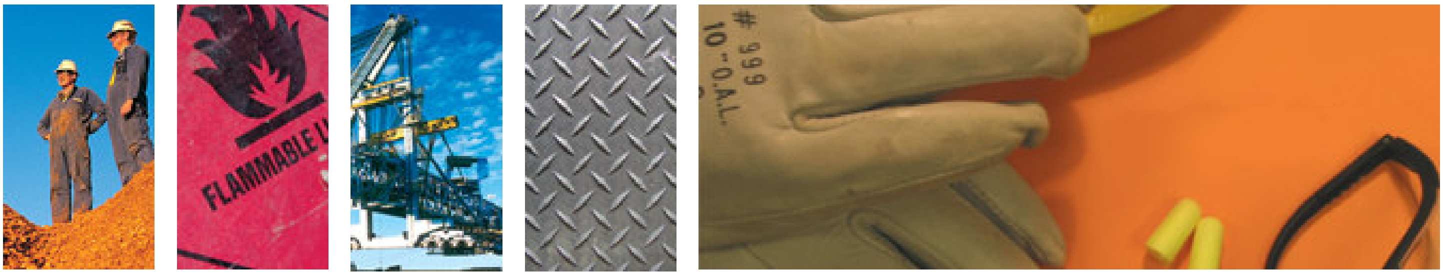
Department of Consumer and Employment Protection
Government of Western Australia

Resources Safety



Diesel Particulate Exposure and Control in Western Australian Underground Mines 2006

17/07/07

Contents

1. Executive summary

This report presents the results of CONTAM sampling for diesel particulate sin undergrounds mines in WA for the period January to December 2006. Recommendations for further action are also provided.

Objective

To assess levels of exposure and improve the control of diesel particulates in underground mines in Western Australia.

Risk assessment and statistical analysis techniques have been used to quantify occupational exposure hazards to underground miners and show the relative level of risk due to diesel particulates compared to other underground atmospheric contaminants. Control options are summaries to provide means by which control of the hazards associated with diesel particulates in underground mines can be improved. By increasing awareness of hazard, quantifying exposure and promoting control options to both the mines safety regulators and the underground mining industry this report aims to reduce some of the risks associated with underground mining.

Summary Results

The summary statistics in the table below clearly indicate that underground mine workers are often being exposed to levels of diesel particulate above the interim exposure standard.

Table 1- summary statistics

Descriptor	**Outcome**	
Number of samples	347	
Mean	0.09	mg/m^3 (MVUE)
Number of samples exceeding the proposed occupational exposure limit	85	24.5% of samples over OEL
Geometric Mean	0.05	
Geometric Standard Deviation	2.81	
UTL (95% UCL of 95% CI)	0.334	mg/m^3

Note: ***Interim Occupational Exposure Limit (OEL) 0.1 mg/m^3.***
Data distribution is lognormal.

Recommendations

- Continue to raise awareness of diesel particulate hazard through media (website, MineSafe etc)
- Present results to Division, Department and industry
- Promote MDG 29 "Guideline for the Management of Diesel Engine Pollutants in Underground Environments" (NSW-DPI, 2007)
- Increase monitoring efforts, improve data quality through additional information gathering
- Assess / audit management of diesels and underground ventilation:
- Develop control option resource targeted at WA underground mines.
- Develop preferred emission monitoring proposal with industry.
- Develop Diesel Particulate (or Diesel Emission) Control guideline for WA underground mines.
- Provide more information about the analytical issues concerning LOD, filter size, volume samples and DP concentration to ventilation officers and registered samplers.
- Comprehensive sampling program to scientifically assess the level of diesel particulates in WA undergrounds mines
- Sampling program that assesses different sampling options
    - SKC DPM cassette sampling
    - Respirable combustible dust method
    - Bosch smoke meter assessment
    - Sampling using respirable cyclone sampling (without DMP cassette)
    - Diesel detective – exhaust particulate emission monitor (being developed by SKC)
    - Sample for gas components of exhaust (NO_X) to assess potential for surrogate assessment using gas monitors.
- **CONTAM**
    - **Request submission of diesel register with quarterly samples from underground mines.**
    - **Request targeted information:**
        - **Number of units UG during sampling**
        - **Worker in cab etc**
        - **Location as per vent plan**
        - **Summary of air flow in work areas**

Recent Developments

- Paper on diesel particulates exposure in Queensland underground mines in AIOH newsletter
- New sampling equipment (photoelectrical sensors) released in US.
- AIOH position paper (internal to AIOH)

2. Background

Mining is a field of endeavor in which the employees are subject to many hazards. In particular, underground mining is widely held both involve significant dangers. Many of these hazards have caused significant loss of life and are now subject to significant safety controls through both regulation and safe mining practices.
There are also some hazards that are not well understood or, at least, the level of risk is not well known. It is into this category that diesel particulates can be currently placed.

Since a link between diesel exhaust and cancer was formally proposed by NIOSH in 1988 (NIOSH, 1988) there have been significant developments in the measurement and control of both the gas and particulate fractions of diesel exhausts.

> ***"It is of particular importance that the fuel entering at the mouth should be thoroughly consumed and without the formation of soot."***
> ***--Rudolf Diesel***
> ***From US Patent Number 00608845 dated August 9, 1898***

2.1 Diesel Particulates

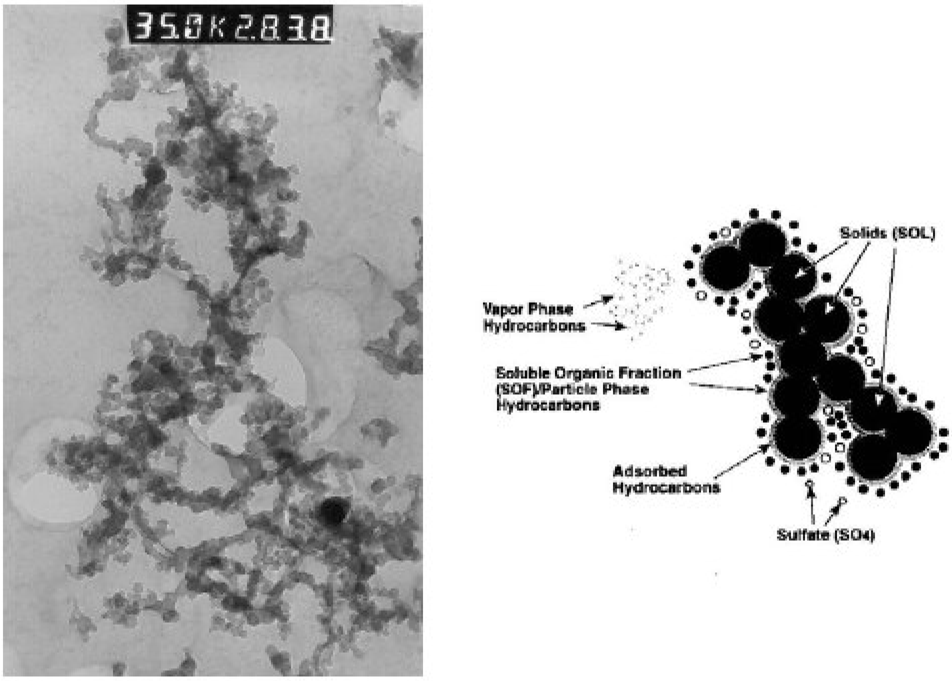
The particulate phase of the exhaust of a diesel engine typically consists of:

- Elemental carbon (EC)
- Organic carbon (OC)
- Other trace elements such as metals, sulphates, minerals, nitrates etc

DP = OP + EC + other components
(NSW- DPI, 2007)

Small particles called spherules are formed during the combustion process. These range in size from 15 to 30 nanometres (nm). The spherules agglomerate together to form larger particles, typically less than 1 micrometre (µm) diameter. The large surface area of the particles provides adsorption surfaces for the hydrocarbons such as polycyclic aromatic hydrocarbons (PAHs) and adsorbed gas components (Davies, Rogers, 2004).

