Diesel Emission Reduction

Mining Diesel Emission Council Conference (MDEC) 2019

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Occupational Health Clinics for Ontario Workers Inc. | Centres de santé des travailleurs (ses) de l'Ontario Inc.

Prevention Through Intervention

Purpose

This presentation will discuss and identify some "key drivers" to reduce diesel emission and thus reduce exposure.

Why is this such an important issue?

Organisation	Year	Comments
HEI[1]	1999	**Evidence not strong enough**
ACGIH[2]	2002	Recommended 0.02mg/m^3 (measured as REC)
ACGIH[2]	2003	Recommended limit withdrawn
MSHA[3]	2008	**Evidence becoming stronger -** Effective date for Occupational exposure limit (OEL) in the US for underground metal / non-metal 0.16mg/m^3(TC) ~ 0.12 (REC)
IARC[1]	2012	**Strong evidence –** IARC monograph – confirmed carcinogen.
NCI / NIOSH[4]	2010 - 2013	Study findings support a much lower OEL which may have a significant impact on UG mining.
HEI[1]	2013	**Expert panel established**
HEI[1]	2014 6 March	Workshop held in Boston – open to public, academia, regulators , industry and engine manufacturers.
HEI[1]	November 2015	Expert panel review released. **Strong evidence! Likely significant impact especially in UG mining!**

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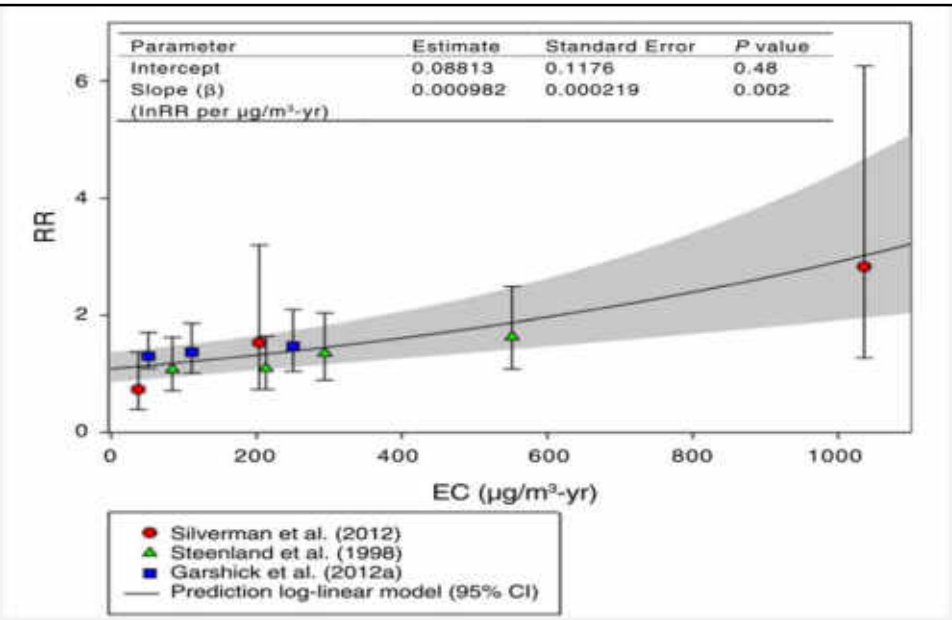

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SOURCE: Vermeulen R, Silverman DT, Garshick E, Vlaanderen J, Portengen L, Steenland K. 2014b. Exposure–response estimates for diesel engine exhaust and lung cancer mortality based on data from three occupational cohorts. Environ Health Perspect 122:172–177. doi: 10.1289/ehp.1306880.

The meta-analyis by Vermeulen et al (2014) played a big part in the review and indicate that at the current OELs for underground mining in both the US and Australia with 15 years exposure at the current OEL can result in a doubling of the risk for lung cancer indicated.

These findings pave the way for compensation claims for lung cancer and of course also provide the impetus to integrate new technology into mining such as battery powered vehicles which are now being introduced into a number of underground mines especially for deeper mines.

What about older engines?

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TABLE 1: Annual burden of occupational cancer in Canada by carcinogen

CARCINOGEN	IARC EVALUATION FOR CARCINOGENICITY	NUMBER OF CANADIAN WORKERS EXPOSED	NUMBER OF CANCERS ATTRIBUTABLE TO OCCUPATIONAL EXPOSURE (PROPORTION OF ALL CANCER CASES DUE TO OCCUPATIONAL EXPOSURE)
Solar ultraviolet radiation	Definite	1,476,000	4,600 non-melanoma skin (6.3%)
Asbestos	Definite	152,000	1,900 lung (8.0%) 430 mesothelioma (80.5%) 45 larynx (2.7%) 15 ovarian (0.5%)
Diesel engine exhaust	Definite	897,000	560 lung (2.4%) 200 bladder (2.7%)
Silica (crystalline)	Definite	382,000	570 lung (2.4%)
Welding fumes* Nickel compounds Chromium (VI)	Definite Definite Definite	333,000 117,000 104,000	310 lung (1.3%) 170 lung (0.7%) 50 lung (0.2%)
Radon	Definite	188,000	390 lung (0.8%)
Second-hand smoke	Definite	520,000	130 lung (0.6%) 35 pharynx (2.4%) 20 larynx (1.6%)
Night shift work	Probable	1.9 million	470-1,200 breast (2.0-5.2%)
Polycyclic aromatic hydrocarbons (PAHs)	Definite, probable, possible, unclassifiable	350,000	130 lung (0.6%) 60 bladder (1.1%) 50 skin (0.07%)
Arsenic	Definite	25,000	60 lung (0.3%)
Benzene	Definite	374,000	20 leukemia (0.5%) 5 multiple myeloma (0.2%)

