



Government of **Western Australia**
Department of **Mines, Industry Regulation and Safety**

Nano Diesel Particulate Matter Working Group close out report

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Executive summary

Diesel engine exhaust (DEE) is a known hazard for mining operations, especially in underground mines. Widespread use of diesel vehicles and equipment makes it critical to control DEE at the source and provide appropriate ventilation, to ensure worker health and safety. Recent research has suggested that the extremely fine components of DEE, called nano diesel particulate matter (nDPM) may be responsible for negative health impacts, especially lung cancer, in exposed workers.

In 2016, the Mining Industry Advisory Committee (MIAC) commissioned research projects into the physical-chemical properties of nDPM in an underground mine, and the potential health effects on workers from exposure. The Department of Mines, Industry Regulation and Safety (DMIRS) and the Mineral Research Institute of Western Australia (MRIWA) co-funded the first research project.

DMIRS funded a second research project into the possible health impacts of DEE exposures. Twenty above-ground and 80 underground miners underwent a series of health screening tests and were fitted with personal exposure monitoring equipment to investigate whether their work exposures had an effect on their health status.

Curtin University, the ChemCentre and the University of Western Australia conducted the research in collaboration with DMIRS and MRIWA. The projects commenced in early 2018 and final reports were received by MIAC in mid-2019.

The research projects were managed by DMIRS, with oversight provided by a special sub-committee of MIAC called the nDPM Working Group, comprising tripartite representatives, supported by a number of mining, health and allied technical specialists.

A public forum was hosted by DMIRS on 29 July 2019, during which the findings of the literature survey and two research projects were discussed. MIAC released a media statement at the conclusion of the public forum advising "...now that the research has been finalised, MIAC will consider the findings and make recommendations to the Minister for Mines and Petroleum Bill Johnston".

The nDPM Working Group made seven recommendations to MIAC in October 2019, to address the hazards of nDPM. In summary, these included:

- a new diesel particulate matter (DPM) workplace exposure standard of 100 micrograms per cubic metre of air ($\mu\text{g}/\text{m}^3$) ($0.1 \text{ mg}/\text{m}^3$), including associated changes to regulations
- development of a new code of practice on underground mine ventilation
- additional DPM research
- promotion of real-time monitoring of elemental carbon (EC) to assist in possible future research.

Introduction

The Mining Industry Advisory Committee (MIAC) was established in April 2005 under section 14A of the *Occupational Safety and Health Act 1984* (the OSH Act). It was formed as an advisory body to the Minister responsible for administration of the OSH Act and the Minister responsible for administration of the *Mines Safety and Inspection Act 1994* (MSI Act), on matters relating to occupational safety and health in the mining industry.

Diesel engine exhaust (DEE) is a known hazard for mining operations, especially in underground mines where widespread use of diesel vehicles and equipment emphasises that ventilation is critical.

Monitoring of elemental carbon (EC) has been a convenient measure of diesel emissions, but it is not the ideal method to indicate nDPM as it is biased towards measuring larger (higher mass) particles and cannot accurately detect short-term peak exposures. Furthermore, the EC measurement method (NIOSH5040) can have interferences from other ultrafine particles present in the mine environment.

Research around the world indicates that nDPM is a harmful carcinogenic component of exhaust emissions that can be absorbed through the lungs into the bloodstream. An evaluation of nDPM would assist the development of control measures to protect workers in underground mines and other environments where nDPM is generated.

The Department of Mines, Industry Regulation and Safety (DMIRS), formerly the Department of Mines and Petroleum (DMP), conducted a preliminary mass-based evaluation of exposure in Western Australian underground mines. This research demonstrated to mine operators the need to develop diesel emission management plans, based on DMP's guideline, *Management of diesel emissions in Western Australian mining operations* to reduce emissions. However, DMP did not carry out any study of nDPM exposure to workers in underground mines.

To assist MIAC gain a better understanding of the exposure effects of nDPM on workers, it was agreed by MIAC early in 2016 to establish the Nano Diesel Particulate Matter Working Group (nDPM Working Group).

Role of the nDPM Working Group

As set out in their Terms of Reference version 6, updated in February 2018, the role of the nDPM Working Group was to provide information through MIAC to government and industry on:

- (a) a more meaningful marker for the measurement of nDPM
- (b) the sizing of particulates and occurrence of other contaminants
- (c) the health effects of exposure to nDPM on workers
- (d) the possibility of developing after-treatment devices capable of removing carcinogenic/mutagenic diesel exhaust products
- (e) other mitigation initiatives to reduce the risks of exposure to nDPM.

