MVSA Position on DPM

The Mine Ventilation Society of Australia (MVSA) was founded in 2012 by Australian mine ventilation practitioners, who share a common passion, dedication and commitment to ensure a safe and healthy work environment for fellow Underground mine workers.

The MVSA's vision is to assist the mining industry on continuous improvement and management in ventilation practices which would also lead to improved safety and productivity.

The MVSA ultimately serves our fellow underground mine workers to ensure and maintain a safe and healthy working environment. Having this as our core focus we need to:

- Respect the view of all members and industry partners with regards to ventilation and provide feedback.
- Seek continuous improvement in all ventilation aspects
- Share our knowledge and experience
- Act in a professional manner

Keeping the above in mind the MVSA looked at an area which required immediate focus and in 2013 released a white paper on diesel particulate matter and the management thereof. The MVSA has a vested interest in exposures to Diesel Particulate Matter (DPM) in the workplace as underground mines utilise large diesel fleets and our members are likely to be the professionals tasked with managing and controlling the hazards and risk associated with this exposure.

In June 2012 the International Agency for Research (IARC) on cancer which forms part of the World Health Organization (WHO) upgraded the status of diesel engine exhaust from 'probably carcinogenic' (Group 2A) to carcinogenic to humans (Group1). *"The scientific evidence was compelling and the Working Group's conclusion was unanimous: diesel engine exhaust causes lung cancer in humans.*
Given the additional health impacts from diesel particulates, exposure to this mixture of chemicals should be reduced worldwide"(IARC, 2012).

The classification is significant as it places DPM in the same light as other known carcinogens such as Silica and Asbestos. A clear distinction between dilution rates for managing exhaust gas and that required for diesel particulate matter is required industry wide. The MSHA model used in the United States is a good example of how this could be implemented. Having said this, caution should be exercised when changing, adopting new or harmonising standards that impact ventilation. Any increase in ventilation requirements will significantly impact the operating cost which in return will impact on mines financial viability. Relevant role players representing the mining industry, ventilation professionals, occupational hygiene professionals and safety professionals should be consulted. Finally the MVSA takes the position that DPM should first and foremost be **controlled** or filtered **at the source** prior to being introduced to the general body of air. We therefore encourage the use of DPM filters, higher class diesel engine, electrical vehicles, low emission hydrocarbons and or alternative fuels. We do realise that vast amounts of research still has to be done, and that there are unknowns, but to merely sit back and not engage the problem is not an option.

What is diesel particulate matter?

DPM is the solid particulate component of the exhaust gases resulting from incomplete combustion, typically consisting of elemental carbon (EC), organic carbon (OC), ash and various sulphur compounds. The solid carbon spheres adsorb hydrocarbons and other chemicals on the surface creating a vehicle for these elements to penetrate the lungs when inhaled. In context with the underground environment diesel particulate matter may be classed as unwanted.

Classification of diesel engines

Diesel engines are continuously improving as technology advances and indeed there are strict guidelines imposed on engine manufacturers regarding diesel exhaust. The two most notable guidelines include the European standard that refers to stages and United States standard (USEPA, 2013) referring to a tier classification. The table below summarises the emission targets for the different standard.

USA Standard	Intro Year	DPM Limit	Euro Standard	Intro Year	DPM Limit
Tier 1	1996	0.54g/kWhr	Euro stage I	1999	0.54g/kWhr
Tier 2	2003	0.20g/kWhr	Euro stage II	2002	0.20g/kWhr
Tier 3	2006	0.20g/kWhr	Euro stage IIIA	2006	0.20g/kWhr
Tier 4	2011	0.02g/kWhr	Euro stage IIIB/IV	2011	0.02g/kWhr
					0.01g/kWhr

The reality is that currently only Tier 1/Stage I and Tier 2/Stage II type diesel engines are commercially available in underground vehicles. Tier 3/Stage II is available but there are long lead times for delivery. Diesel particulate levels will be the same even with the introduction of Tier 3/Stage IIIA engines underground. Tier 4/Stage IIIB engine guidelines were only introduced in 2011 and the reality is that it will be some time before these are available to underground mining companies. A number of Australian mines still operate with engines that remain unclassified. The MVSA believes that when purchasing diesel equipment, mining suppliers must be set stringent targets and mining companies should consider making DPM filtration systems compulsory. These issues must be given due consideration during equipment procurement or contractor engagement which in return will help **eliminate** and **control** at the source.