* Since workers may be exposed to both nickel compounds and chromium (VI) compounds through welding fumes, we have grouped these three carcinogens together. Exposure estimates for nickel compounds and chromium (VI) compounds include welders. Burden estimates for exposures to nickel compounds and chromium (VI) compounds do not include welders.

Diesel engine exhaust (annual burden)

897,000 exposed

560 lung cancers (2.4%)

200 bladder cancers (2.7%)

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Source: Occupational Cancer Research Centre (OCRC Sept. 2019, p. 11) – Burden of Occupational Cancer in Canada

High levels of DEE compared to workers exposed to low and moderate levels, from a health standpoint, these exposures are significant because cancer risk increases with level of exposure. This increased risk is reflected in the burden estimates.

Figure 6: Number of workers occupationally exposed to DEE by level of exposure and industry in Canada in 2006

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Source: Occupational Cancer Research Centre (OCRC Sept. 2019, p. 40) – Burden of Occupational Cancer in Canada

Exposure to diesel exhaust from diesel powered trains

Exposure	Electric ($n = 29$)	Diesel ($n = 54$)	Mean difference (95% CI)
Black carbon (μg/m^3)	1.8 (0.5)	10.3 (2.0)	8.5 (7.9; 9.1)***
Ultrafine particles from DiscMini (#/cm^3) [a]	8100 (2400)	189,200 (91,900)	181,000 (153,700; 208,400)***
Ultrafine particles from NanoTracer (#/cm^3)	9100 (3500)	133,400 (52,100)	124,300 (110,000; 138,500)***
NOx (μg/m^3)	45 (16)	363 (73)	317 (297; 338)***
NO_2 (μg/m^3)	18 (9)	54 (16)	36 (31; 42)***

The exposure was assigned to study participants (study participants rode the trains in groups of different sizes. The exposure average levels for each calendar day were assigned to all members of the relevant group). Exposure levels in both scenarios are presented as mean and standard deviation. $PM_{2.5}$, polycyclic aromatic hydrocarbons and aldehydes are not assigned to study participants, as the data were not collected throughout all the study period. [a] missing values for DiscMini equipment indexed to four study persons for the exposure scenarios ($n = 46$ diesel and $n = 25$ for electric). ***$p < 0.001$

Source: Anderson et al. 2019, Health effects of exposure to diesel exhaust in diesel-powered trains.

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Source: Occupational Cancer Research Centre (OCRC Sept. 2019, p. 40) – Burden of Occupational Cancer in Canada

Health effects of exposure to diesel exhaust from diesel powered trains

Table 3 Association between exposure levels and biomarkers estimated by mixed-effects model adjusted for age and sex

Exposure levels	FVC	FEV1	FEV1/FVC	PEF	LF	DNA SB
UFP (NanoTracer)	↓	↓↓↓	↓	↓	↑↑	↑↑↑
UFP (DiscMini)	-	↓↓	-	↓↓	↑↑	↑↑↑
BC	↓	↓↓↓	↓	↓	↑↑	↑↑
NO_x	↓	↓↓↓	↓	↓↓	↑↑↑	↑↑
NO_2	↓	↓	-	↓↓↓	↑↑↑	-

Exposure levels are averages of 3 days
UFP ultrafine particles, *BC* black carbon, *FVC* forced vital capacity, *FEV1* forced expiratory volume in one second, *PEF* peak expiratory flow rate, *LF* low frequency component, *DNA SB* DNA strand breaks
↓↓↓↓↓↓ $p \leq 0.05$; < 0.05; < 0.01; < 0.001, respectively

Source: Anderson et al. 2019, Health effects of exposure to diesel exhaust in diesel-powered trains.
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Health effects of exposure to diesel exhaust in diesel powered trains

Combustion-derived air pollutants were considerably higher in the passenger carriages of diesel trains compared with electric trains. The concentrations of black carbon was 8.5 µg /m^3 (0.008mg/m^3) higher, respectively, in diesel as compared to electric trains.

Net increases of NO_x and NO_2 concentrations were 317 µg/m^3 and 36 µg/m^3 respectively.

Exposure to diesel exhaust was associated with:

- reduced lung function (poorer lung health),
- increased levels of DNA strand breaks (cell death and potential for cancer),
- cardiovascular (heart) health effects.

Source: Anderson et al. 2019, Health effects of exposure to diesel exhaust in diesel-powered trains.

