0.7
Eimco	0.15-0.3
MPV	O.15-0.25
PJB	0.05-0.2
Domino	0.05-0.1
DMC	0.1-0.5
Wagner	0.2-0.25
Grader	0.1-0.6
Myne Bus	0.3
Loco	0.1-0.3

TABLE 3
Breakdown of Exposures for Machine Operators at The Eight Mines Sampled

As a result of extensive testing project No C3080 concluded that:

- Chemical decoking of engines does reduce employee exposure to diesel aerosol particulates.
- Cleanliness of water-filled scrubber tanks does not in general relate to their efficiency in reducing DP.
- Cleanliness of air intake filters does not affect DP emissions unless they are completely blocked.
- Disposable exhaust filter systems are highly effective in reducing diesel aerosol particulate emissions.
- Reasonable relationships between diesel aerosol particulates and increasing airflow exist for two vehicles currently used in NSW coal mines, however the existence of a uniform relationship to cover all vehicles is unclear.
- The use of multiple vehicles in the one heading can have a significant affect on the ventilation pattern in that heading.
- Sampling at eight NSW underground coal mines confirmed the extensive employee exposure database previously collected at Tower Colliery. In all cases the highest levels were experienced during longwall transfers.

JOINT COAL BOARD HEALTH & SAFETY TRUST RESEARCH (JCBHST)

In 1991 the Joint Coal Board Health & Safety Trust was established to fund research into occupational health & safety of coal miners in Australia. Two projects that are currently funded on DP are:

- The investigation of exposure to diesel particulates in NSW coal mines.
- Exposure to diesel particulates under various operating conditions in Qld underground coal mines.

The aim of the research is to measure workforce exposure to diesel particulates (DP) in underground coal mines and relate this to factors such as work practices, ventilation, engine design maintenance and engine controls such as fuel quality and exhaust filtration. The study is designed to determine if different operating conditions in Queensland coal mines lead to higher workforce DP exposures than is found in NSW. The preliminary findings in NSW indicate that the measurement of elemental carbon and submicron mass are good measures of DP exposure and good measures of the efficacy of control at each mine.

ALAN ROGERS OH&S PTY LTD, INTERIM REPORT NSW DIESEL PARTICULATE RESEARCH, DECEMBER 1997

Interlaboratory Trials

The international laboratory comparison of diesel particulate analysis involving 10 laboratories indicated a considerable spread of results. When the laboratories are grouped according to the method they use the results are a little clearer. For Total Carbon the spread of results is reasonable however for Elemental Carbon (the basis of the proposed exposure standard) the variability in results are disturbing. Laboratories in Europe (n = 3) that use a coulometric method of analysis are presenting elemental carbon results much higher than those using thermal optical methods (n = 7). For pure diesel truck exhaust samples this amounts to values 2.4X higher than results from USA thermal optical method. It is interesting to note that the Canadians (low results) and the Germans (high results) both of have operational diesel particulate exposure standards in their countries, and appear to be at opposite ends of the results obtained by those

laboratories using US thermal optical methods. The UK Health and Safety Executive (the UK regulatory authority) is reading about 30-40% higher than the US investigators. The results that we obtained (JCBHST) are very close to those of the other US thermal optical laboratories (NIOSH, MSHA, Sunset Labs all of which will be part of the US regulatory system).

It would appear at first examination of the results that the variability is dependent on the laboratory=s method and its ability to consistently separate organic carbon from elemental carbon.

All the US laboratories and the JCBHST instrument use the same furnace and software to separate organic carbon from elemental carbon.

It is obvious that a considerable amount of work needs to be completed before such analytical methods can be incorporated into international exposure standards.

Comparative Results from International Laboratory Trial
(all results standardised against the mean of all Thermal Optical Laboratories)

	Elemental Carbon		Total Carbon	
	Urban Air	**Diesel Truck Exhaust**	**Urban Air**	**Diesel Truck Exhaust**
European Coulometric method	4.7	2.4	1.07	0.97
UK Health Safety Executive	1.28	1.40	0.76	0.93
CANMET	0.65	0.60	1.05	1.06
JCB HST	1.00	0.97	0.97	0.93
USA Thermal Optical Method [1]	1.00	1.00	1.00	1.00

[1] RSD of the TOM method determined as 9% for the 7 participating laboratories.

EXPOSURE SAMPLING

The Joint Coal Board Health & Safety Trust research grant is being conducted in NSW and Queensland coal mines using modern sampling and analytical methods designed to specifically capture and analyse the sub micron fraction of DP and to measure elemental carbon content. The aim is to determine the suitability of these monitoring systems for the Australian coal industry and for applicability to any future exposure standards. (Pratt 1998).