Ventilation for gas versus DPM dilution

Diesel dilution rates as a volumetric flow rate per rated engine kilowatt is typically used as a guideline or statutory limit depending on the country or state a mine operates in. Typical dilution factors range between 0.05m³/s per rated kW and 0.1m³/s per rated kW. In Australia the following limits apply for New South Wales and Western Australia.

- New South Wales coal (CMHSR,2001) 0.06m³/s per rated kW
- Western Australia (WAMSIR, 1995) 0.04-0.06m³/s per rated kW

It is important to note that these limits are based on gas dilution requirements for Carbon Monoxide and Nitrous Oxides. There is no guarantee that when the statutory dilution rates are applied the diesel particulate concentrations will be below the guideline of 0.1 mg/m³ elemental carbon. In the Unites States and Canada diesel engines are tested by MSHA and CANMET respectively before they can be used underground. Normally the engine supplier applies for the certification. In the Unites States MSHA provides two ventilation rates, the 'ventilation rate' for gaseous emissions and 'particulate index' which cater for particulate emission. These rates are printed and fixed to vehicles and need to be supplied (displayed) for a machine when underground. CANMET follows a similar approach which differs slightly in the detail.

MSHA example:

- ***Particulate Index (PI)*** is the airflow quantity needed to dilute DPM emissions to 1 mg/m³ (Tomko, nd).
- ***MSHA Part 7 Ventilation Rate*** is the quantity of air required to dilute CO2 to 5000 ppm, CO to 50 ppm NO to 25 ppm and NO2 to 5 ppm.

The typical parameters for an underground haul truck are given in the table below (Atlas Copco, 2013):

Description	Value
Engine classification	Tier I
Engine rating	485 kW
MSHA 7 particulate index	934 m³/min (16 m³/s)
MSHA 7 ventilation rate	1,274 m3/min (21 m³/s)

A typical analysis of the ventilation and dilution rate is given in the following table:

Description		Value	Comment
Truck power rating	P	485 kW	
MSHA 7 ventilation rate	VR_G	21 m³/s	Gas dilution rate
Dilution rate for gas	DR_G	0.04 m³/s per rated kW	VR_G/P = 21/485
MSHA 7 particulate index	PI	16m³/s	Particulate dilution rate to achieve 1mg/m³
DPM reference	DPM_R	1mg/m³	Reference Limit
DPM limit	DPM_L	0.16 mg/m³	Current US limit
Ventilation rate for particulates	VR_P	100 m³/s	PI x (DPM_R/DPM_L)
Dilution rate for particulates	DR_P	0.21 m³/s per rated kW	VR_P/P = 100/485

A 50 tonne, 485 kW rated Tier 1 truck in the USA would require 21m³/s for gas dilution, this equates to approximately 0.04 m³/s per rated kW and very similar to Australian requirements. The same vehicle has a particulate index of 16m³/s and per the definition for Particulate Index this will reduce DPM to 1.0mg/m³. The current US limit for DPM is 0.16mg/m³. Total Carbon (TC), thus a mine operator would have to provide 16 x 1/0.16 = 100 m³/s to dilute DPM. Obviously a lot more air compared to the gas dilution rate and the effective ventilation rate will have to be 0.21m³/s per rated kW. If however an approved DPM filter is used which is say 80% efficient, the required dilution rate will be 20% x 100 = 20m³/s to meet the DPM limit and 21m³/s for gas dilution. The higher dilution quantity of the two (gas and diesel particulate) will be used, 21m³/s. With the DPM filter in place both the gas requirement and a strict DPM requirement of 0.16mg/m³ is satisfied with 21m³/s in the United States. However without the filter five times more air will be required. In Western Australia the airflow requirement will be higher with a slightly lower DPM limit of 0.1mg/m³. Ventilation rates are also based on typical statutory limits which are appropriate for gas dilution but not necessarily DPM for vehicles without filter technology. The following should be considered when applying dilution rates:

- ventilation rates should be based on the engine rated kW, without applying any utilisation factors, and that the rate be applicable at point of operation
- when considering the overall ventilation requirement of a ventilation district then the sum of the plated kilowatt of all diesel vehicles working within a ventilation district should be applied.
- the current Western Australian legislation exempts drill rigs and vehicles of small engine size used intermittently in assessing the airflow. Using this exemption to exclude auxiliary vehicles such as graders, I.T's, spraymech, small trucks and similar vehicles from the aggregate determination is discouraged. It is recommended that only drill rigs,

jumbos and standard four wheel drives vehicles used as personnel carriers be considered under this clause and the implications should be considered (a more correct way of doing it would be to proportionally factor in the equipment),

- there is also a case to argue that a diesel particulate index similar to the one adopted in the United States should ultimately be considered to define ventilation rates for underground diesel engines.

