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WHWB
workplace health without borders

Mining Diesel Emissions Council (MDEC) Conference 2022

The Past, Present & Future: Diesel Exhaust Exposures in Mining – A Tool to Assess Lung Cancer Risk

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http://www.ohcow.on.ca/

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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, 56 sec)

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

Please share

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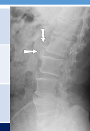
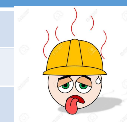
Hazard	Exposures
Whole body vibration (WBV)	
Noise	
Heat	
Diesel engine exhaust (DEE)	



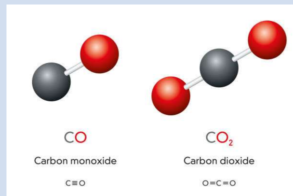


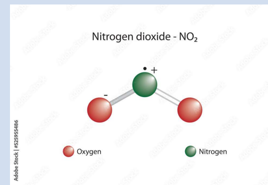
Gas

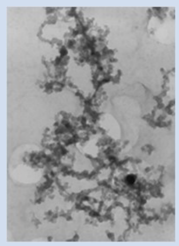
- Carbon monoxide (CO)
- Carbon dioxide (CO)
- Nitric oxide (NO)
- Nitrogen dioxide (NO_2)

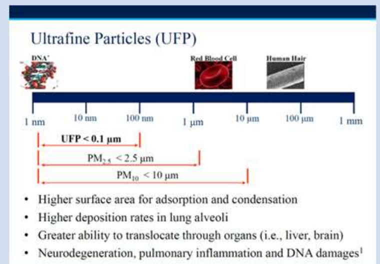
Diesel particulate matter (DPM)

- Total carbon (TC)
- Elemental carbon (EC)
- Other









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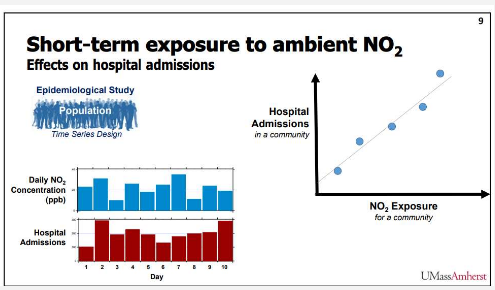
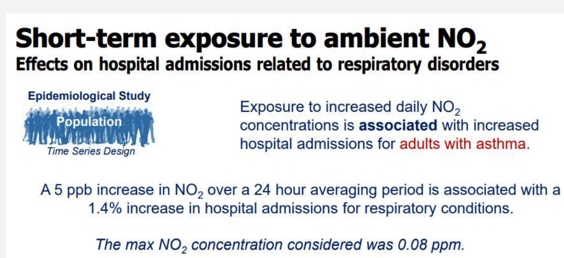
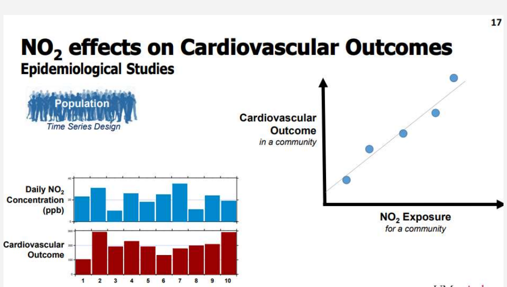
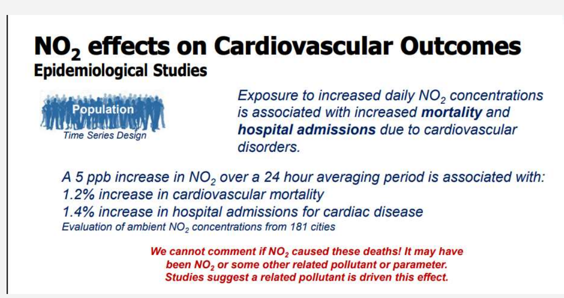
Exposure to nitrogen dioxide (NO_2) is important!