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Findings:

Exposure to diesel exhaust (DE) inside diesel-powered trains for 3 days was associated with **reduced lung function** and systemic effects in terms of **altered heart rate variability** and increased levels of **DNA strand breaks** in peripheral blood mononuclear cells (PBMCs) compared with electric trains.

Source: Anderson et al. 2019, Health effects of exposure to diesel exhaust in diesel-powered trains.

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Air pollution particles found on foetal side of placentas - study

Research finds black carbon breathed by mothers can cross into unborn children

▲ The research examined 25 placentas from non-smoking women in the town of Hasselt, Belgium. Photograph: Craig Holmes Premium / Alamy/Alamy

Air pollution particles have been found on the foetal side of placentas, indicating that unborn babies are directly exposed to the black carbon produced by motor traffic and fuel burning.

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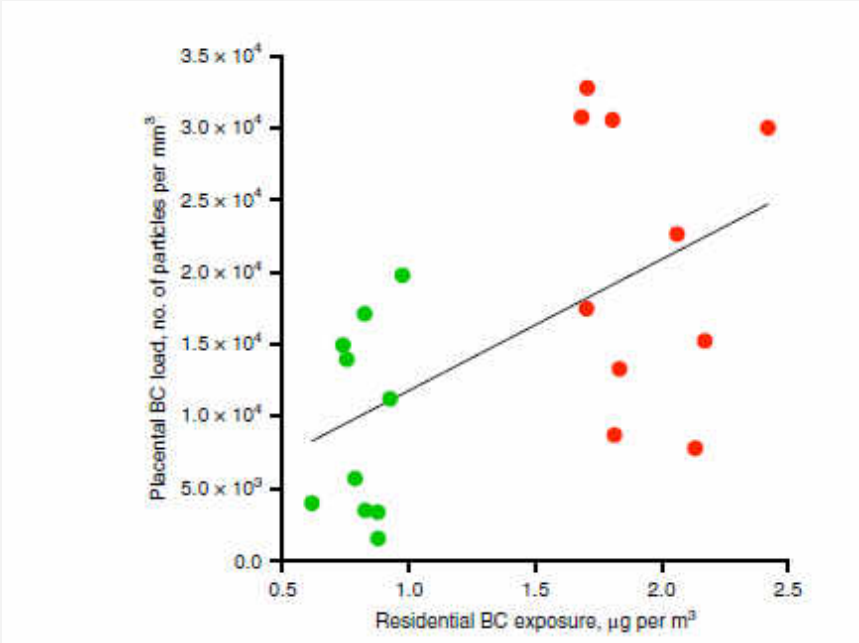
Source: The Guardian 17 Sept. 2019, https://www.theguardian.com/environment/2019/sep/17/air-pollution-particles-found-on-foetal-side-of-placentas-study



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Source: Bove et al. 2019, Ambient black carbon particles reach the fetal side of human placenta. Nature Communications (2019) 10: 3866 https://www.nature.com/articles/s41467-019-11654-3

Organisation	Year	Comments
BHPB[6]	November 2015	After reviews by a leading Australian Epidemiologist and the IOM[7] BHPB (Global Standard) – Exposure must be **as low as technically feasible**. Interim target set at **0.03mg/m³** (measured as EC NIOSH 5040)
Health Canada[8]	2017	Human Health Risk Assessment for Diesel Exhaust. **Causal lung cancer, suggestive bladder cancer.**
OCRC[9]	2017	Burden of Occupational Cancer in Ontario. Policy Recommendations For Diesel Engine Exhaust: 1. Adopt occupational exposure limits of **0.02mg/m³ (elemental carbon EC) for the mining industry and 0.005 EC mg/m³ for other workplaces).** 2. Upgrade or replace old on-road and off-road trucks and diesel engines. (OCRC, 2017 p.25).

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Are regulators setting occupational exposure limits, **at levels low enough,** to drive continuous improvement and provide the impetus for newer technology / retrofits

- higher tier engines and / or battery powered vehicles
- and / or install diesel particulate filters (DPFs)?

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Is setting a suitably protective occupational exposure limit (OEL) or target for diesel particulate matter (DPM) a **"key driver"** to reduce exposure?

Mining Diesel Emissions Council (MDEC 2017)

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POLICY RECOMMENDATIONS FOR DIESEL ENGINE EXHAUST

1. Adopt occupational exposure limits of 20 µg/m³ elemental carbon for the mining industry and 5 µg/m³ elemental carbon for other workplaces. The Ontario Occupational Health and Safety Act (OHSA) prescribes occupational exposure limits for many of the gases and particulates found in DEE.[1] Limits for exposure to total carbon and elemental carbon, which is used as a surrogate for the carcinogenic effects of DEE, have been set for underground mines under Regulation 854 (Mines and Mining Plants).[2] However, the OHSA does not currently prescribe limits for elemental carbon. Other jurisdictions, including Finland, have implemented standards of 300 µg/m³ elemental carbon.[3,4] The Finnish Institute for Occupational Health recommends occupational exposure limits of 20 µg/m³ elemental carbon for the mining industry and 5 µg/m³ elemental carbon for other workplaces,[4] based on evidence of health effects and feasibility considerations. These more stringent limits would substantially reduce exposure and protect worker health given the large number of workers occupationally exposed to DEE in Ontario and growing scientific evidence demonstrating adverse health effects of DEE, even at low concentrations.[5,6,7]