Figure 1,Electron micrograph and schema of diesel particulate
(Davies, Rogers, 2004)



It important to note that the composition of diesel particulates varies due to a number of factors such as fuel types, engine types, and emission controls and this may affect the toxicity of the particulates. This potential variation in the nature of diesel particulate and hence toxicity of the particles is not, in itself, a valid argument or rationale to dismiss diesel particulates as a hazard.

It is common to assess the risks of exposure to diesel exhaust, or emissions from diesel engines as a whole (both gas and particle emissions). The Draft NSW Guideline has taken an approach of assessing all “pollutants” that have the potential to effect worker health (NSW-DPI, 2007), including noise and vibration “emissions”. The development of electronic direct reading and logging atmospheric and exhaust gas testing instruments has significantly improved the ability of underground ventilation officers to assess and air quality in underground mines. This report is primarily concerned with diesel particulate emissions.

Diesel particulates have been identified as a significant problem associated with the growing use of diesel vehicles in urban areas. In many countries this is being addressed through strict emission control requirements which have included particulate matter emission limits. Australia is implementing a nation wide emission testing program for road vehicles.

2.2 Underground Mines

The use of diesel vehicles in underground mines underwent a rapid increase in the second half of last century. In Western Australia all underground mines use diesel-powered vehicles underground. There are underground mines in other jurisdictions that don’t use diesels underground. Underground coalmines are markedly different operations to underground hard rock mines for many reasons such as the mine layout, extractions methods, gas hazards and equipment used. There are currently no underground coalmines in Western Australia, where "underground mining " is referred to in this report it will be referring to hard rock mines unless stated otherwise.

2.3 Diesel Particulates in Underground Mines

2.3.1 Worldwide

Canada has been using a respirable combustible dust method for measuring carbon fractions of dusts in underground mines. This method has been found to be unsuitable for DPM as the lower limit of detection is too high, at 0.5 mg/m^3 (Davies, Rogers, 2004, p22), compared with the proposed exposure standards for diesel particulates of 0.1mg/m^3. The Canadian exposure limit for diesel particulates, measured as respirable combustible dust, is 1.5 mg/m^3 (Gangal, Greiner, 2002).

In the United States the ACGIH (American Conference of Government Hygienists) published an exposure standard for diesel particulate that was withdrawn due to the protracted legal challenges to the adoption of a diesel exposure standard by the US Mines Safety and Health Administration (MSHA). The challenges by industry groups delayed the standard until 2005. The MSHA standard has a three phase implementation as follows:

Date	Permissible Exposure Limit	Units
May 20, 2006	308	µg/m^3 as EC
January 20 2007	350	µg/m^3 as TC
May 20, 2008	160	µg/m^3 as TC

(MSHA, 2006)

For these standards TC (total carbon) will be measured as 1.3 x EC (elemental carbon) as the elemental carbon fraction of diesel particulates is considered the most useful surrogate of DP exposure (NIOSH, 2003, chapter Q).

The UK does not have an exposure standard; it has published guidance on control that recommends reducing exposure to below 150 µg/m^3 as EC (HSE, 2004).

2.3.2 Australia

Much of the assessment of diesel particulate that has been carried out in Australia in recent years has been undertaken in underground coalmines (Davies, 2004).
The national organization responsible for setting exposure standards the Australian Safety and Compensation Council has no public proposal for a diesel particulate exposure standard. Two of the most experienced scientists in the occupational health field, Alan Rogers and Brian Davies have undertaken considerable research in this area culminating in the document "A Guideline for the Evaluation and Control of Diesel Particulate in the Occupational Environment". (Davies, Rogers, 2004). This guideline proposed a workplace exposure standard for 0.1 mg/m3; this has been adopted as an interim standard in Western Australian (Minesafe, 2005).

2.3.3 Western Australia

The regulatory authority for Western Australian mine occupational safety and Health is currently the Resources Safety Division of the Department of Consumer and Employment Protection. This Division administers the Mines Safety and Inspection Act (1994) and Mines Safety and Inspection Regulations (1995). Prior this legislation the safety legislation was the Mines Regulation Act (1946) and Mines Regulation

Regulations (1976). Research has been undertaken into occupational health and safety issues associated with the use of diesels underground, as far back as 1991 (Kirwin, 91).

The Mines Safety and Inspection Regulations (1995) based the control of particulates on the Opacity Test. Research was conducted on this method of testing (Fisher, 1996). However the opacity regulation was removed following concern over the impracticability of this test method and dependant on type of meter used. (Torlach, 1999, Appendix 3a). No replacement method for measuring exhaust emissions has been proposed by the Department. In the same year MSHA published a document aimed at assisting mines to reduce worker exposure to DP (MSHA- Toolbox)

The WA 1995 regulations required registration and reporting to the Department of all diesel units used underground (MSIR 10.50), information was recorded on a Lotus Notes Database. This reporting requirement was replaced with a set of record keeping requirements by the State Mining Engineer (Knee, 2002, Appendix 3a).

Diesel particulate matter samples were collected from a number of mines in WA, as part of a wider project on mine dusts, for a MERIWA project in 1998 (Terry, 1998). Since that time there has been very little reporting of DPM to the Department and hence the levels of exposure to DPM for mine employees was unknown. While the MERIWA project used different sampling techniques to current sampling methods, the results of this earlier work did indicate at the time that exposure to DP is significant.

3. Method of Research / Analysis

3.1 Scoping work

Scoping work has been conducted to determine how to conduct exposure monitoring, emission monitoring and emission control devices. Mines have had diesel particulates included in CONTAM quotas.

3.2 Literature search and review

A full literature review is provided in Appendix 2. Main key words used in literature searches included: diesel, particulate, matter, underground, mine, exposure, emission, dust exhaust, control. Much of the useful information was found at the following sites:
MSHA – Mines Safety and Health Administration (US)
http://www.msha.gov/01-995/dieselpart.HTM
HSE – Health Safety Executive (UK)
DEEP – Diesel Emissions Evaluation Program
http://www.deep.org/
Diesel Net
http://www.dieselnet.com/
NIOSH – National Institute for Occupational Safety and Health (US) 0- Diesel Exhaust Topic Page
http://www.cdc.gov/niosh/mining/topics/topicpage2.htm
In particular DEEP, MSHA and NIOSH have a large amount of published project report information available.

3.3 Hazard analysis

3.3.1 Health Effects

Since diesel particulates were assessed as having potential carcinogenic effects "Carcinogenic effects of diesel exhaust" (NIOSH, 1998), and further support came from the International Agency for Research on Cancer (IARC) classification of diesel exhausts as Group 2A- probable carcinogen (IARC, 1989). The potential for diesel exhaust to be a carcinogen had been proposed earlier and mainly focused on the presence of known carcinogens such as the poly aromatic hydrocarbon (PAHs), which were also known to be constituents of diesel exhausts (Schenker, 1980). There have been many studies conducted on animals some of which have been used to classify diesel exhausts as potentially carcinogenic (US EPA, 2003). There have been epidemiological studies on humans and several meta-analyses of these studies (Silverman, 1998). The difficulty with the human studies is that there are often estimations of exposure levels as there has been little historical data on exposure (Davies et al, 2004). The potential for long-term health effects such as cancer is important in making decisions that affect control of exposure, such as whether the exposure standards should be adjusted for extended shifts.

There is also evidence of short-term respiratory effects and non-cancer effects such as asthma (HEI, 2003). The AIOH proposed exposure standard is clearly based on minimizing employee irritation (Davies, et al, 2004). Health data is being collected from all mine workers in the Western Australia through the MineHealth program. While some information has been published (Turner, 2003) there is potential for analysis of this data to provide some indication on the effects of (at least) working in the underground environment on workers lung function.