Keynote Krystal Pollitt, PhD MDEC 2015 NO2 Underground: What Exposure Level is Safe?









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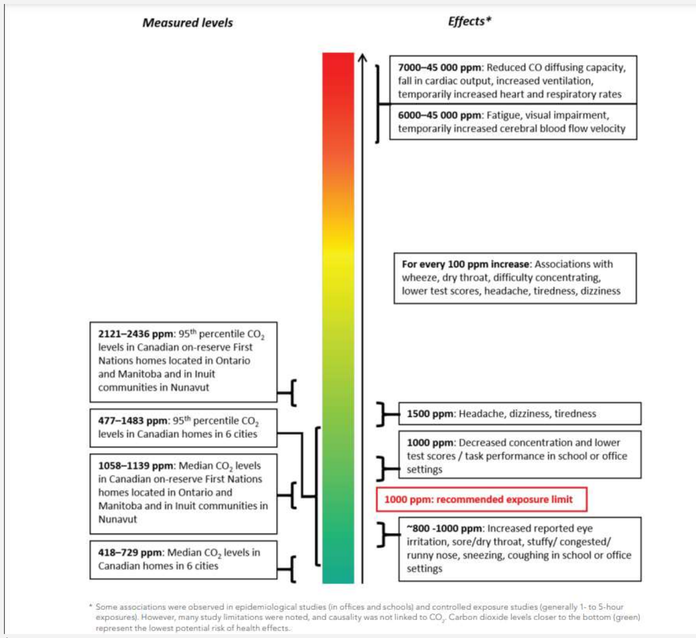
What about carbon dioxide?

[RESIDENTIAL INDOOR AIR QUALITY GUIDELINES CARBON DIOXIDE]

Health Canada 2021



Tiredness / decreased concentration

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Increase in carbon dioxide!

https://twitter.com/CleanAirStars/status/1572551769343008770

Tiredness!

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Exposure to diesel particulate matter (DPM) 2004 vs. 2007

IARC MONOGRAPH – 105

Fig. 1.6 Trends in selected polycyclic aromatic hydrocarbon species with developing technology

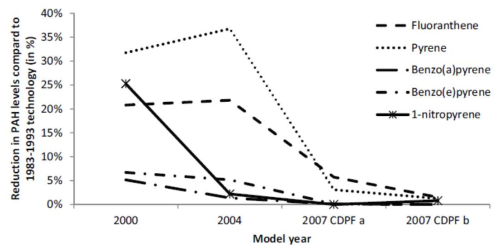

Table 1.4 Unregulated emissions for all 12 repeats of the 16-hour cycles for four 2007 ACES engines and for 2004 technology engines used in CRC E55/E59

Compound	2004 engines (average ± SD, mg/h)	2007 engines (average ± SD, mg/h)	2007 engines[a] (average ± SD, mg/bhp-h)	Average percentage reduction relative to 2004 technology engines
Single-ring aromatics	405.0 ± 148.5	71.6 ± 32.97	0.76 ± 0.35	82
PAHs	325.0 ± 106.1	69.7 ± 23.55	0.74 ± 0.25	79
Alkanes	1030.0 ± 240.4	154.5 ± 78.19	1.64 ± 0.83	85
Hopanes/steranes	8.2 ± 6.9	0.1 ± 0.12	0.0011 ± 0.0013	99
Alcohols and organic acids	555.0 ± 134.4	107.4 ± 25.4	1.14 ± 0.27	81
Nitro-PAHs	0.3 ± 0.0	0.1 ± 0.0	0.0065 ± 0.0028	81
Carbonyls	12 500.0 ± 3535.5	255.3 ± 95.2	2.68 ± 1.00	98
Inorganic ions	320.0 ± 155.6	92.3 ± 37.7	0.98 ± 0.40	71
Metals and elements	400.0 ± 141.4	6.7 ± 3.0	0.071 ± 0.032	98
Organic carbon	1180.0 ± 70.7	52.8 ± 47.1	0.56 ± 0.50	96
Elemental carbon	3445.0 ± 1110.0	22.6 ± 4.7	0.24 ± 0.05	99
Dioxins/furans	NA	$6.2 \times 10^{-5} \pm 5.2 \times 10^{-5}$	$6.6 \times 10^{-7} \pm 5.5 \times 10^{-7}$	99[b]