In addition, the nDPM Working Group coordinated applications for funding for research initiatives into nDPM and made recommendations to MIAC. The nDPM Working Group provided regular reports on its progress to MIAC.

This final report of the nDPM Working Group is being submitted to MIAC as close out to the working group.

Meetings

Since its first meeting on 22 March 2016, the nDPM Working Group met on 11 separate occasions. These meetings include:

- 3 meetings in 2016
- 4 meetings in 2017
- 2 meetings in 2018
- 2 meetings in 2019.

Public forum

A public forum was hosted by DMIRS on 29 July 2019 to facilitate presentation and discussion of the findings of the literature survey and two research projects.

Following the public forum, MIAC released a media statement advising "...now that the research has been finalised, MIAC will consider the findings and make recommendations to the Minister for Mines and Petroleum Bill Johnston".

DMIRS Director Mines Safety and Chair of MIAC, Mr Andrew Chaplyn, announced the completion of the two research projects on diesel emissions in the WA underground mining industry.

Project outcomes

DMIRS and the Mineral Research Institute of Western Australia (MRIWA) co-funded the first research project, which focussed on evaluating the physical-chemical aspects of DEE. Results were published in two parts:

- Part A: A Study of Nano Diesel Particulate Matter (nDPM) Behaviour and Physico-chemical Changes in Underground Hard Rock Mines of Western Australia
- Part B: Personal and Stationary Monitoring, Ventilation Modelling and Deeper Mines Study.

DMIRS also funded a second research project into the possible health impacts of DEE exposures. Twenty above-ground and 80 underground miners underwent a series of health screening tests and were fitted with personal exposure monitoring equipment to investigate whether their work exposures had an effect on their health status. The findings from this research are undergoing peer review prior to publication in academic journals, and will be the first published paper on alternate urinary biomarkers.

Curtin University, the ChemCentre and the University of Western Australia conducted the research in collaboration with DMIRS and MRIWA.

The research reinforces DMIRS guidelines on DEE, which highlight the importance of monitoring diesel emissions and implementing control measures to make the environment suitable for workers.

This includes focusing on the fuel and combustion efficiency of on-site diesel engines and ensuring the efficiency is maintained via an appropriate maintenance program; implementing and maintaining effective engine filtration systems, adopting good ventilation design standards and regular employee training to promote the importance of minimising emissions and controlling worker exposures.

The diesel particulate research reinforces the importance of managing DEE, and will assist mining operators develop emission exposure controls and long-term health management strategies.

The findings of the research projects were outlined at the 29 July 2019 public forum hosted by DMIRS. A copy of the consolidated report on the physical-chemical aspects of DEE is available at <http://www.dmp.wa.gov.au/Safety/Reports-16199.aspx>.

Also available is a literature review of recent research¹ findings relevant to worker exposure to DEE, with a specific focus on newer engine and after-treatment technologies.

¹ Critical review of recent diesel exhaust exposure health impact research relevant to the underground hardrock mining industry
http://www.dmp.wa.gov.au/Documents/Safety/MSH_nPDM_Study_LitReview.pdf

Ongoing work

DMIRS recommends mining operators consider technological advancements in monitoring nanoparticles and emerging epidemiological studies when developing their long-term management strategies.

Applying the principles contained in the MIAC-endorsed guideline, *Management of diesel emissions in Western Australian mining operations* will assist mining operators to act proactively and promote a safe and healthy work environment.

DMIRS Mines Inspectors continue to conduct research aimed at evaluating underground working environments in order to minimise worker exposures to a range of potentially harmful agents, including DEE.

Previously, the Inspectorate focused on evaluating DEE concentrations in underground mines in the Goldfields, and in 2018 a similar campaign was commenced, specifically targeting nanoparticles in underground mines in the Murchison district.

Developing recommendations

Officers from DMIRS met with the researchers and members of the nDPM Working Group to ascertain which of the findings of the research projects should be prioritised for action. A list of seven matters, with recommendations, was compiled and tabled at the MIAC meeting in October 2019:

1. That MIAC recommends to the Minister as provided for under Regulation 9.2 to use his authority to adopt $100 \mu\text{g}/\text{m}^3$ as the effective *exposure standard* for diesel particulate matter (DPM) to be applied for an 8-hour working day in Western Australian mining operations.
 - For exposure periods longer than 8 hours, the exposure standard is to be adjusted in accordance with the DMIRS' guidance, *Adjustment of atmospheric contaminant exposure standards* (March 2019).
2. Re-implement the health surveillance regulations previously found in Division 4 of Part 3 of the Mines Safety and Inspection Regulations, and were repealed in January 2013.
3. Development of a code of practice on underground mine ventilation, and in particular management of atmospheric contaminants (including nDPM) be expedited.
4. DMIRS and industry should jointly fund research into the occurrence and behaviour of nitric oxide (NO) which is thought to be the agent that causes acute responses in exposed workers such as blurred vision and fatigue.
5. Industry should be encouraged to conduct (or continue) campaigns of real-time monitoring of elemental carbon (EC) and establish a baseline of particle count in underground mining operations to assist in possible future research.