3.3.2 Data Collection

Centralised collection of occupational exposure data from the WA Mining industry has been occurring in various forms since the 1970s. The current CONTAM system collects approximately 10,000 samples per year from mines and mineral processing refining operations across WA. (Contam Procedures, 2006, 1998). Most of the samples are submitted as "quota" samples, these are samples that are requested by the Department on an annual (business year) basis)

Development of the SKC diesel impactor cassettes and, more importantly, the carbon analyzer analytical instrument has enabled sampling for diesel particulate to be added to the CONTAM system and be included as part of underground mine's CONTAM Quotas. Quota sampling for DP was added to the second half of the 05/06 quotas. Sample numbers were assigned using workforce survey information provided to the CONTAM system biannually. It must be noted that this is not a structured sampling program such as one that a site or company would undertake. Once the quotas are assigned there is little control over when the sampling is conducted at a site. Some sites have trained ventilation officers or technicians who undertake this work. Many of the underground mines engage sampling consultants or contractors.

When diesel particulate samples were added to the CONTAM Quotas for WA underground mines in 2005 an information letter was sent out requesting that sampling and analysis use NIOSH 5040 in conjunction with the SKC DP impactor. (Turner, 2005 – appendix) The SKC sampling devices are readily available in WA, analysis of the samples was being conducted interstate or overseas, and a local analytical laboratory has recently purchased a carbon analyser. This lab had been using the Respirable Combustible Dust (RCD) method and attempted to lower the analytical detection limits of the RCD method to meet the requirements of the proposed exposure standard.

The AIOH Guideline (Davies, Rogers, 2004) was used to set an exposure standard of 0.1mg/m^3, measured as the elemental carbon fraction of the diesel particulate matter.

This report used the CONTAM "front end" to get basic sample numbers, means and number over exposure standard, by site, location and occupation. MS ACESS was used to extract raw data and build reporting tables for further analysis in Access, Excel (IH Stat), LogNorm2 and R.

The following filters were used to select the required data:

Table 2 – data filters

Field	**Filter**	**Details**
Contaminant code	DP	Diesel particulates
Sample status	V	"valid" samples only
Location Code	Like "1*"	All underground locations
Occupation	Like "2*"	All underground occupations
Sample date	Between 01/01/2006 and 31/12/2006	Selects samples collected within these dates

The data was assessed by:

- Site
- Occupation group
- Location
- Commodity
- Operator / contractor employee

3.3.3 Statistical analysis.

The main purpose of the statistical analyses was to gain an understanding of the exposures and identify exposure patterns, exposure groups. The analysis was also used to assess the relevance of the "demographic" information gathered (occupation, location, site, commodity, site type, shift length, shift pattern, sampling duration and start time. The DB2P (base data storage software) view of the CONTAM tables was used to develop a reporting table that could be used to export data to LogNorm2 and Excel and also provide some reporting functions in MS Access.

3.4 Risk management

There are two distinct risk management approached the need to be described. The regulatory risk management strategies and the site/ company risk management strategies. This is predominantly a function of the duty of care provision of the MSIA. It is the site/ company's responsibility to ensure the health and safety of the employees is protected and the responsibility of the Department ensures that sites/ companies meet their duty of care.

3.4.1 Regulatory

The US has a large underground mining industry and a well-funded federal safety regulator – MSHA. MSHA inspectors conduct compliance inspections that involve inspectors placing personal monitoring devices on workers during the inspection and any exposures over the agreed exposure standards triggers a formal process to address the overexposures. Much of the US regulatory approach is explicitly stated in the regulation (US DOL, 2005). This is not the case in Western Australia and is somewhat contrary to the general principles of occupational monitoring to consider individual exposure results above occupational exposure limits as proof of over exposed workers (Grantham 2001, CH10).

At the very least there needs to be increased publication information about the risks associated with diesel particulate, to ensure that the Department is effectively communicating the potential risks.

Possible additional regulatory provisions:

- Diesel particulate matter exposure standard or ALARP statement.
- Specified emission standards for diesel particulate
- Regulated exposure monitoring
- Enforcement sampling (US model)
- Regulatory adoption of a code of practice or guideline as a minimum standard
- Comprehensive reporting of underground ventilation management including:
    - Exposure sampling data
    - Emission sampling data
    - Ventilation data and modelling
    - Contaminant control plan
    - Management report that demonstrates that the occupational exposures are as low as reasonably practical (ALARP)

While this last reporting suggestion seems extreme it is comparable to some to the environmental reporting mines are currently required to undertake. This type of reporting could be an element of a different regulatory approach such as a formal safety management system requirement (safety case).

3.4.2 Site / Company

Risk management by mine site has to begin with acceptance and / or identification of the hazard which is preferably stated in site policy on diesel particulates / diesel emissions or policies on working conditions underground. A proper risk management plan is needed to ensure that the exposure monitoring – is properly planned not just to CONTAM requirements but to properly assess exposures and similarly that the exhaust emission monitoring is conducted as part of the ventilation management of the underground mine, not just to meet the regulatory requirements. Underground mines, by their nature, are dynamic environments. The iterative approach to risk management as described in the Australian Standard (AS 4360, 2004) has such an iterative approach. The risk management approach documents by a mine site should be a demonstration of due diligence and appropriate duty of care by the site management.

4. Findings:

4.1 Exposure data analysis

For the 2006 calendar year there were 364 diesel particulate samples, collected at underground workplaces, reported to CONTAM. When the data filtering was applied to this data 347 samples remained and it is this data set that was further analysed using the statistical package LogNorm2.

Table 3 – data overview

Factor	Number
Samples	347
Sites	36
Commodity	4
Work Location	11 (3)
Occupation • 2A production • 2B transport • 2C services	 123 171 53
Sampling Equipment: • Cyclone • Diesel cassette	 264 83

- All samples were tagged as being taken during normal operating conditions.
- 52 samples indicated that respirators were worn.
- 8 of the samples indicated that they were collected in a confined space.
- 39 of the samples indicated that they were less than the LOD.
- Summary statistical plots for all the underground DPM samples are available

Table 4 – Summary Statistics – 2006 Diesel Particulate Exposure Data

Descriptor	Result	Units
Number of samples	347	
Mean (MVUE: minimum variance unbiased estimate)	0.09	mg/m^3 (MVUE)
Number of samples exceeding the OEL	85	
Number of samples at lower limit of detection	39	
Mean LCL (Lands 95%)	0.081	mg/m^3
Mean UCL (Lands 95%)	0.101	mg/m^3
Geometric Mean	0.053	
Geometric Standard Deviation	2.81	
UTL (95% UCL of 95% CI)	0.334	mg/m^3

Table 5 – 2006 DP Exposure Data by Commodity

Descriptor	Gold	Nickel	Other
Number of samples	151	139	57
Mean (MVUE: minimum variance unbiased estimate)	0.109		0.056
Number of samples exceeding the OEL	49	31	5
Number of samples at lower limit of detection	19	10	10
Mean LCL (Lands 95%)	0.092	0.073	0.044
Mean UCL (Lands 95%)	0.135	0.099	0.075
Geometric Mean	0.059	0.055	0.035
Geometric Standard Deviation	3.054	2.530	2.655
UTL (95% UCL of 95% CI)	0.047	0.313	0.253

Table 6 – 2006 DP Exposure Data by Location

Descriptor	Li- U/G general	Lii-decline / access ways	Liii -mining areas
Number of samples	196	32	119
Mean (MVUE: minimum variance unbiased estimate)	0.094	0.051	0.092
Number of samples exceeding the OEL	51	4	30
Number of samples at lower limit of detection	17	5	17
Mean LCL (Lands 95%)	0.082	0.038	0.077
Mean UCL (Lands 95%)	0.111	0.079	0.115
Geometric Mean	0.056	0.032	0.053
Geometric Standard Deviation	2.769	2.683	2.85
UTL (95% UCL of 95% CI)	0.366	0.277	1