The ACARP & JCB data base at June 1998 has approximately 700 personal full shift machine operator exposure samples from NSW and Qld mines (11 mines). Additional data is available with the 200 control technology samples from the Tower Colliery test station. The exposure data base is the largest in the world. The data base is being managed by Mr Brian Davies of AEHS. An example of the 1997-98 range of results is set out in Table 4.
EC - Elemental Carbon, TC - Total Carbon = EC + Organic Carbon.

Mine & Operation	DP mg/m;	EC/DP	EC/TC	TC/DP
A - General Duties	0.04-0.32	0.32	0.47	0.68
Longwall Move	0.14-0.25	0.44	0.46	0.96
B - Longwall Move 1	0.12-0.69	0.72	0.74	0.97
Longwall Move 2	0.21-0.65	0.77	0.79	1.03
C - Longwall Move	0.06-0.50	0.44	0.58	0.76
D - Place Changing	0.04-0.08	0.46	0.34	-

TABLE 4
Elemental Carbon Measurements in Some Australian Coal Mines

A breakdown of the exposures of various machine operators in Queensland coal mines is provided in Table 5.

Vehicle	DP mg/m;	EC mg/m;
PJB	0.06	0.03
Eimco 936	0.13 - 0.29	0.06 - 0.14
Eimco EJ130	0.13 - 0.38	0.05 - 0.19
Mine Dozer	0.25 - 0.35	0.15 - 0.19

Note: Range of results dependent upon workload of vehicle

TABLE 5
Exposures for Machine Operators - Qld

Exposure levels for DP range considerably with results dependant upon the work load of the vehicle. Heavy duty vehicles give the highest results. Highest exposures occur during longwall moves. Control technologies that have been developed significantly reduce exposure to DP.

Exposure studies conducted on coal miners in the USA, indicate that only diesel operated coal mines that incorporate control strategies similar to those developed by BHP Tower Colliery, comply with the proposed DP exposure standard (Haney 1996). Preliminary results from studies in NSW coal mines indicate similar outcomes (Rogers and Wheelan 1996).

Monitoring methods used in the USA is a mixture ie elemental carbon, total carbon, diesel particulates. All the methods achieve different or variable results.

JOINT COAL BOARD DIESEL PARTICULATE SUB-COMMITTEE

The Joint Coal Board (NSW) under the tri-partite Standing Committee on Dust Research and Control decided to include a watching brief on diesel particulates. In December 1997 a sub-committee was formed in order to ensure the health of mineworkers is not put at undue risk by exposure to diesel particulate. The committee is undertaking a critical review of all available literature on diesel particulate. Reviewing all workplace exposure data currently being collected in NSW and Qld mines as part of the JCB Health & Safety Trust Projects. Standardised method for the monitoring of diesel particulate and highlight those activities that generate high levels of employee exposure. Development of an education package covering all aspects of exposure and indicating practical means by which exposure may be reduced. Consideration for the development of a workplace exposure standard for diesel particulate applicable to underground coal miners based on best practice Atechnical limit≅. This would follow the principle that if you lower the exposure you lower the risk which is consistent with good occupational health and hygiene principles.

If the Australian coal industry is to address the diesel particulate issue all stakeholders need to be made aware as to the situation with diesel emissions as it stands today. The diesel particulate sub-committee has proposed a technical seminar to be held in September 1998 where issues such as health effects, monitoring methods and control strategies are discussed. As MSHA recently released a proposed AUS regulation (US Federal Register 9 April 1998) Diesel particulate Matter Exposure of Underground Coal Miners; Proposed Rule≅ it is intended to invite US speakers to discuss the basis of that legislation. The intended outcome of this seminar is to obtain a general recognition within the Industry as to what needs to be done to manage the diesel particulate issue.

ACARP CURRENT RESEARCH - DP

Two particular projects:

- C6042. Design criteria for four wheel drive type vehicles in NSW underground coal mines. Reviewing the current design criteria for underground light duty vehicles in terms of safety and practicability with the view of developing a commercially available four wheel drive vehicle design for use in the non-hazardous zone of NSW underground coal mines. The more efficient electronically controlled engines may provide an alternate and future approach to control of diesel particulates (Pratt 1998)

- C7014. Application of an elemental carbon analyser to the measurement of particulate levels from diesel vehicles. The anticipated outcome is to provide the industry with a quick, reliable and accurate measurement technique for diesel particulate which can be used for type testing, emission control and for the evaluation of new control technologies (ACARP 1998). This instrument has arrived in Australia and is currently being validated with a laboratory based instrument used in the JCB Health & Safety Trust projects.

DIESEL PARTICULATE CONCLUSION

Control technology can deliver operational benefits by way of improved efficiency and a more motivated

workforce. Current control technology is only an interim measure. There is a need to develop equipment that doesn't provide high levels of pollutants. It is only a matter of time before the industry has an operating exposure standard. This will be used to minimise exposure and set targets for equipment manufacturers. Industry should be pro-active to encourage the setting of standards to minimise the risk to the workforce.

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