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(For Noting)

DIESEL PARTICULATE MATTER POSITION PAPER

Background

Diesel Particulate Matter (DPM) has been classified as a carcinogen to humans (Group 1) by the International Agency for Research on Cancer (IARC) and the World Health Organisation (WHO) in June 2011. The classification then required the Group Environmental Engineers committee (GEEs), a committee at the Chamber of Mines to discuss the occupational health issues related to diesel engine exhaust, specifically diesel particulate matter (DPM), exposures and to provide guidance to the industry on the matter. Therefore the GEEs has a keen interest in the potential for workplace exposures to DPM, as its members are the professionals most likely to be asked to identify associated hazards, assess any exposure risks and advise on control measures.

Currently in South Africa there are no personal occupational exposure limits or legally binding tailpipe emissions standards in place for DPM. Mining companies are however obliged to conduct risk assessments in terms of Section 11 of the Mine Health and Safety Act (Act 29 of 1996) on all factors that could adversely affect the health and safety of the workforce and institute appropriate mitigation measures, where no local regulations exist, international best practice should be utilised. OEMs are also required to provide a full disclosure, in terms of Section 21 of the Mine Health and Safety Act (Act 29 of 1996) of the health and safety impact of the equipment being sold to a mining company and advice on appropriate measures that can be taken to eliminate or reduce the risk.

Way forward

The Group Environmental Engineers committee formulated a task team to develop a mining industry DPM position, whereby the attached position paper has been approved by the Group Environmental Engineers committee in order to assist the mining industry to:

- conduct risk assessment on DPM exposures;
- Identify DPM exposure sources;
- Evaluate DPM exposures;
- Develop strategy in order to control employee's exposures to DPM

Recommendation

It is recommended that the mining companies develop and implement a strategy that will minimize exposure to DPM by using the attached DPM position paper as guidance.

Regards,

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DIESEL PARTICULATE MATTER (DPM) AND OCCUPATIONAL HEALTH RISKS

BACKGROUND

A national OEL has not been established because there are various factors that limit the control of DPM in South Africa compared to other countries such as those in the European Union. One of the constraints faced by the mining industry is the poor quality of fuel available in South Africa, which in turn limits the use of diesel engines with better fuel combustion and which have reduced emissions (Venter 2008, Carolin 2010). For the past couple of years efforts have been made by the Department of Mineral Resources (DMR) and the industry to determine which concentration of DPM could be used as an OEL. There was a proposal to implement a target value of 0.300 mg/m³ elemental carbon (EC) and to further reduce the target value over a number of years (Mine Health & Safety Council, MOHAC DPM Task Team, 2009/2010), however, the proposal was never formalised.

The recent reclassification of DPM as a carcinogenic to humans (Group 1) by the International Agency for Research on Cancer (IARC) needed the GEEs to discuss the occupational health issues related to occupational exposure to DPM and to provide guidance to the industry on the matter.

THE COM GROUP ENVIRONMENTAL ENGINEERS

The Group Environmental Engineers is a sub-committee of the Health Policy Committee. The GEEs are mandated to:

- Continue to keep abreast of developments in its areas of expertise, e.g. technical, education, training, safety and health, environment etc.
- Identify opportunities and threats in its field of expertise;
- Conduct specialist investigations, through issue driven working groups where necessary;
- Comment on matters of industry concern in its field of expertise.
- Recommend joint industry actions to the Chamber policy committees;
- Consider and make recommendations on education, training and certification concerning the mine environmental engineering and occupational hygiene disciplines and to provide input on such matters to outside bodies involved in training and education such as universities, MQA etc.
- Promote and oversee research and development in its areas of concern; and
- Promote networking with relevant persons/bodies to promote matters that benefit the mining industry and are related to mine environmental engineering and occupational hygiene.

Therefore the GEEs have a keen interest in the potential for workplace exposures to DPMS as the GEEs (i.e. the Ventilation and Occupational Hygiene Practitioners) are the professionals most likely to be asked to identify, evaluate and control occupational exposure to DPMS.