Table 7 – 2006 DP Exposure Data by Occupation Group

Descriptor	2A miners	2B transport occs	2C service occs
Number of samples	123	171	53
Mean (MVUE: minimum variance unbiased estimate)	0.110	0.083	0.068
Number of samples exceeding the OEL	32	45	8
Number of samples at lower limit of detection	15	18	6
Mean LCL (Lands 95%)	0.091	0.072	0.055
Mean UCL (Lands 95%)	0.140	0.099	0.09
Geometric Mean	0.059	0.0504	0.045
Geometric Standard Deviation	3.068	2.735	2.471
UTL (95% UCL of 95% CI)	0.493	0.325	0.289

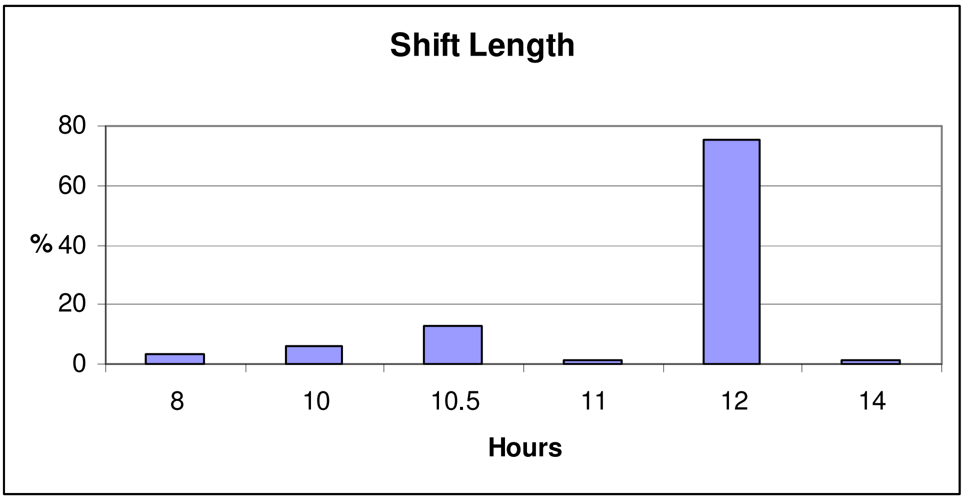
Table 8 – 2006 DP Exposure Data by Occ Group – transport

Descriptor	2B diesel loader	2B mechanical bogger	2B truck driver
Number of samples	52	32	78
Mean (MVUE: minimum variance unbiased estimate)	0.116	0.122	0.051
Number of samples exceeding the OEL	19	14	10
Number of samples at lower limit of detection	5	2	10
Mean LCL (Lands 95%)	0.090	0.089	0.044
Mean UCL (Lands 95%)	0.166	0.202	00.063
Geometric Mean	0.0677	0.0709	0.0361
Geometric Standard Deviation	2.8621	2.9097	2.3369
UTL (95% UCL of 95% CI)	0.5837	0.7386	0.1913

4.2 Exposure Standard Adjustment

The graph below clearly shows that most of the workers (over 80%) monitored for diesel particulate exposure work 12-hour shifts.

Graph 1- Shift Length



Initial advice indicated that the 0.1mg/m3 exposure standard proposed (AIOH) is an eight-hour time weighed average standard. Best practice, as per the MIAC CoP for Working Hours and other relevant guidelines is to apply a reduction factor to the exposure standard for extended shifts (greater than 8 hours per day, 40 hours per week).

Around half the workers reported working a 14 / 7 shift pattern.
For the purposes of this analysis and report the 12-hour shift, 14 / 7 pattern is used and the typical working arrangement.

Graph 2 – Shift Pattern

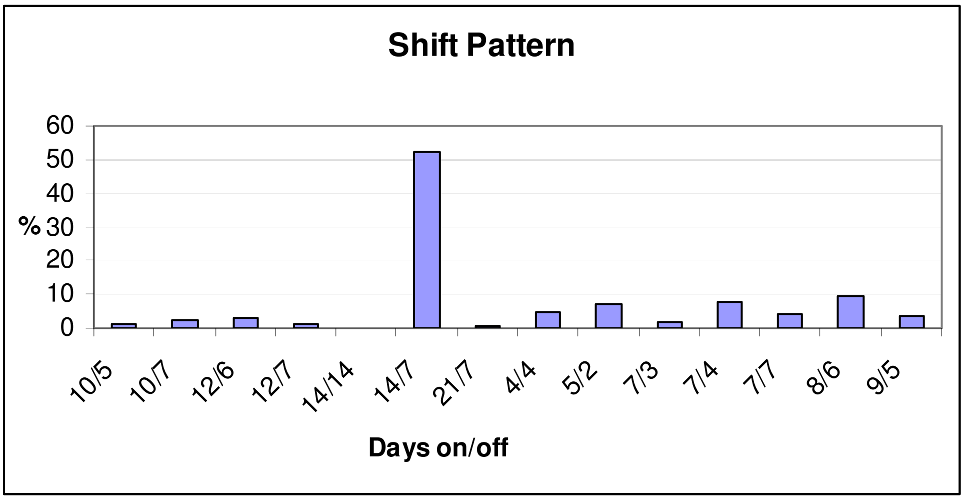


Table 9 – exposure standard adjustment

Method of adjustment for extended shifts	Reduction Factor	Adjusted Exposure Standard (mg/m3)
Hours per day: (SITARS and DME)	0.5	0.05
SIMTARS: hours per week	0.625	0.063
DME: hours per month	0.75	0.075

Analysing the CONTAM 2006 diesel particulate data using these adjusted exposure standards cam be summarised as follows:

Table 10 – exposure standard adjustment analysis

Method of adjustment for extended shifts	Adjusted Exposure Standard (mg/m3)	Percent of samples above adjusted exposure standard
Hours per day: (SITARS and DME)	0.05	52.4
SIMTARS: hours per week	0.063	44.9
DME: hours per month	0.075	38.0

4.3 Sampling and Analytical range

The analytical technique, NIOSH 5040, (NIOSH, 2003) used to determine DP has an analytical range of 0.3 to 103 μg of EC per filter portion. A 1.5 cm2 portion of the filter is punched out and placed in the instrument so the man and min amounts of carbon collected on the filter can be calculated. Filter size, quantity of air sampled and DP concentration are all factors that affect the mass of DP sampled (on the filter).

In summary the large (35mm) filters have a high lower limit of detection at low volumes and the 25mm filters may be overloaded at high sample volumes.

It is preferable to sample for as much of a workers shift as possible to get a good representative sample of their exposure.

Table 11- detection ranges

Filter	Volume (L)	MIN mg/m^3	MAX mg/m^3
37mm	480	0.004	1.260
	960	0.002	0.630
	1440	0.001	0.420
25mm	480	0.001	0.510
	960	0.001	0.255
	1440	0.0005	0.170

As the CONTAM data contains flow rate and sampling time information as well as analyte concentration it was possible to identify several samples that would have been outside the analytical range of the instrument if the incorrect filter had been used.

Hence the true lower limit of detection can vary for each sample based on filter size and volume (flow rate x time) samples. Also the size of the sample of filter taken allows a second sample to be taken from the larger 37m filters. A smaller size sample would be needed if duplicate sampling of the 25mm filters was required.

4.4 MERIWA Data

The MERIWA research report data (Terry, 1996) represents the only available data for diesel particulate exposure of Western Australian underground miners until the recent COTAM data became available. The exposure data was reported as total carbon.

Table 12 Summary of MERIWA Data

	Number of samples (n)	Mean - MVUE
Gold	31	0.43
Alumina	42	0.19
Base Metals	44	0.25
Nickel 2A-miners	14	0.42
Nickel 2Bii - loaders	33	0.39
Nickel 2Biii - drivers	30	0.47

It is feasible to process the results to obtain the equivalent data as elemental carbon, which would be dividing the exposure concentration by 1.3 according to the MSHA. However the MERIWA study did not detail the analytical technique used to using the MSHA conversion factor would be making a large assumption. The MERIWA data is useful in that it indicates significant exposures (greater than 0.2 for total carbon) for many of the groups. In summary this MERIWA data corroborates the 2006 CONTAM exposure data.