2. Upgrade or replace old on-road and off-road trucks and diesel engines. Engine replacement and/or installation of engineering controls are better able to reduce overall DEE emissions than administrative controls, such as maintenance.[8] Regulations that outline allowable emissions for new models of on-road vehicles and engines were implemented under Canada's Environmental Protection Act from 2001 to 2012.[9,10] However, immediate significant decreases in diesel particulate matter are not expected, since older engines are not covered under these regulations and can continue to be used until they need replacement.[4] For off-road diesel engines, there are regulations that limit emissions, such as Off-Road Compression-Ignition Engine Emission Regulations (SOR/2005-32), and Marine Spark-Ignition Engine, Vessel and Off-Road Recreational Vehicle Emission Regulations.[11,12] Upgrading or replacing old off-road diesel engines is a larger challenge than on-road diesel engines. There is a precedence of mandating the transition to upgraded or newer on-road engines in other jurisdictions, such as California.[13] Upgrading old engines or vehicles may be costly, so regulations could be rolled out incrementally and accompanied with financial supports for companies affected (e.g., through financial awards or tax credits).[14]

Occupational Cancer Research Centre

Report Release: Burden of Occupational Cancer in Ontario (2017)

The Finnish Institute for Occupational Health recommends occupational exposure limits of 20 µg/m³ elemental carbon for the mining industry

and 5 µg/m³ elemental carbon for other workplaces, based on evidence of health effects and feasibility considerations.

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https://www.healthcouncil.nl/documents/advisory-reports/2019/03/13/diesel-engine-exhaust

How low is low enough?

The Dutch Committee on Occupational Safety (DECOS) has estimated so-called health-based calculated occupational cancer risk values (HBC-OCRVs) The DECOS estimates that the exposure concentrations of respirable elemental carbon in the air, which serve as parameter for exposure to diesel engine exhaust powered by petroleum-diesel fuels, and which corresponds to:

- 4 extra death cases of lung cancer per 100,000 (target risk level), for 40 years of occupational exposure, equals to 0.011 µg REC/m^3,
- 4 extra death cases of lung cancer per 1,000 (prohibition risk level), for 40 years of occupational exposure, equals to 1.03 µg REC/m^3.

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While safe levels of exposure “promulgated” as occupational exposure limits (OELs), are being discussed and debated,

it appears that previously acceptable OELs are no longer safe.
Therefore it is important that the internal responsibility system be implemented and the precautionary principle approach be followed, especially as it may be some time before a suitably protective OEL specifically for diesel particulate matter (DPM) is in place.

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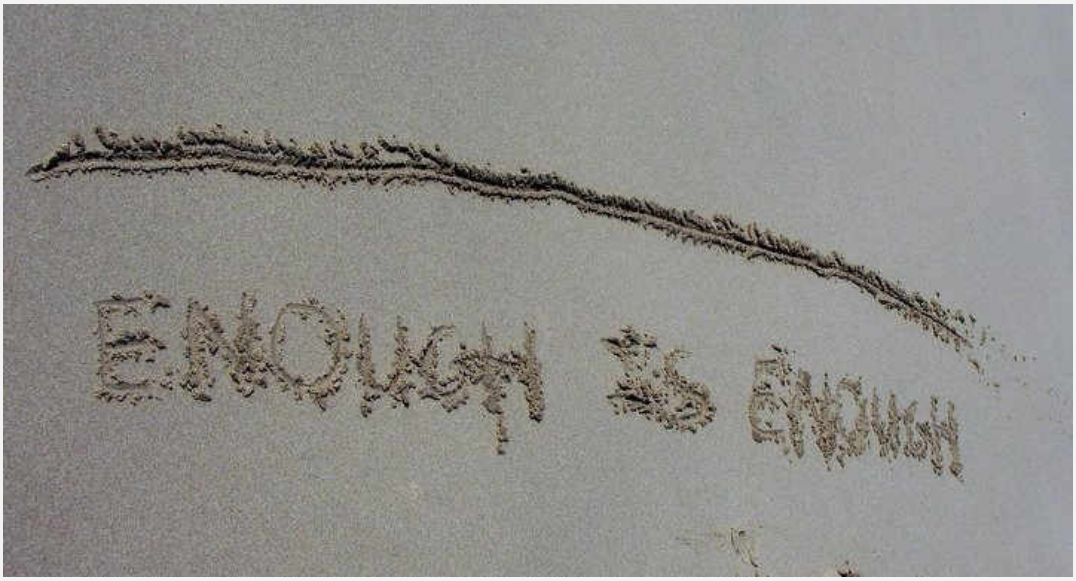
Nevertheless - There must be a line in the sand!