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6. The Mines Safety Directorate to conduct targeted inspections of underground mining operations that have not submitted Health and Hygiene Management Plans, and have not submitted sufficient EC sampling results to be able to effectively identify the level of exposure of their workers.
7. DMIRS to call for proposals to further refine the science relating changes in worker urinary levels of 1-aminopyrene (1-AP) and the relationship with exposure to EC.

MIAC members provided feedback from consultation with their stakeholders at the December 2019 MIAC meeting:

- There was a consensus of support for Recommendations 1, 3, 4, 5 and 6.
 - It is noted that some jurisdictions in the European Union are planning moves towards a more restrictive workplace exposure standard.
- MIAC considered that further discussion was required in relation to Recommendation 7.
- Widely differing views were expressed in relation to Recommendation 2, and much further consultation is required before this recommendation can be progressed.
 - A centralised health surveillance system was considered as a positive move, but is recognised as being part of the proposed legislative changes introduced in the *Work Health and Safety Act*.

Recommendation 1, to implement a new workplace exposure standard for diesel particulate matter, was completed on 4 December 2020, with gazettal of amendments to the Mines Safety and Inspection Regulations 1995.

Recommendations 3, 4, 5 and 6 can be implemented by the Mines Safety Directorate.

Deliverables

At the October 2019 MIAC meeting, the seven draft recommendations for 'next steps' were tabled and discussed.

It was resolved that MIAC members would present the draft recommendations to their stakeholders and provide feedback at the December 2019 MIAC meeting.

One change was requested to Recommendation 1 – which was the implementation of the $100 \mu\text{g}/\text{m}^3$ ($0.1 \text{ mg}/\text{m}^3$) proposed standard into legislation, so that it becomes an enforceable requirement (to be revisited at a future time as the science in relation to health effects becomes further established).

- The workplace exposure standard would be adjusted for a non 8-hour working week, in accordance with the Department's guidance note *Adjustment of atmospheric contaminant exposure standards* (March 2019).
- MIAC requested inclusion of a workplace exposure standard for a 10-hour working day and a 12-hour working day.

Three matters need to be clarified:

1. The long-established methodology of adjustment for longer shift hours is based upon an adjustment model called Brief and Scala. It was designed for the petrochemical industry where the effects of over-exposure to a (usually organic) substance would result in health effects within a month or two after exposure. This does not apply to the nDPM and dusts and other contaminants (excluding gases) commonly encountered in the mining industry.
2. The exposure standards guidance note has adopted the Quebec model of adjustment.
 - a. Because exposure to nDPM is linked to long-term exposure effects such as cancers, the adjustment factor is based around the average number of hours worked per normal working week
 - b. Hours worked per day are important, but only in order that the average hours per week can be calculated.
3. The adjustment factor is therefore dependent upon a worker's roster (the swing) and the hours worked per day.

An extract from the exposure standards guidance note for the adjustment factors for various average hours worked per week are as follows:

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Category 3	
h/wk	<i>F_a</i>
40	1.00
41	0.98
42	0.95
43	0.93
44	0.91
45	0.89
46	0.87
47	0.85
48	0.83
49	0.82
50	0.80
51	0.78
52	0.77
53	0.75
54	0.74
55	0.73
56	0.71

However, as the workplace exposure standard is based upon a five day, 40 hour working week, stating a workplace exposure standard for a 10-hour working day and a 12-hour working day is not quite straightforward. An adjustment factor for 'typical swings' should be included. For example:

- 7 days on, 7 days off, 12 hour days = 84 hours worked in 14 days, which averages 42 hours per week. The workplace exposure standard would be 95 $\mu\text{g}/\text{m}^3$
- 14 days on, 7 days off, 12 hour days = 168 hours worked in 21 days which averages 56 hours per week. The workplace exposure standard would be 71 $\mu\text{g}/\text{m}^3$.

Conclusion

The nDPM Working Group members have agreed that the nDPM Working Group has concluded its work. This close out report is the final concluding action and further work will now be undertaken by MIAC.