4.5 MSHA (US)

The US Mines Safety and Health Administration standard is set to be 160 ug/m3 of total carbon (8hr TWA) in May 2008. This is equivalent (according to MSHA) to 0.123 mg/m3 EC (*hr) which equates to a 0.06 mg/m3 12 hour Exposure standard.

MSHA uses a compliance monitoring approach where samples, collected by MSHA inspectors, measuring over the exposure standard (including an error margin) result in a citation (violation).

MSHA Data Summary
The US Mines Safety and Health Administration (MSHA) has mad a data set of the baseline sampling of diesel particulate sampling available publicly on the MSHA website. A summary of this data is presented in Table. The exposure data was back calculated to elemental carbon (EC) to provide exposure data in the same format as that collected for the WA CONTAM program. The US data appears slightly higher than the CONTAM, further analysis is required for any quantitative statement to be made, and the results are broadly comparable.

MSHA information on DMP Sample Results:

> **Baseline DPM Sample Results**
> *This 1,194-sample dataset is MSHA'S final version of the baseline sampling for diesel particulate matter (DPM) in metal and nonmetal mines conducted from October 2002 through October 2003. MSHA conducted additional DPM baseline sampling after July 19, 2003 in response to mine operators' concerns that some mines were either not in operation or were implementing major changes to ventilation systems during the original baseline period. This revised dataset includes DPM samples from seasonal and intermittent mines, and mines that were either under-represented, or unrepresented, in the original 874 dataset.*
>
> (Extract from MSHA website at: http://www.msha.gov/01-995/Dieselpartmnm.htm)

Table 13 MSHA DPM sample results summary

Commodity Group	Number of Samples	Mean Diesel Particulate Exposure (as EC mg/m^3)
Metal	284	0.27
Other N/M	196	0.15
Stone	689	0.18
Trona	25	0.08

4.6 Comparative Risk Analysis

To put the underground worker exposure to diesel particulate into context it is possible to look at all personal exposure samples submitted to CONTAM from workers in underground locations. Several CONTAM “All Contaminant Summary” reports are provided in Appendix 6, these reports list contaminants, number of samples max min and mean concentrations and also the percent of samples recorded as over the listed exposure standard (“%> ES”). The table from the report showing all underground samples collected in 2006 (2307) is shown below; of these there were 350 diesel particulate samples collected. The second column from the right gives the percentage of samples, for each contaminant, that are over the listed exposure standard (not adjusted for shift length). The percentage of diesel particulate samples over the exposure standard is 24.3%; the next highest contaminant in these terns is inspirable (inhalable) dust at 1.2

Table 14 CONTAM All Contaminant Report –Underground Locations 2006

Contaminant		No of Samples	Min Concen	Max Concen	Arith. Mean	Std. Dev	Units	% > ES	ES
			Concentration						
-AS	Arsenic Compounds	22	0.0010	0.0080	0.0040	0.0020	mg/m3	0.0	0.0500
ASB	Asbestos	170	0.0100	0.2600	0.0182	0.0225	f/mL	0.6	0.1000
-CU	Copper	12	0.0010	0.0070	0.0022	0.0021	mg/m3	0.0	1.0000
DP	Diesel Particulate	350	0.0100	0.6300	0.0692	0.1135	mg/m3	24.3	0.1000
INS	Inspirable dust	245	0.1000	26.0000	1.3224	2.8695	mg/m3	1.2	10.0000
-NI	Nickel, metal	57	0.0010	0.1200	0.0138	0.0216	mg/m3	0.0	1.0000
NIS	Nickel sulphide roasting (fume	36	0.0020	0.2400	0.0166	0.0394	mg/m3	0.0	1.0000
-PB	Lead, inorganic dusts & fumes	12	0.0010	0.0080	0.0022	0.0022	mg/m3	0.0	0.1500
RES	Respirable Dust	822	0.1000	5.4000	0.3419	0.4332	mg/m3	0.4	3.0000
SIL	Silica, crystalline	569	0.0010	0.1900	0.0128	0.0184	mg/m3	0.9	0.1000
-ZN	Zinc	12	0.0010	0.0340	0.0100	0.0122	mg/m3	0.0	10.0000
Totals		2307							

It is also worth noting the high number of samples that are being collected for respirable dust (822) and silica (569), when there appears to be little evidence of significant exposure to these atmospheric contaminants.

5. Control Options

There are a number of options that have been identified, costs of each vary and some of the options can be used together.

5.1 Diesel Fuels

Low sulfur fuels have already had beneficial impacts on the quality of air in underground mines. Even lower sulfur fuels and biodiesels and oxidation catalysts have the potential to further reduce emissions (Watts, Spears, Johnson, 1998)

5.2 Diesel Engines

Improvements in diesel engine design have resulted is significant reduction in emissions. The main areas where improvements have led to reduced emission are (ESI, 1999):

- Improved fuel techniques
- Improved management methods
- Improved combustion chamber design
- Improved oil control

While it is likely to result in reduced emissions in Western Australian underground mines there is also the possibility that used equipment from the US or other countries is supplied to Australian mines slowing the uptake of newer engines.

5.3 Emission Control Options

The ultimate diesel particulate emission control option would be to remove diesels from underground mines. There are alternative systems such as the electric monorail system proposed by researchers at the Kalgoorlie School of mines. There are other options such as the electric trucks (http://www.gia.se/eng/index.htm) that have also been around for some time and in use in other parts of the world.

Water Scrubbers with disposable particle filters have been identified as the best option in Australian coal mines (Davies, et al, 2004). The coal mines need the wet scrubbers to reduce the exhaust temperatures to below auto ignition temperatures for flammable gasses that occur in coal mines. Apparently wet scrubbers were trailed in WA underground mines but were found to introduce additional problems through increased NO2 and nitric acid emissions (Hussey, 2007).

There are many options available when using some of these technologies and they can be used in combination (Conrad, 1996 and McGinn 2004). Ceramic filters and enhanced catalytic converters represent the most practical retrofit emission control options available to the industry right now. MSHA has created an online, interactive guide to assist in filter selection, this guide is at:
http://www.msha.gov/nioshmnmfilterselectionguide/dpmfilterguide.htm

5.4 Exhaust Particulate Emission Testing

Diesel engine exhaust emission testing is one facet of the emission control (and hence exposure control) management that that is has had no guidance from the state safety regulator since the opacity-monitoring requirement was exempted in 1999.
There are three aspects of exhaust emission testing that need to be considered:

1. What technology or range of technologies are to be used to conduct the testing and,
2. How is the testing to be conducted (stall test, under load etc), what frequency is requires/ suggested and
3. What standards are to be used to assess the results of the test, i.e. what is pass / fail for emission levels?

The current WA regulations for ventilation requirements use air flow (m^3 per second) per engine power ratings that are used in many underground mining regulations (MSIR 10.52). Together with open-ended “exhaust treatment device” requirements and some specification for CO and NO_X emission testing (MSIR 10.53, 10.54) these regulations allow emission testing and underground ventilation requirement to be managed separately.

The Bosch Smoke meter has been suggested for use in the UK, this device has the advantage of being used as a surrogate exposure monitor also (HSE 2004). It is also currently in the standard for diesel engines in coal mines (AS 3584.2 -2003).

A Mobile Raw Exhaust Test Trailer (Davies, Rogers, 2004, p 33) has potential for very high quality analysis but may be suited to the NSW coal industry where the mines are generally closer. This would be a high cost option and would require a very compelling case to be adopted in Western Australia.

There are pressure drop devices, such as the “Diesel Detective” which is still underdevelopment by SKC. These devices have the advantage of being easy to use and have been developed with the intention of providing maintenance fitters at mines with these devices so that they can perform exhaust particulate testing more frequently than possible using large (expensive) Mobile Raw Exhaust Test Trailers.