[a] Data shown in brake-specific emissions for completeness; no comparable data on brake-specific emissions were available
[b] Relative to 1998 technology engines
bhp, brake horse power; h, hour; NA, not applicable; PAHs, polycyclic aromatic hydrocarbons; SD, standard deviation

https://monographs.iarc.who.int/wp-content/uploads/2018/06/mono105.pdf

IARC monograph 105

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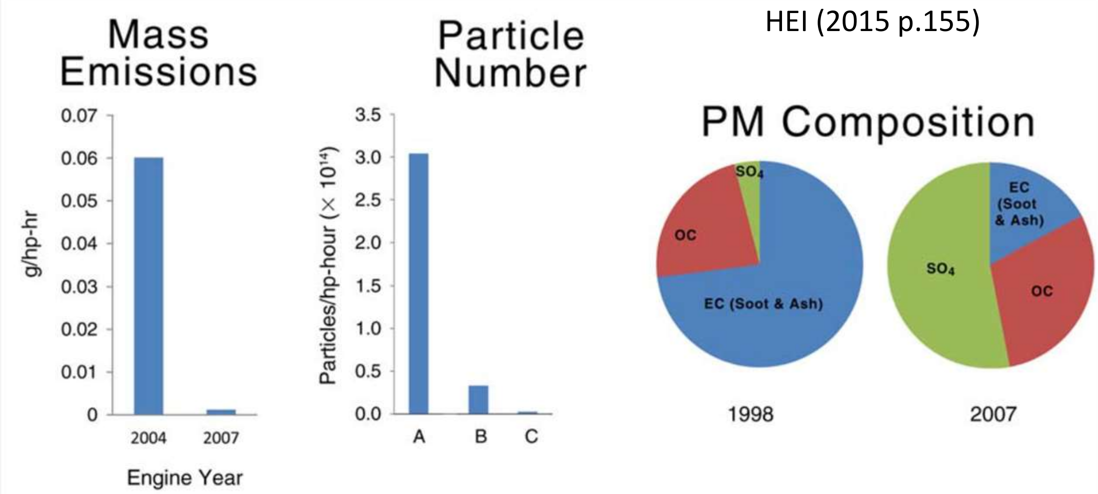
HEI (2015 p.155)



Commentary Figure. Comparison of PM in traditional-technology diesel exhaust (pre-2007) and new-technology diesel exhaust (2007-compliant) by mass, particle number, and composition. The particle number graph shows the results as measured using the Federal Test Procedure from (A) a 2004 engine with no diesel particulate filter (DPF); (B) a 2007-compliant engine with a DPF and with active regeneration; (C) a 2007-compliant engine with a DPF and without active regeneration. (EC = elemental carbon; OC = organic carbon; SO4 = sulfate.) (Data from Clark et al. 2007; Khalek and Merritt 2009; personal communication, Imad Khalek, 22 March 2012.)

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https://www.healtheffects.org/publication/advanced-collaborative-emissions-study-aces-lifetime-cancer-and-non-cancer-assessment