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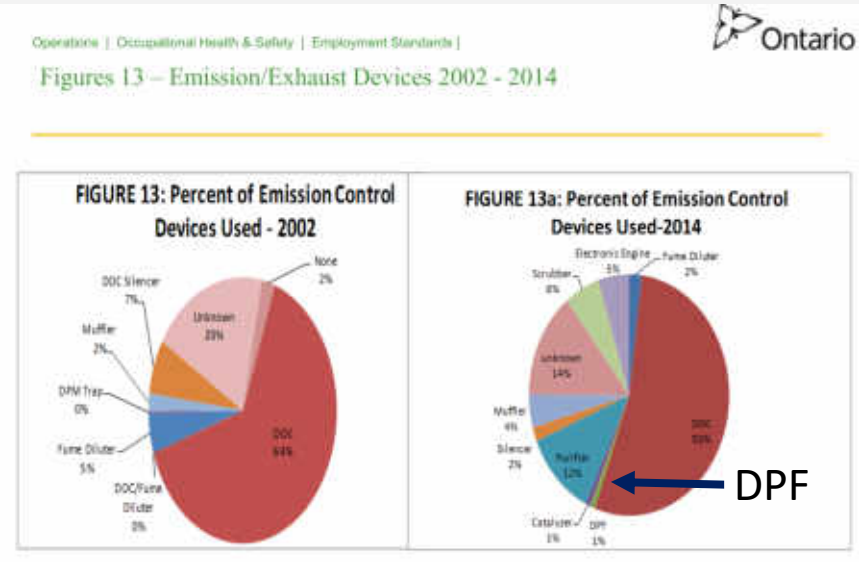
Ministry of Labour 2014 Underground Diesel Survey Outcomes



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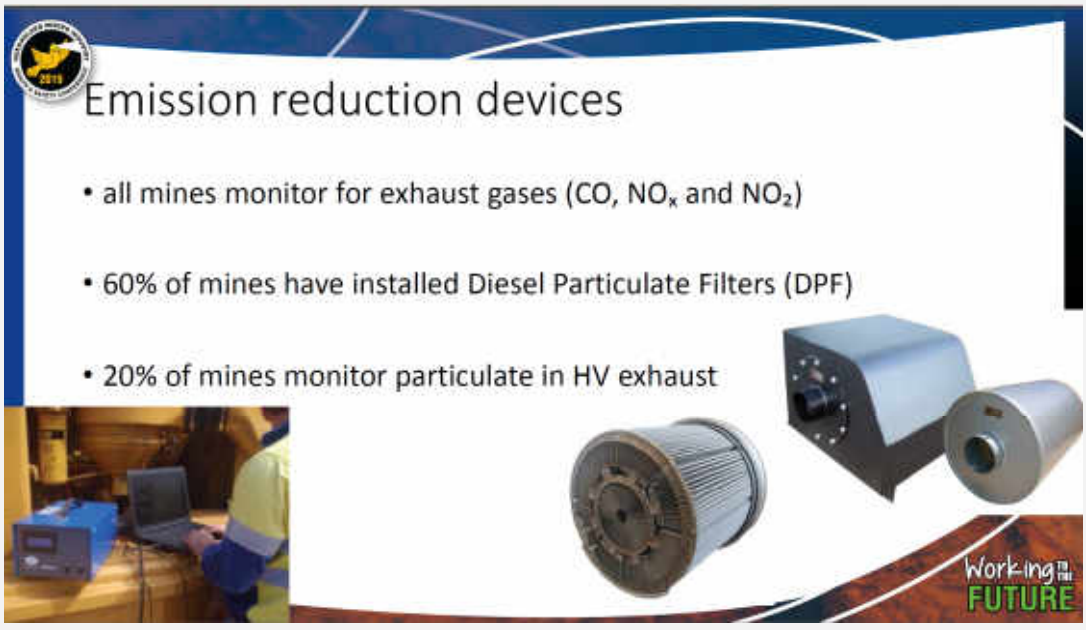
Why?



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Recent survey of Australian, Queensland Metal Mines