The Emission Assisted Monitoring Procedure (EAMP) being suggested by the US - NIOHS doe not specify which emission monitoring technique is to be used.
http://www.cdc.gov/niosh/mining/topics/diesel/eamp/eamp.htm

While some techniques, such as the Bosch Smoke Meter have been considered unsatisfactory (Davies, et al, 2004) and others such as the SKC "Diesel Detective" are still being developed into commercial products and there may be other techniques not identified by this review, it is preferable, at this stage to present the options and propose some targeted research and practical testing be conducted with industry to identify the preferred options for the WA underground mining industry.

5.5 Underground Ventilation

Improved training for underground ventilation officers, there is a CERT IV course in underground ventilation that could be mandatory for underground ventilation officers to attend.

The Canadian Air Quality Index (AQI) has the potential to be a useful management tool for underground ventilation officers to assess air quality. The original had two equations and used the respirable combustible dust technique for measuring diesel particulate (French and Mildon, 1990). These equations have been updated and combined to give the following formula:

$$AQI = CO/50 + NO/2.5 + DPM/2 + 1.5((SO_2/3) + (DPM/2)) + 1.2((NO_2/3) + (DPM/2))$$

Where the gas concentrations (CO, NO, SO_2, NO_2) are in parts per million (ppm) and the diesel particulate matter is in milligrams per cubic metre (mg/m^3).

It is recommended that the AQI does not exceed 3. The same formula is called the Emission Quality Index when used to measure exhaust emission toxicity and is used at eth criterion of exhaust toxicity o the Canadian Standards Association standards (Gangal et al, 2002).

The Australian national guideline for atmospheric contaminants (NOHSC 3008, 1995) recommends a similar approach when there is a mixture of substances with similar effects. Unfortunately this approach is not well understood and little used in general industry. Using an AQI approach would ensure that monitoring and control of diesel particulates does not replace monitoring and control of other contaminants. It would also be useful to raise awareness and understanding that diesel particulates are a hazard, just like the other exhaust constituents.

Each mine site in Western Australia is required to appoint a ventilation officer (MSIR 9.3). Qualifications and duties of the ventilation officer are also prescribed (MSIR 9.4, 9.5). For underground mines the ventilation officer is usually a mining engineer. It is common practice for the most junior engineer at an underground mine to be the designated ventilation officer. (Brake, 2006 – Minesafe March 2006)

5.6 Enclosed Cabs

Much of the modern underground diesel fleet uses enclosed cabs. These cabs can reduce the exposure of workers to many of the common hazards in the underground mine environment. If these cabs are a significant control element then is may be relevant to assess their effectiveness. The least preferred control option for an atmospheric contaminant hazard such as diesel particulates is to use personal respiratory protection.

Enclosed Cabs require adequate seals, proper air conditioning units to maintain positive pressure and adequately filter air. Significant reductions in diesel particulate exposure, from 30 to 87%, are reported from the use of well-designed enclosed cabs with adequate filtering of air (Davies, et al 2004).

Enclosed cabs have the potential to reduce exposure to noise, vibration and heat as well as atmospheric contaminants. Most underground miners work twelve-hour shifts in Western Australia. Hearing loss is a significant factor in the Western Australian mining industry. Very little assessment has been done at an industry level on vibration. Heat stress is one of the main human factor issues associated with underground miners, and only increases and mines become deeper and hotter (Brake, 2006).

Enclosed cabs have become much more widely used for various underground mining equipment such as jumbo drill rigs and boggers (loaders). It is likely that there are additional requirements for use of enclosed cabs if they are to be used to reduce exposure to diesel particulates as well as heat, noise and vibration. Managing these physical factors assists in managing other issues such as fatigue. Mainly in maintenance of door seals, filters and ensuring that miners stay in the cabs (with windows closed) as much as practicable.

Using enclosed cabs as control options may assist mines with diesel particulate exposure control problems minimize exposures. For example, a certain area of the mine may only be ventilated using series ventilation, with significant particulate loading of the incoming air. So a management strategy may be to mandate enclosed cabs, with limited out of cab work – with RPE, until the ventilation system can be improved.

6. Discussion

There is no national (ASCC) exposure standard of diesel particulates and there has been no public indication of any plan to introd no plan to introduce a national exposure standard has been . Not having a national exposure standard presents difficulties in hazard recognition. There is a perception in some areas of industry that if there is no exposure standard then there is no point in monitoring because there is no standard with which to compare the results. The lack of a regulatory exhaust particulate emission limit or level has the same issues. There is also wariness after apparent difficulties in application of Opacity regulation.

There are limited facilities currently available in Western Australia for emission testing at mine sites. The vehicle emission testing is typically conducted by contract companies that mainly ensure that the regulatory requirements for emission testing are met (gas emission testing). Rather than conducting emission testing as a compo net of the underground ventilation management. Exposure monitoring is largely managed in the same manner at underground mines, contract samplers ensure enough samples are collected so that sites meet their Contam quotas, rather than using sampling to properly assess miner exposure.

There are obvious budgetary constraints of mine operations, this typically means that they won't fit additional emission control devices if not mandated in regulation. This review of underground mine workers exposure to diesel particulate matter illustrates some of the limitations of the CONTAM system.

The CONTAM system does not record enough supporting information about the individual sites, locations within sites, work activity and other factors that affect exposure. Analysis of CONTAM data can provide some direction in where to target inspection, audit or review activity.

It would be useful to compare the conclusions reached from analyzing this industry wide data with targeted, intensive monitoring of individual mine sites. Through this type of comparison it would be possible to quantitatively assess the usefulness of analysing CONTAM data at the industry level.

Data analysis and reporting of results can take many different forms. A selection of graphs is provided in the appendix as a demonstration of the various ways this data can be presented.

6.1 Exposure Standard Adjustment

Recent advice from principal researchers in NSW has indicated that the 0.1 mg/m^3 exposure standard for diesel particulates (measures as elemental carbon) be used and an absolute limit, not to be adjusted for different shifts.

The exposure standards being used for DPM have no specific legislative foundation at this stage. The ASCC has not indicated that a national exposure standard for DPM is being considered. It is important to make this clear when providing advice to industry. The new WA Working Hours code of practice of Working Hours has a process for assessment of risk associated with any hazards that may be affected by hours of work.

There are several different health effects linked to long tern exposure to diesel exhausts and this would normally lead to applying a adjustment to the exposure standard for diesel particulates which, as has been shown, would significantly increase the portion of samples collected being over the (adjusted) occupational exposure standard.

Much of the risk assessment work has been addressed at the available occupational exposure data. It is considered that the best driver for improving efforts to recognize and control this hazard it to present a strong case that indicates unacceptable over exposure is occurring.

7. Conclusions

It is not the intention to establish an ongoing data collection program as an end in itself. When the exposure is well categorised the sampling effort should shift to specific areas of uncertainty. Over time it is intended that areas with high diesel particulate concentrations will be targeted for improvement; areas with low diesel particulate concentrations will be revisited for periodic testing.

The issues with air quality generally in underground mines are well known. Diesel particulates represent one of the significant chronic occupational hazards in underground mines. CONTAM has proved useful in raising awareness of the DPM hazard among some underground miners.

During the phase in period for diesel particulate sampling in the CONTAM program, concerns over DPM exposure have been raised in areas where diesel engine vehicles are used in surface operations (forklifts and loaders working in stockpile sheds, maintenance workshops etc.).

There is a wealth of readily available information on the risks associated with diesel particulates, techniques for exposure monitoring, techniques for emission testing, emission controls and other control methods. Very little diesel particulates exposure monitoring was undertaken in WA underground mines prior to the introduction of diesel particulate in CONTAM quotas in 05/06. Personal exposure results indicate that there room for significant improvement in exposure control.

If the mining industry is not controlling the hazard independently there may need to be increased regulatory controls. A guideline developed in conjunction with the WA hard rock mining industry is an option that may be of most use. The development phase could be used to increase awareness of this issue and set out a reasonable time frame for improvements that has been agreed to by industry.