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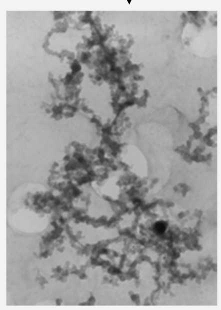
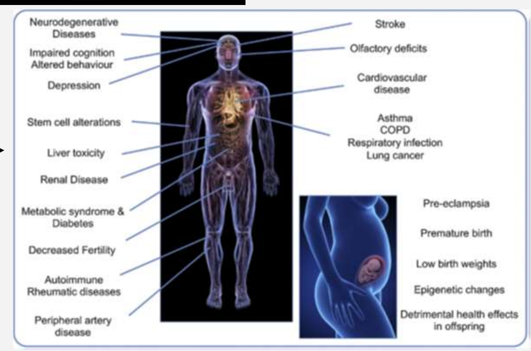
Jennifer B. Raftis, Mark R. Miller (2019) University/BHF Centre for Cardiovascular Science, University of Edinburgh, Edinburgh, United Kingdom

Nano Today, Vol. 26, pp.8 - 12

[**Nanoparticle translocation** and multi-organ toxicity: A particularly small problem]





Particulate air pollution has been linked to a wide range of conditions affecting many different organs of the body.

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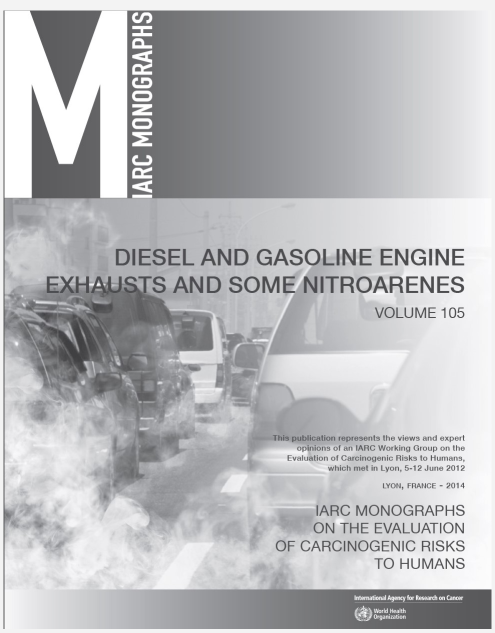

6. EVALUATION

6.1 Cancer in humans

There is *sufficient evidence* in humans for the carcinogenicity of diesel engine exhaust. Diesel engine exhaust causes cancer of the lung. A positive association has been observed between exposure to diesel engine exhaust and cancer of the urinary bladder.

There is *inadequate evidence* in humans for the carcinogenicity of gasoline engine exhaust.

6.2 Cancer in experimental animals

There is *sufficient evidence* in experimental animals for the carcinogenicity of whole diesel engine exhaust.

There is *inadequate evidence* in experimental animals for the carcinogenicity of gas-phase diesel engine exhaust.

There is *sufficient evidence* in experimental animals for the carcinogenicity of diesel engine exhaust particulate matter.

There is *sufficient evidence* in experimental animals for the carcinogenicity of extracts of diesel engine exhaust particles.

There is *inadequate evidence* in experimental animals for the carcinogenicity of whole gasoline engine exhaust.

There is *sufficient evidence* in experimental animals for the carcinogenicity of condensates of gasoline engine exhaust.

6.3 Overall evaluation

Diesel engine exhaust is *carcinogenic to humans* (Group 1).

Gasoline engine exhaust is *possibly carcinogenic to humans (Group 2B)*.

Diesel exhaust causes **cancer of the lung**. A positive association has been observed between exposure to diesel exhaust and **bladder cancer**.

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Health Canada (2016) –
Human Health Risk Assessment for Diesel Exhaust

Health effects	Evidence
Lung cancer	**Sufficient**
Acute adverse respiratory health outcomes	**Sufficient**
Chronic adverse respiratory health outcomes	**Sufficient**
Acute adverse cardiovascular health outcomes	**Sufficient**
Immunological effects	**Sufficient**
Bladder cancer	Suggestive
Chronic adverse cardiovascular health outcomes	Suggestive
Reproductive and developmental effects	Suggestive
Central nervous system effects based on acute neurophysiological symptoms in overexposed workers	Suggestive

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HEI study in Europe finds evidence of health effects at lower levels of air pollution

2021 *Air Pollution, Nitrogen Oxides, Multipollutant Mixtures, Ozone & Oxidants, Particulate Matter, Exposure Methods*

A **major new HEI report** presents a study examining associations between exposures to relatively low levels of air pollution and several health outcomes among participants in 22 European cohorts.