POSITION PAPER DRAFTING TEAM

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POSITION ON DIESEL PARTICULATE AND ITS POTENTIAL OCCUPATIONAL HEALTH RISKS

What is Diesel Particulate Matter (DPM)?

Diesel-powered equipment is used on a large scale in all industries and in numerous mining operations – both on surface and underground. The tail-pipe emissions from these engines contain gases (carbon monoxide, carbon dioxide and oxides of nitrogen) which are poisonous. In addition, un-burnt fuel particulates act as adsorption and condensation sites for a number of hydrocarbon vapours present in the fuel mixture or formed in the combustion chamber. These agglomerates typically have an aerodynamic diameter varying between 0.1µm and 1µm and are collectively known as diesel particulate matter or DPM.

Considering its physical properties, DPM is classified as “respirable” matter and may be deposited in the lung’s alveoli. Furthermore, Organizations such as the WHO, US EPA, NIOSH, IARC, ACGIH and others have classified DPM as a “likely”, “suspected”, “probable” and “potential” carcinogen and most recently (June 2012), the WHO has classified Diesel Exhaust Emissions as a Group 1 carcinogen. In addition to suspected carcinogenetic effects, DPMs cause irritation of the nose, eyes and respiratory tract, exacerbate asthma and may induce cardiovascular disorders.

Considering the number of disciplines concerned in motivating, purchasing, use, repair, maintenance, and assessment of impact on workers and occupational environment related to the use of diesel-powered vehicles, wide representation need to be sought for the mitigation of harmful diesel engine emissions in workplaces and subsequent possible exposure of employees to the emissions whilst at work.

Exposure measurement methodology

Methods for the quantification of employee exposure to diesel exhaust emissions (incl. particulates) have been developing over approximately 30 years. The most advanced and specific method involves capturing the submicron fraction of the workplace aerosol and then determining the amount of the core component of diesel particulate (carbon). Recent commercial developments provide ease in routine submicron sampling using a single use impactor cassette fitted into a respirable aerosol cyclone which is necessary when sampling in dusty atmospheres to prevent clogging of the cassette impactor holes.

Sample analysis methodology

Sample analysis on the captured aerosol is best conducted using NIOSH method 5040 (NIOSH 2003) for determination of carbon species (especially elemental carbon), however care needs to be exercised to minimise errors due to sampling, blank filter interpretation and instrument operating parameters (Davies & Rogers, 2004).

The South African mining industry exposure scenario

Potential for exposure to DPM exists whenever workers are in close proximity to operating diesel equipment. In many cases the fact that the equipment is operating in the open environment significantly reduces the potential for excessive exposures. Conversely, where diesel equipment is operating in confined areas (e.g. underground mines) there is a significant risk of exposure.

In South Africa a SIMRAC study conducted in 2002 in two gold mines, one coal mine and two platinum mines, indicated that workers were exposed to mean EC concentrations that exceeded the American Conference of Governmental Industrial Hygienists (ACGIH) guidelines of 0.02 mg/m³ and some samples exceeded the MSHA guidelines of 0.160 mg/m³. (Van Niekerk et al. 2002).

The study suggested that the factors contributing to the problem of these high exposures to EC were the densities of underground diesel-powered vehicles used in the mines, variation in the types of diesel-powered vehicles used, underground ventilation practices and the maintenance of vehicles or the lack thereof. The study further reiterated the need for assessment and the introduction of measures to reduce emissions and worker exposure and regulations to control exposure to DPM (Van Niekerk et al. 2002).