8. Recommendations

- Continue to raise awareness of diesel particulate hazard through relevant (website, MineSafe etc)
- Present exposure results to Division, Department and industry
- Promote MDG 29 “Guideline for the Management of Diesel Engine Pollutants in Underground Environments”
- Increase monitoring efforts, improve data quality through additional information gathering
- Assess / audit management of diesels and underground ventilation:
  - Audit of mine ventilation, exposure assessment and management of diesel engines and emission controls. This could be undertaken separately (as part of the MODAMS audit program) or in conjunction with the sampling program. Combining an audit with a sampling program would provide very useful information that would enable some quantification of controls
- Develop control option resource targeted at WA underground mines.
- Develop preferred emission monitoring proposal with industry.
- Develop Diesel Particulate (or Diesel Emission) Control guideline for WA underground mines
- Provide more information about the analytical issues concerning LOD, filter size, volume samples and DP concentration to ventilation officers and registered samplers

- Comprehensive sampling program to scientifically assess the level of diesel particulates in WA undergrounds mines
- Sampling program that assesses different sampling options
  - SKC DPM cassette sampling
  - Respirable combustible dust method
  - Bosch smoke meter assessment
  - Sampling using respirable cyclone sampling (without DMP cassette)
  - Diesel detective – exhaust particulate emission monitor (being developed by SKC)
  - Sample for gas components of exhaust (NO_X) to assess potential for surrogate assessment using gas monitors.
-
- **CONTAM**
  - **Request submission of diesel register with quarterly samples from underground mines.**
  - **Request targeted information:**
    - **Number of units UG during sampling**
    - **Worker in cab etc**
    - **Location as per vent plan**
    - **Summary of air flow in work areas**

9. Proposal for future work

A targeted sampling program, utilizing a customised audit would be highly beneficial in providing a scientific basis for the regulation of this OH&S issues by Resources Safety including:
Sampling for diesel particulates
Assessing ventilation of mine during sampling period

- Number of vehicles, horsepower,
- Ventilation officer (training, awareness of issues)
- Ventilation system
- Size of mine
- Maintenance on vehicles
- Exhaust systems
- Opacity (Bosch opacity meter)
- Cabin ventilation, filter systems

IH Stats and Lognorm2 were useful statistical packages for statistical analysis. However both require cut and pasting of data. Future development of similar statistical features in MS Access and R-stats that could significantly improve our ability to use current occupational hygiene statistics.

Watch developments through relevant organisations and conferences such as the mining diesel emission conference: http://www.dieselnet.com/mdec/.

A guideline for WA mining industry is needed. This is a conclusion reached as a result of preparing this report. Until now it was considered that providing information sources and utilizing the other guidelines available (AIOH, NSW etc) would be sufficient. However the main Australian guidance has been developed from work at underground coal mines in the main and

Discussion around future research projects with the Minerals and Energy Research Institute of Western Australia and the WA Chemistry Centre. The Chemistry Centre is interested in exposure monitoring for some of the known toxics in diesel particulates such as nitro poly aromatic hydrocarbons and even using urinary biomarkers to assess exposure

Review Departmental databases and analyse:

- Underground ventilation management audits (around 70 audits between 1997 to present)
- Data on diesel units used in underground mines (no longer recorded)

International Society of Mine Safety Professionals:
Special day targeted at underground ventilation with proposals for action developed on the day as per the Noise, Safety approaches

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11. Appendices

Appendix 1 Glossary

AIOH	Australian Institute of Occupational Hygienists
ALARP	As low as reasonably practicable
AS	Australian Standard
ASCC	Australian Safety and Compensations Council (formerly NOHSC)
CANMET	Canadian Mining and Mineral Sciences Laboratories
CDC	Centre for Disease Control (US)
CME	Chamber of Minerals and Energy (Perth)
DEEP	Diesel Emissions Evaluation Program (Canada)
DME	Department of Minerals and Energy (Western Australia)
DOCEP	Department of Consumer and Employment Protection (W.A.)
DOL	Department of Labor (US)
DP	Diesel Particulate
DPM	Diesel Particulate Matter
EC	Elemental carbon
HSE	Health and Safety Executive (UK)
LOD	Limit of detection
MDG	Mine Design Guideline (NSW)
MSHA	Mines Safety and Health Administration (US)
Mg/m^3 –	milligram per cubic metre
MVUE	minimum variance unbiased estimate
NIOSH	National Institute of Occupational Safety and Health (US)
NOHSC	National Occupational Health and Safety Committee (Australia)
OC	Organic carbon
OSHA	Occupational Safety and Health Administration
PAH	Poly aromatic hydrocarbon
PPM	Parts per million
TC	total carbon

Appendix 2 Diesel Engine Audit

DRAFT AUDIT POINTS

Policy

- Does the site have a policy on the management of diesel engine pollutants in the underground mine?
- Does the policy include a commitment to maintain pollutants to as low as practicable?

Management

Diesel Unit Register

- Does the site maintain a diesel unit register?
- Does the register include all relevant information as per the SME requirements:
    - List of all underground mines under the jurisdiction of the manager where the unit will be used
    - Name of owner of the unit
    - Asset or reference number of the unit
    - Make of the unit
    - Model of the unit
    - Make of the diesel engine
    - Model of diesel engine
    - Diesel engine number
    - Approximate flywheel power rating of the engine in kW
    - Maximum undiluted exhaust emission measurements for oxides of nitrogen and carbon monoxide in parts per million taken at the last test together with the date of that test
    - A record of any exhaust treatment device or other device and of any special conditions of use determined by the manager to be necessary for the safe operation of the unit underground
    - A record of the type and capacity of all fire fighting appliances and/or equipment installed on the unit
    - A record of the ventilating air requirements for the unit calculated pursuant to Regulation 10.52(5)
    - In an engine is replaced in any diesel unit details of that replacement engine, containing items (f), (g), (h), (i), (j) and (k) of condition (2), shall be entered in the register
    - If a diesel unit is removed permanently from an underground mine a record of the removal shall be made in the register
    - Every entry in the register shall be signed and dated by the manager and his authorised representative

Fuel, Fuel additives

- Does the site have a specification for fuel type

- Is this specification part of supply contacts
- Does is specify low sulphur fuels?
- Do the fuels used comply with the relevant standards?
- Are fuel additives used on this site
- Do these additives comply with the relevant standards
- Are there MSDS forms for fuels and additives?
- Fuel storage
- Fuel useage – is the fuel used within the designated storage time frames
- Fuel quality testing
    - Reports on fuel as delivered
    - Reports/ testing of site stored fuel?
    -

Engine specifications

- Is there a register of diesel units ?
- Does the site maintain relevant documents from the diesel engine manufacturer relating to use and maintenance of the engine
- Are the engines being used according to manufacturers specifications (load, etc)
- Are the relevant records being kept relating to engine use (hours, etc) as per the manufacturers requirements

Engine Maintenance

- Does the site maintain manufacturer's instructions for engine maintenance?
- Does the site conduct ensure that engine maintenance is undertaken by suitably qualified professionals?
- Does the site maintain the engines according toe the manufacturers instructions?
    - Does the site maintain documentation to show this?
- Does the site have an alternative maintenance schedule?
    - Does the site have documentation to show that the alternative maintenance schedule is as good as the manufacturers schedule?

Emission control

- Are the underground diesel engines fitted with emission control devices?
- Are the emission control devices listed on the Register?
    - Are the emission control devices maintained to the manufacturers instructions

Emission monitoring

- Is there a formal emission monitoring program at the mine?

Underground ventilation

- Is there an underground ventilation plan for the mine
- Does the plan reference the ventilation air requirements as listed in the Register?
- Does the ventilation circuit used recirculation
- Is the air quality tested periodically (to a set monitoring plan)

-

Vehicle Cabs, A/C

- Is there a maintenance system for vehicle cabs?
- Are vehicle cabs used with windows closed?
- Are there appropriate filter dev

Occupational Exposures

- Is there an occupational exposure monitoring program at the mine?
- Are diesel emissions (gasses, DPM) included in the exposure monitoring?