In the report, the investigators describe the development of new exposure models for all of Europe for four pollutants: fine particulate matter ($PM_{2.5}$), black carbon (BC), nitrogen dioxide (NO_2), and ozone (O_3), as well as $PM_{2.5}$ particle composition.

Bert Brunekreef at the Institute for Risk Assessment Sciences, Utrecht University, the Netherlands, and colleagues reported that exposure to $PM_{2.5}$, BC, and NO_2 showed significant associations of air pollution exposure with natural-cause, cardiovascular, respiratory, and lung cancer mortality. They also reported that they did not find positive associations between O_3 and all causes of death examined.

https://www.healtheffects.org/announcements/hei-study-europe-finds-evidence-health-effects-lower-levels-air-pollution

Mortality and Morbidity Effects of Long-Term Exposure to Low-Level PM2.5, BC, NO2, and O3: An Analysis of European Cohorts in the ELAPSE Project (Health Effects Institute, 2021)

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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.

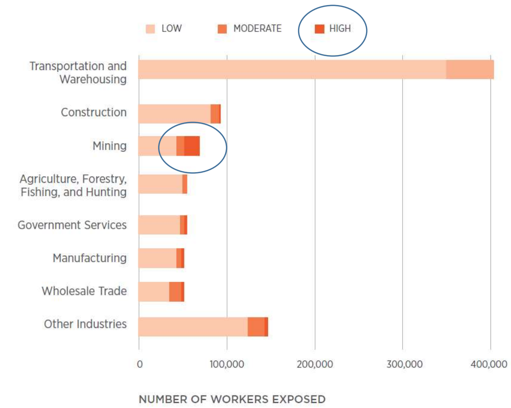

Figure 8. Number of workers occupationally exposed to DEE by level of exposure and industry in Canada in 2006.

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

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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 (3.7%) 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[a] 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	190 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%) 80 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%)

[a] 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

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Criteria overview: GHS H-codes and categories for Tier 1

Classification		Labelling				Hazard statement codes
Hazard class	Hazard category	Pictogram		Signal word	Hazard statement	
		GHS	UN Model Regulations			
Carcinogenicity	1, 1A, 1B		*Not required*	**Danger**	May cause cancer *(state route of exposure if it is conclusively proven that no other routes of exposure cause the hazard)*	H350
	2		*Not required*	**Warning**	Suspected of causing cancer *(state route of exposure if it is conclusively proven that no other routes of exposure cause the hazard)*	H351

GHS (Rev.8) (2019)
Globally Harmonized System of Classification and Labelling of Chemicals (GHS)

NIOSH Tier 1 Criteria	C	D	E
Exposure ranges			
Dust/particle	>0.1 to ≤1 mg/m³	>0.01 to ≤0.1 mg/m³	≤0.01 mg/m³
Gas/vapor	>1 to ≤10 ppm	>0.1 to ≤1 ppm	≤0.1 ppm
Carcinogenicity	—	—	H350, Category 1, 1A, or 1B
	—	—	H351, Category 2
Reproductive toxicity	H361, Category 2	H360, Category 1B	H360, Category 1 or 1A
Specific target organ toxicity-repeated exposure	H371, Category 2	—	H370, Category 1
	H373, Category 2	—	H372, Category 1
Genotoxicity	—	H341, Category 2	H340, Category 1, 1A or 1B
Respiratory and skin sensitization	H317, Category 1B (skin)	H317, Category 1 or 1A	—
	H335, Category 3	H334, Category 1B	H334, Category 1 or 1A

TECHNICAL REPORT The NIOSH (2019) Occupational Exposure Banding Process for Chemical Risk Management