Engineering controls

Dilution is traditionally used to manage diesel exhaust however as highlighted previously this alone will not be sufficient to dilute DPM to below the guideline limit of 0.1mg/m³. Ventilation rate is a crucial factor and therefore should be optimised by designs, checked regularly and maintained, especially in secondary ventilated work areas. Dilution rates differ between states and harmonisation of legislation may in future see a push to nationally adopt the higher standard applied in New South Wales. An increased ventilation flow requirement will limit the underground diesel fleet size of numerous existing operations or significantly increase their capital and operating ventilation cost. Although this will have a positive impact on diesel particulate matter emission management, any consideration to increase dilution factor, needs to be done in close consultation with relevant industry groups. ***In any pollutant management strategy controlling the emissions at their source to prevent contaminants entering the atmosphere should be the primary objective***. DPM filters or other means of post treatment will reduce DPM exhaust levels for engines rated as Tier 1, Tier 2 and Tier 3. Indeed to achieve the emissions targets for Tier 4, engines will likely be fitted with DPM filters as standard. The current filter technologies can typically remove 85% of particles. The choice of filter will depend on the quality of the diesel fuel supply, duty cycle of the engine, maintenance and cost. The ability to regenerate (or clean) filters is important for their operation and needs special consideration (care must be taken not to expose persons during this process). The regeneration cycle is normally improved by adding a catalyst, increasing exhaust air temperatures or through reverse pulsed compressed air. The MVSA encourage the use of diesel particulate filters as a means to manage DPM exposure.

A number of alternative strategies are available and should be given due consideration in mine studies, design, operational improvement and research. These include the following:

- Filter technologies (engine exhaust and in cabin),
- Introducing lower emissions rated diesel engines,
- isolating personnel through automated vehicles or fully enclosed cabins,
- electrical alternatives,
- low emission hydrocarbons (lubricants and fuels),
- alternative fuels,
- alternative haulage strategies,
- consideration should be given to change the current use of force ventilation system in development heading to force/exhaust systems. Thereby extracting contaminated ventilation in ducts directly to surface, rather than forcing clean air in ducts thereby exposing employees to contaminated air flowing back along the drives,
- create segregated intake airways to reduce contamination of intake air thus eliminating or reducing diesel vehicle traffic in declines that act as main intake airways,
- by considering alternative haulage systems such as conveyors and shaft hoisting,
- Introduce administrative controls such as rotational shifts in and out of exposed areas.

Health surveillance programmes

The MVSA is concerned about the fact that the Mine Health assessments, conducted when a worker entered the Western Australian mining industry and periodically, were ceased on 13 January 2013. These assessments included work history, respiratory questionnaire, lung function test, audiometric

(hearing) test and in some cases, a chest x-ray (DMP, 2013). We believe the information collected under the previous program provides valuable data that could be used for further research regarding the long term health of workers not only from a diesel exhaust exposure perspective but also dust, noise and other contaminants.

Conclusions

The WHO classification of diesel exhaust as carcinogenic highlights the long term health effects of exposure to diesel exhaust in particular DPM. Whilst these effects do not represent an immediate safety and corporate risk to mining companies, the future effects could be profound. The MVSA welcomes the recent adoption of the WA diesel exhaust guideline and the incorporation therein of the AIOH DPM limits. We caution that the application of statutory dilution rates alone will not guarantee that these limits will be met. DPM should be managed **at the source** firstly by applying exhaust filter technologies, cleaner fuel and lubricants, improved maintenance and so on, followed by the provision of ventilation air to dilute the portion not effectively captured.

The Mine Ventilation Society of Australia (MVSA) encourages all role players to share knowledge and work together in the progressive interest of providing a safer working environment for all. By joining the MVSA and actively participating in discussion groups and knowledge shares this will become a reality across all of the industry, Hard rock as well as coal. For more information please visit our web page or e-mail the Mine Ventilation Society of Australia at admin@mvsaus.org.au

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