PPE

- Is there a PPE program at the site
- Is PPE part of the system for controlling exposure to DP?

Appendix 3 Literature Review

HEALTH
Diesel particulates are one of the components of diesel engine exhausts which have been suspected of being carcinogenic for some time. The Schenker (1980) paper assessing the potential carcinogenicity of diesel exhausts raised the issue of the known carcinogens poly-aromatic hydrocarbons (PAHs) being constituents of diesel exhaust and the increased risk posed by the carbon particles in diesel exhaust. While there has been extensive work conducted on health effects of diesel particulate leading to classifications as a probable carcinogen by NIOSH (1988) and IARC (1989) it must be noted that technically there is still debate Silverman (1998). The issue of health effects for diesel particulates has significant implications for population health in general hence the most comprehensive health assessment review to date has been conducted through the US Environmental Protection Authority. Prior to this EPA report the most significant report was targeted at underground miners in the report on Health Implications of Exposure of Underground Miner workers to Diesel Exhaust Emissions (French, Mildon, 1990). The French and Mildon report is also notable for describing the Air Quality Index (AQI), which has apparently been further refined into the AUQ/EQI as describes in the CANMET overview (Gangal, 2002). The collection of mine worker health data in Western Australia, an overview of which is provided by Turner (2003), may enable an assessment of effects that working in underground mines has on lung function and / or respiratory health to be undertaken.

MONITORING
The AIOH document A Guideline for the Evaluation and Management & Control of Diesel Particulate in the Occupational Environment, (Davies and Rogers 2004) is central to the development of my understanding of the risks of diesel exhaust constituents to underground miners, especially diesel particulates. This guideline was available in draft format on the AIOH website in 2003. The authors are very experienced occupational hygienists and the most useful component of this guideline was the proposed occupational exposure standard. When this document was published the US exposure standards for diesel particulates in underground mines was still being renegotiated through the US legal system (refer to 30CFR57). This document described the composition of diesel particulates, reviewed what was known about the health effects, workplace exposure standards, monitoring and sampling and control technologies. The authors of this guideline have been involved in most of the research that has been conducted in Australia to date through BHP –Coal, Coal Services and the NSW DPI. The guideline also follows on from work conducted for Davies' thesis (Davies, 2004).

The NSW work has culminated in the Guideline for the Management of Diesel Engine Pollutants in Underground Environments, MDG 29 (NSW Department of Primary Industries – Draft January 2007). This guideline is essentially an update of the earlier document: Diesel Emission in Underground Mines- Management and Control (NSW Minerals Council 1999).

Many of the OSH regulatory authorities are pursuing "Robens" style "outcomes based" legislative frameworks and one element of this is the placement of much of the prescriptive detail for OSH management into codes of practice and guidelines. The updated NSW guideline is an example of this, of setting out what is considered "good practice". The subtle change from emissions to pollutants indicates the more holistic assessment of components that are sources from diesel engines that may have detrimental effects; the new guideline considers noise and vibration as well as the gas and particulate emissions.

The old NSW guideline uses the 0.2 mg/m^3 total diesel particulate as recommended exposure standards. The new NSW (draft) guideline uses the 0.1 mg/m^3 (elemental carbon) as per the AIOH guideline. Neither guideline directs on how to adjust for extended shifts however the old guideline does refer to the ALARP – as low as reasonably practicable approach (which is being removed from a lot newer occupational exposure guidance materials). Techniques for adjustment of exposure standards for extended shifts are provided by SIMTARS and DME (1999). Exposure standards are typically stated as time weighted average (TWA) standards for eight hour days / five working days per week, NOHSC (1995). There are also short term exposure limits (STEL) and peak exposure limits, gasses often have STEL's or peak exposure standards. The exposure standards for diesel particulates provided by the AIOH and NSW guidelines do not state that the standards are TWA exposure standards.

While discussion over whether to adjust the exposure standards for extended shifts and which exposure sampling technique to use will undoubtedly continue, these debates should not prevent action being taken to adequately control exposure to diesel particulates.

Most of the research on control of engine emissions and diesel particulate exposure that has led to the AIOH and NSW guidelines has taken place in underground coal mines. Underground coal mining is a significant, if not main, component of underground mining in NSW and Queensland. WA has no operating underground coal mines at this point in time. The underground coal ventilation officer is more likely to be a senior engineer in coal mines than the underground ventilation officer in hard rock mines due to the risks associated with flammable gasses in underground coal mines.

The UK HSE guideline (HSE, 2003) is useful in that it explicitly refers to non-coal mines and proposes, via the Bosch Smoke meter, a useful tool for testing exhaust particulate emissions and estimating ambient articulate levels. While this approach doesn't receive much comment from the work in the US or NSW the Australian Standard for underground diesel engine systems (AS 3584-2003) specifically mentions the Bosch smoke meter. The UK HSE guideline represents a potentially straight forward and low cost method for measuring emissions and ambient particles and for this reason merits further investigation.

The literature review identified several different techniques used to sample for occupational exposure to diesel particulates (Davies, Rogers, 2004). The RCD and gravimetric techniques have limited application due to the relatively high lower limits of detection. The coulometric methods have been in use for some time but the carbon analyzer method as described in the NIOSH 5040 method (NIOSH, 2003) was the most readily documented method and the method that was found to be most accessible. The NIOSH Manual of Analytical Methods (NIOHS, 2003) is one of the most reliable sources for sampling and analytical methods. All the methods in this compilation have been through comprehensive quality assurance testing programs. This document has a whole chapter dedicated to monitoring diesel particulates in the workplace that has to be considered as a key guidance document.

International

The US Code of Federal Regulations 30 CFR Part 57 is the final US regulatory instrument, developed after the legal challenges to the original Federal ruling on diesel particulate matter in underground mines and sets out the way forward for managing diesel particulates in underground mines in the US. This adversarial legal process for developing legislation results more in a compromise situation rather than best practice. The phase in process for a diesel particulate matter standard involves using both total carbon and elemental carbon limits. The 30 CFR57 regulations as supported by a useful MSHA guidance document (MSHA, 2006). The guidance illustrated the high level of direction provided by the US mines safety regulator – MSHA in both the actual regulations and also in support information, such ash the Toolbox - Practical ways to reduce emissions (MSHA- Toolbox).

Western Australia

The level of importance placed on ventilation management in underground mines in WA is a significant issue in any approach to reducing exposure to DP in underground mines in WA. Effecting adequate control of diesel particulates may require significant changes in the resourcing of ventilation management at underground mines in WA. Brake has developed a comprehensive training package for underground ventilation (2006i). A well respected expert in underground mine ventilation it is worth noting the comments by Brake (2006) in the MineSafe publication on the skills, training and resources required for quality management of underground ventilation systems.

In Western Australia, the mining safety legislation was re-written in the Mines Safety Inspection Act 1994 and Mines Safety Inspection Regulations 1995. This new legislation contained a while division relating to underground diesel units in Part 10 of the regulations. These regulations were significantly altered by State Mining Engineer exemptions by Torlach (1999) and Knee (2002). The state mining regulator, the Department of Minerals and Energy (DME) , did produce a set of guidance documents on diesel transport , storage and refueling underground, purchase operation and maintenance of underground diesel engine mining equipment and underground ventilation .

Emission Control

While there has been a significant amount of research into emission testing and control in Australia the Diesel Emissions Evaluation Program (DEEP) and the research projects sponsored by MSHA. Both organizations have made the project reports available through their web sites and detailed consideration of all these report will be necessary as various emission testing and control options are considered in Western Australian underground mines. DEEP projects referred to in this report have assessed fuel types and fuel oxidation catalysts (Watts, Spears, Johnson, 1998), general emission control strategies (ESI, 1999) as well as two major projects assessing exhaust filter technologies (Conrad 2006 and McGinn, 2004).

Websites:

http://www.deep.org/
http://www.dieselforum.org/
http://www.dieselnet.com/
http://www.msha.gov/01-995/dieselpart.HTM
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