	A	B	C	D	E
Particulate/Dust	>10 mg/m³	>1 to 10 mg/m³	>0.1 to 1 mg/m³	>0.01 to 0.1 mg/m³	≤0.01 mg/m³
Gas/Vapor	>100 ppm	>10 to 100 ppm	>1 to 10 ppm	>0.1 to 1 ppm	≤0.1 ppm

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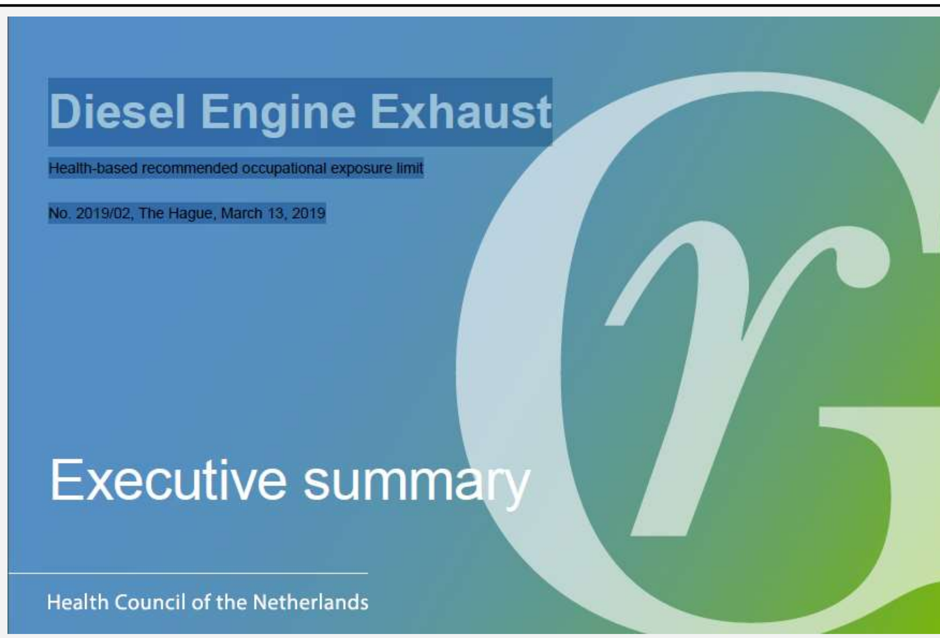

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https://www.healthcouncil.nl/documents/advisory-reports/2019/03/13/diesel-engine-exhaust

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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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Exposure limits

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Annals of Work Exposures and Health, 2021, Vol. 65, No. 4 369

Table 1. Adopted and recommended OELs for DEE particulate in other jurisdictions.

Jurisdiction	OEL	Marker of exposure	Notes
Adopted (and legally enforceable) OELs			
US Mine Safety and Health Administration (MSHA)	8-h TWA (Time-Weighted Average): 160 μg m^{-3}	TC; respirable dust	Since 2006. Applies to underground metal and non-metal mines.
EU	8-h TWA: 50 μg m^{-3}	EC	Adopted December 2018. Becomes effective in 2026 in underground mining and construction tunnels and in 2023 in other industries.
Switzerland	8-h TWA: 100 μg m^{-3}	EC	Since 2012.
Germany	8-h TWA: 50 μg m^{-3}	EC	Set in 2017. Does not apply to underground mines until 2022.
Austria	8-h TWA: 300 μg m^{-3} 8-h TWA: 100 μg m^{-3}	EC/respirable aerosol	Underground mines (since 2011). All other industries (since 2011).
Australia	8-h TWA: 100 μg m^{-3}	EC	Adopted by Queensland, Western Australia, New South Wales.
New Zealand	8-h TWA: 100 μg m^{-3}	EC	Enacted 2016.
Recommended OELs (Note 1)			
California Department of Public Health (California, USA)	8-h TWA: 20 μg m^{-3}	Diesel particulates	
Finnish Institute of Occupational Health (Finland)	8-h TWA: 5 μg m^{-3} 8-h TWA: 20 μg m^{-3}	EC	Applies to general workplaces. Applies to mines, underground construction.
Health Council of the Netherlands (Netherlands)	8-h TWA: 0.011 μg m^{-3} 8-h TWA: 1.03 μg m^{-3}	Respirable EC	Target risk level (Note 2). Prohibition risk level (Note 3).
Australian Institute of Occupational Hygienists (Australia)	8-h TWA: 100 μg m^{-3}	EC	