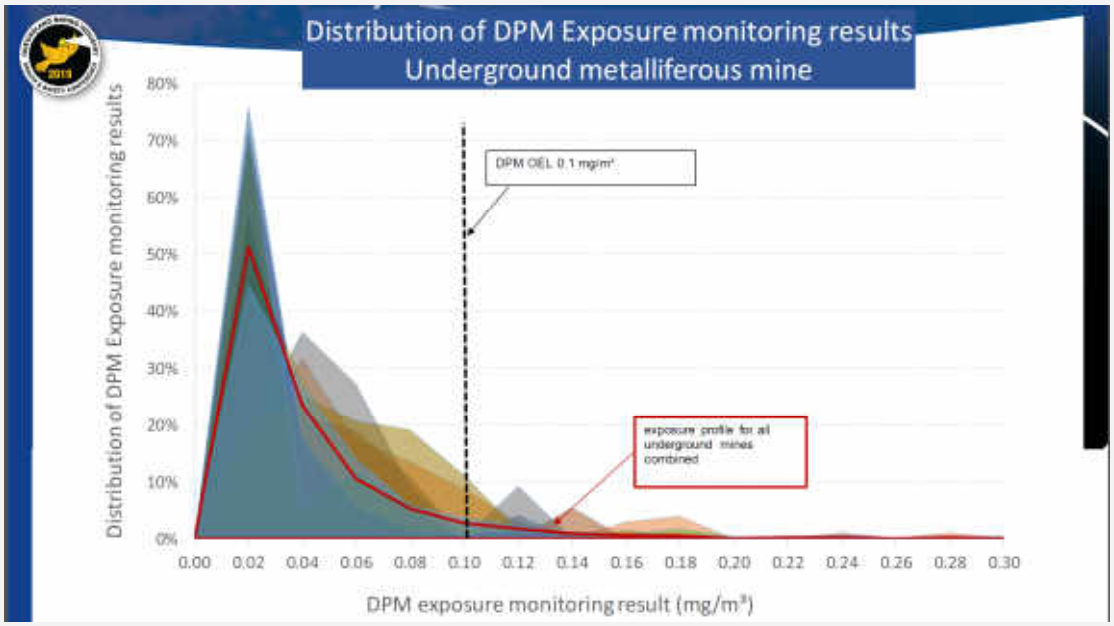
https://qmihsc2019.evertechnology.com/

https://qmihsc2019.evertechnology.com/conference-session/management-diesel-exhaust/

Canada	Early 1990's	1.5mg/m^3
Ontario	2012	0.4 mg/m^3 TC equivalent to **0.31 EC** (Quebec is now the same)
MSHA American mines	2008	0.16 mg/m^3 TC equivalent to **~ 0.12 EC** (dividing TC by 1.3)
Australia		**0.1mg/m^3 EC** (measured as **submicron elemental carbon**)

Note: Occupational Exposure Limit for Provinces in Canada are

3 X US & Australia.



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Latest from Ministry of Labour (March 20 2018) current and proposed exposure limits: On and off-road diesel engines are widely used in other industries such as construction, transportation and warehousing. As an important first step in minimizing and controlling worker exposures to DPM in these sectors, the MOL is proposing to add a new listing and OEL for DPM measured as total carbon, in the Ontario Table (Table 1) in **Regulation 833 based on the revised MSHA limit of 160 µg/m³, (0.16mg/m³)total carbon (~0.12 mg/m³ Elemental Carbon)(MOL, 2018). 45 day consultation period due May 4, 2018.**

For the first time in Canada, an Occupational Exposure Limit (OEL) for diesel particulate matter (DPM), is being proposed, which applies to all workplaces in Ontario.

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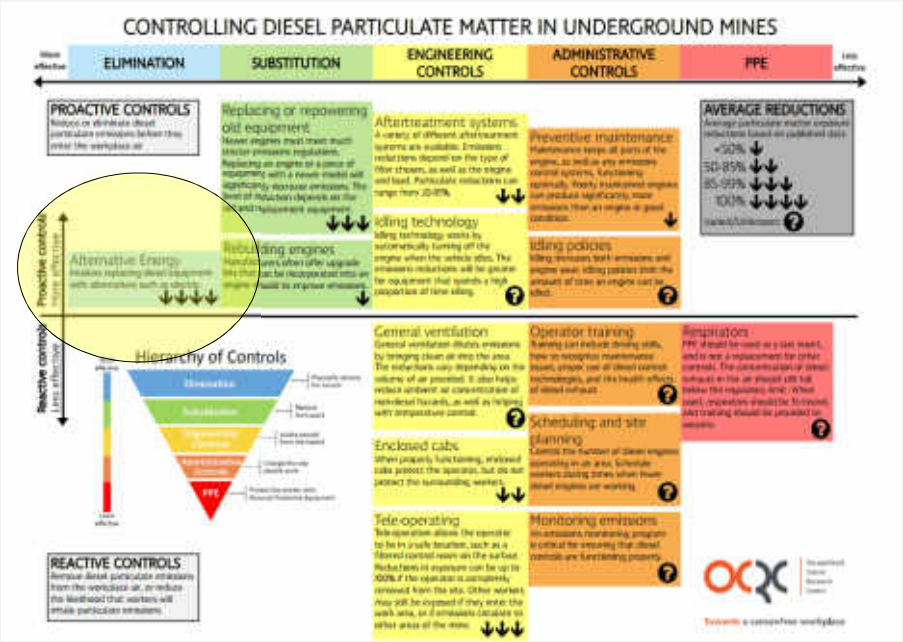
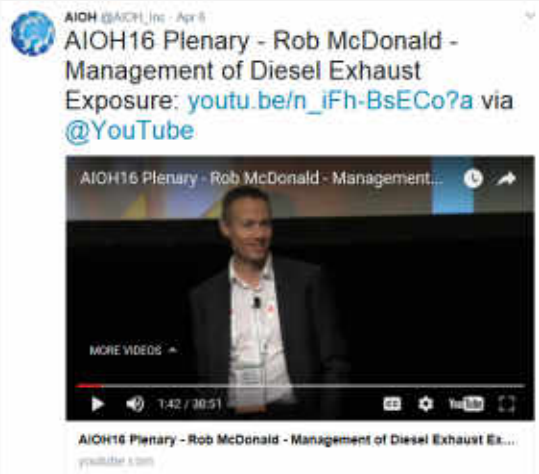
Using battery powered vehicles ie. battery powered scoop used underground.
https://gereports.ca/breathing-easier-underground/ **We have the technology!**