Van Niekerk et al. (2002) state that the South African mining industry shares the same global concern regarding occupational exposure to DPM and its associated health effects, yet there is no OEL or guidelines regarding DPM in the working environment. Belle (2008) revealed that TC versus EC (TC/EC) ratios measured in South African mines have shown the limitations associated with the adoption of international standards because the median TC/EC ratio for underground platinum mines in South Africa is 1.8, with a range of 1.2 to 5.8; coal mines have a median ratio of 1.44, with a range of 1.25 to 2.13, both of which differ from the international ratios, which makes it difficult to rely on the DPM international OELs.

Control strategy

Over the past 15 years considerable research has taken place to develop suitable control technologies, especially for vehicles operating in confined areas (e.g. underground mining).

Proven control technologies include:

- Low emission engines
- Low / Ultra Low sulphur diesel
- Ventilation
- Engine maintenance
- Exhaust filtration systems
- Air conditioned (filtered) operators' cabins
- Operating practices
- Driver and workforce education
- Personal protective equipment

Experience has shown that no one single simple solution exists and that individual mines need to explore which of the above control technologies best fit their circumstances.

Current applicable legislation and standards

Currently, exposure limits are legislated in Australia, Canada, United Kingdom and United States of America. These limits are based on the measurement of particulate constituents as indicated in the table below:

Regulator/Agency	Exposure Guideline/ Limit	Substance Measured
Canada (Ontario province)	400 µg/m ³	Total Carbon or TC
US MSHA	160 µg/m ³	Total Carbon or TC
Australia	160 µg/m ³	Total Carbon or TC
	120 µg/m ³	Elemental Carbon or EC

Internationally, DPM is regulated via two mechanisms i.e. Occupational Health and Safety Standards and Tailpipe Emission Standards. Where diesel engines are used in confined spaces, their operation is regulated by occupational health standards in addition to tailpipe emissions.

In South Africa, the regulatory authority (Department of Minerals and Energy) for Mine Health and Safety would normally promulgate regulations controlling the exposure of the workforce to below a specified Occupational Exposure Limit (OEL), which has a similar definition to a TLV. Under the Mine Health and Safety Act (Act 29 of 1996) a Guideline for a Mandatory Code of Practice on the use of diesel engines should also be considered from a health and explosion prevention perspective. The South African Bureau of Standards (SABS), also publishes engine performance standards that can be made legally binding to OEMs and industry when referred to in legislation.

Currently in South Africa there are no personal occupational exposure limits or legally binding tailpipe emissions standards in place for DPM. Mining companies are however obliged to conduct risk assessments in terms of Section 11 of the Mine Health and Safety Act (Act 29 of 1996) on all factors that could adversely affect the health and safety of the workforce and institute appropriate mitigation measures, where no local regulations exist, international best practice should be utilised. OEMs are also required to provide a full disclosure, in terms of Section 21 of the Mine Health and Safety Act (Act 29 of 1996) of the health and safety impact of the equipment being sold to a mining company and advice on appropriate measures that can be taken to eliminate or reduce the risk.

The GEE's recognise that several International Agencies have imposed limits for DPM, but also that these limits have been developed in countries where:

- Higher quality diesel fuel with low sulphur content is used;
- Latest generation diesel engines are used;
- Maintenance staff is adequately trained and available for employment to work on these units; and
- Exhaust purification systems are used extensively.

To this extent, the GEE's recommendation for action is to introduce an interim DPM exposure control value and gradually lower this exposure control value by means of a "phased-in" approach as follows:

- A DPM exposure control value of 350 $\mu\text{g}/\text{m}^3$ (TC) up to 31 December 2013
- A DPM exposure control value of 250 $\mu\text{g}/\text{m}^3$ (TC) for 01 January 2014 to 31 December 2014
- A DPM exposure control value of 200 $\mu\text{g}/\text{m}^3$ (TC) for 01 January 2015

As from 01 January 2016 a DPM exposure control value of 160 $\mu\text{g}/\text{m}^3$ (TC) will be adopted. This level is however subjected to review should new knowledge on the risks associated with excessive exposure to DPM become available.