Reproduced with permission from OCRC

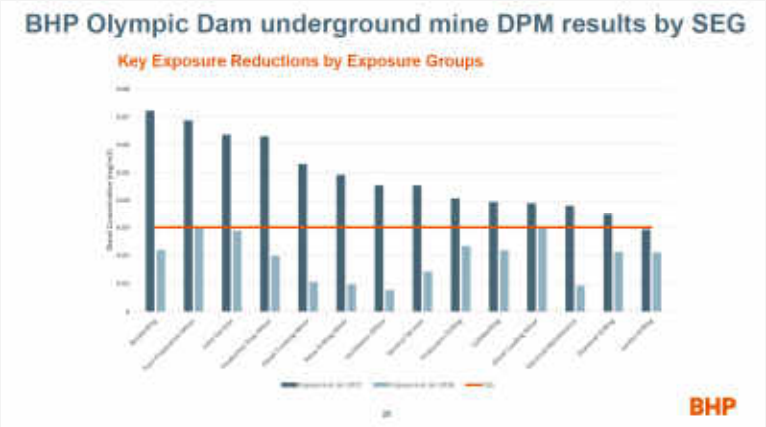


Dr. Rob McDonald VP Health and Hygiene, BHP Billition.

Australian Institute of Occupational Hygienists (AIOH), plenary December 2016.

- "Significant **lag** that exists between regulatory action and the level of science that informs health risk".
- "Should be managing exposure to diesel exhaust to as low as technically feasible".
- Interim target to be managing diesel exhaust to **0.03mg/m^3** TWA 8-hrs measured as elemental carbon.

https://www.youtube.com/watch?v=n_iFh-BsECo&feature=youtu.be&a



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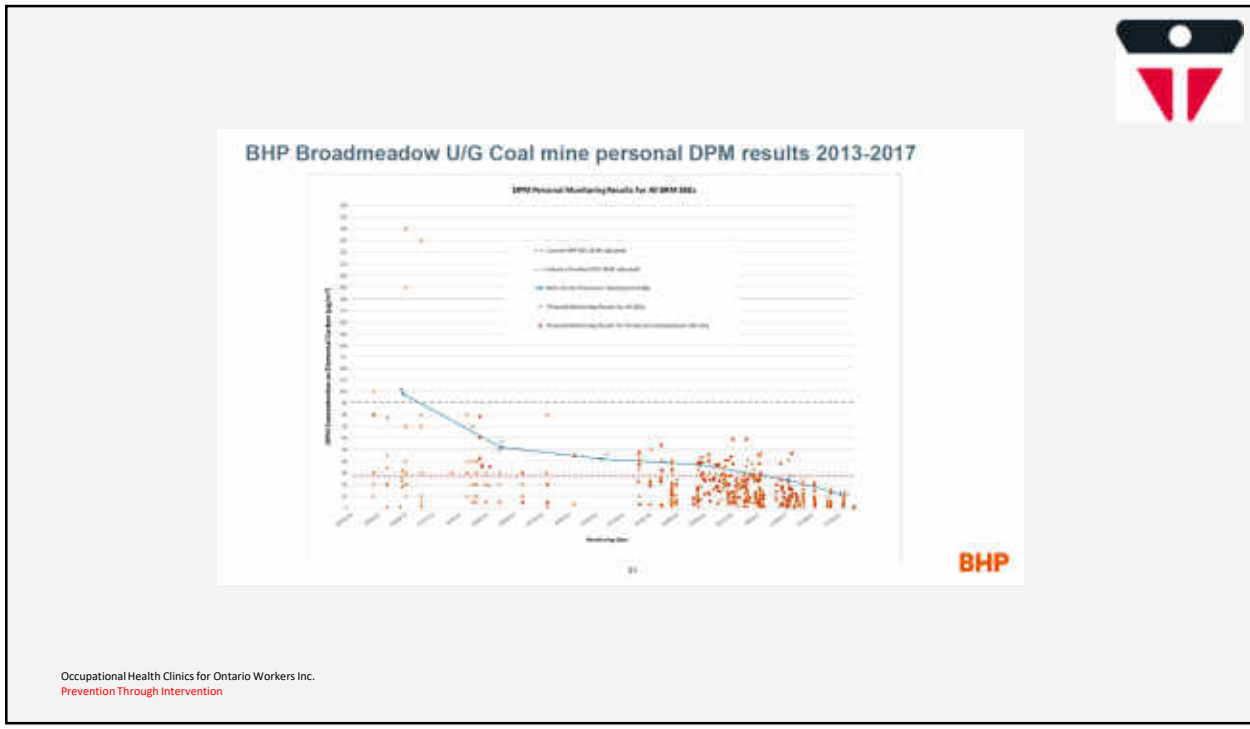