GEE Recommendation

a) DPM exposure control level

Based on the available information and known limitations, the GEEs believe that worker exposure to DPM levels should be reduced step wise over the next five years to below 120 $\mu\text{g}/\text{m}^3$ (measured as submicron total carbon) in 2016.

b) Existing Mines

1. Baseline audit: vehicle fleet

This process consists of determining the equipment type and number of vehicles currently in operation in a mine. The purpose is to establish the “test” emission parameters for engines certified by the US EPA and/or NIOSH and/or CANMET and compare these with actual exhaust emission measurements. The following course of action is proposed:

- Generate a “working vehicle” inventory at each mine
- Identify the required ventilation rates and emission characteristics (from published data).
- Measure emission quality in workshops (as part of maintenance procedure prior to release in the field) and compare with certification data.
- Analyse the data with the view to:
 - Confirm applied ventilation rates;
 - Verify effectiveness of maintenance procedures and intervals;
 - Verify the effectiveness of catalytic treatment of the exhaust – where installed;
 - Consider the feasibility of retrofitting exhaust particulate filters (in consultation with OEMs);
 - Introduce the use of exhaust dilution systems as an alternative;
 - Consider the use of fuel additives (fuel-borne catalysts, in consultation with OEMs and fuel suppliers);
 - Introduce inlet air filtration (where deemed necessary);
 - Identify non-certificated or poorly performing units with the view of prioritising their replacement.

2. Vehicle maintenance

In an effort to ensure and certify adequate vehicle maintenance, mines should perform simple emission tests prior to releasing a vehicle into the underground mine after maintenance - the test results being kept as a record of the condition of the vehicle for further assessment. This will entail the use of multi-gas measuring instrumentation. Vehicles should only be released if they meet a required emission standard.

3. Baseline assessment: worker exposure

The quality of worker exposure assessment is to be improved to make the data more meaningful. This should include amongst others details if the workers’ occupation and activity during the shift in

an effort to facilitate the formation of homogenous exposure groups (HEGs) to be used in a formal monitoring programme.

This will be the first step in structuring a formal monitoring programme that can be used to assess worker exposure accurately with knowledge gained being implemented into formal sampling strategies, and linking the recorded exposures with the employees' records of medical surveillance.

4. Baseline assessment: Environmental conditions

The GEEs recognises that environmental monitoring is necessary to establish the effectiveness of the ventilation system. Mines should consider extending the fire detection system of the continuous monitoring of NO₂ and CO emissions in sections where diesel units are operational in order to monitor the effective dilution of diesel exhaust gases. Where two or more sections are ventilated in series, monitoring should be arranged at the sections' entrance(s) and exit(s) to quantify the gas "make-up" within the section.

It must be noted that the data gathered from the worker and environmental assessments is not likely, nor is intended, to be "equivalent". Each of these strategies is aimed at assessing different aspects of the same problem and although some sequential correlation is expected (i.e. a clean environment should result in lower worker exposure), any direct relationship is not likely.

C. New Projects

The use of electrically-powered vehicles in non-coal mines should be considered for new projects as an alternate to diesel units. Even in the case of partial replacement, in recognition of the fact that diesel machinery offers a greater degree of flexibility and that therefore part of the fleet will be diesel-powered, will contribute to reducing significantly DPM levels in the general atmosphere.

As an alternative, diesel-powered equipment manufacturers and fuel suppliers must be requested to provide latest generation engines and ultra-low emission fuels. These will be utilised pending availability and will require intensive, advanced training of maintenance personnel and the use of exhaust after-treatment (catalysts and particulate filters) together with fuel additives if necessary. In choosing this alternative, it must be noted that new generation engines are likely to be less powerful for the same engine size and are likely to run at comparatively higher temperatures.

In the longer term, the feasibility of using fuel-cell powered machinery should also be investigated as an additional opportunity for new projects. Also the possibility of using remotely-controlled vehicles in conjunction with ventilation strategies that preclude the re-use of air downstream of these vehicles should also be investigated.

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