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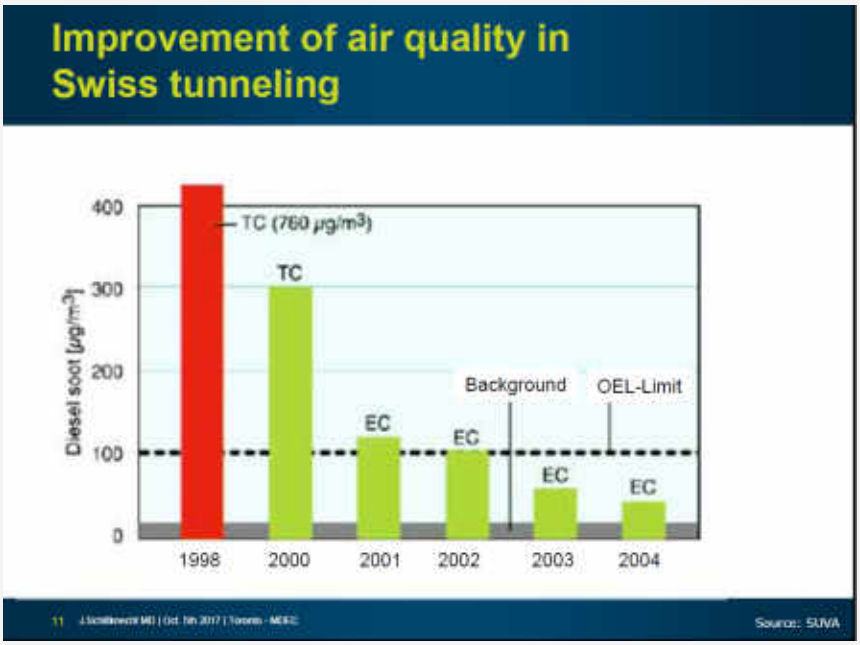

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Is setting a suitably protective occupational exposure limit (OEL) or target for diesel particulate matter (DPM) a **"key driver"** to reduce exposure?

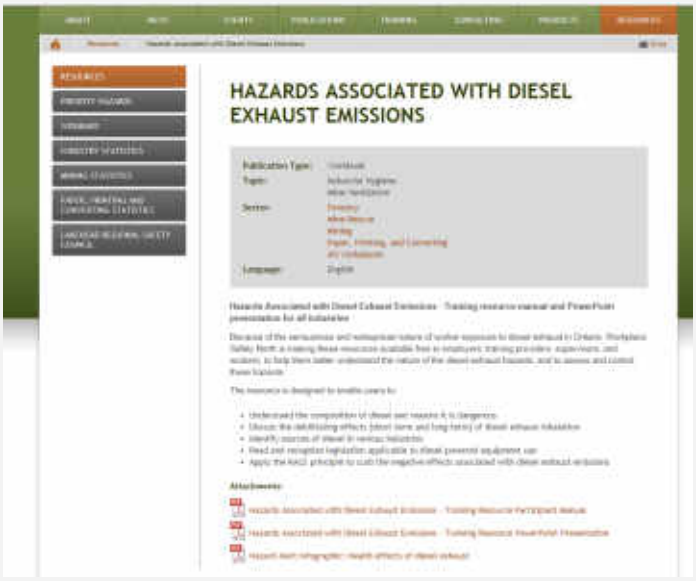
CAREX-OCRC Webinar on Diesel Exposure in Workplaces

This webinar conveys the importance of diesel engine exhaust as a workplace hazard and discusses ways this hazard can be assessed and controlled in the workplace. It was presented in partnership with the **Occupational Cancer Research Centre (OCRC)** and **Ontario Occupational Disease Action Plan (ODAP)** Working Group on Diesel Exhaust.

(39 min, 58 sec)

https://www.carexcanada.ca/en/videos/

Please share



https://www.workplacesafetynorth.ca/resources/hazards-associated-diesel-exhaust-emissions

The future

Switzerland

Diesel engines used in new construction machines must comply with a **Swiss particle number (PN) emission limit**. The PN emission requirements ensures that all construction machines sold in Switzerland be fitted with diesel particulate filters.

https://www.dieselnet.com/standards/ch/

Diesel emission reduction (key drivers)

- Establish an internal Occupational Exposure Limit (OEL). Don't rely on statutory limits.
- Conduct regular monitoring. What gets measured gets noticed what gets noticed gets action.
- Investigate single exceedances (personal monitoring and raw exhaust) and assign corrective actions.
- Train / raise awareness – everyone can play a part in a diesel emission reduction program.
- Control exposure following the hierarchy of control.
- Treat older higher risk (emitting) engines first (install diesel particulate filters).
- Evaluate the effectiveness of control measures.
- **Management commitment!**
- Learn from other operations, jurisdictions, countries.
- Look to the future and consider the global (GHG) and public health impact.

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