Barn et al. 2021, "Canada Should Move Toward Adopting Harmonized Evidence-Based OELs to Consistently and Adequately Protect Workers"

Annals of Work Exposures and Health, 2021, Vol. 65, No. 4, 367–372

https://academic.oup.com/annweh/article/65/4/367/6041193

Ministry of Labour, Training and Skills Development (now MLTISD)

Mining Health and Safety Regulatory Amendment Proposal (August 2021)

C. Occupational Exposure Limit for Elemental Carbon (Current Section 183.1)

Replace the current exposure limit set out in subsection 183.1(5), which is based on not exceeding 0.4 milligrams per cubic metre of air for total carbon, with a requirement that, where diesel-powered equipment is operating, the time-weighted average exposure of a worker to elemental carbon shall not be more than 0.12 milligrams / m^3 of air.

This proposed limit is based on a 2018 consultation regarding adopting a general occupational exposure limit for total carbon of 0.16 milligrams / m^3 of air in Regulation 833 (Control of Exposure to Biological and Chemical Agents).

There is no simple conversion to convert total carbon (TC) to elemental carbon (EC) as the ratio of TC to EC due to the high variability (Noll et al. 2015, p.208) as the range of ratios TC to EC was reported as 1.10 to 1.50. This is particularly important where diesel particulate filters (DPFs) are fitted on equipment where at a concentration of ≤ 0.05 mg/m3 the TC/EC ratio can range from 1 to close to 2.5 (Noll et al. 2015).

Using a conversion factor of 1.27 is therefore not good science.

Using the ratio range of 1.1 to 1.5 of TC/EC means that an exposure of 0.4 mg of TC equates to EC exposures ranging from 0.27 to 0.36.

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In addition, according to by Birch M 2016, NIOSH Manual of Analytical Methods (NMAM), 5th Edition "If EC concentrations are high and samples are relatively free of OC contaminates, the TC concentration is a reasonable measure of the diesel particulate mass, and the EC:TC ratio is representative of the EC fraction of the mass. However, this situation is uncommon outside of mines. **In general industry, EC and OC levels are normally much lower. And when EC levels are low, the EC:TC ratios are not reliable estimates of the EC fraction of DPM** because OC interferences can skew the ratios low and increase variability in the apparent ratio. In such cases, TC is an inaccurate measure of the diesel particulate concentration". https://www.cdc.gov/niosh/docs/2014-151/pdfs/chapters/chapter-dl.pdf

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Noll et al. Page 11

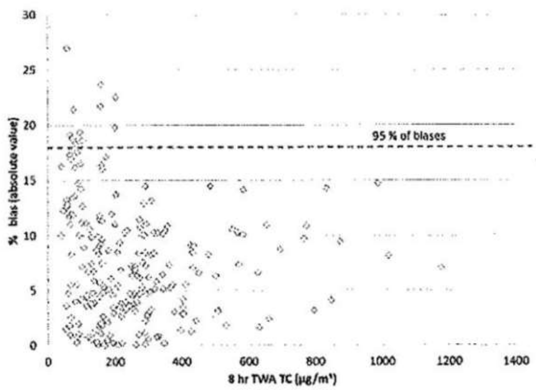

Figure 2.
The absolute value of the % bias of the calculated TC from the TC/EC ratio when compared to the measure TC value from 14 metal/nonmetal mines.

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4487601/pdf/nihms703011.pdf

Conversion factors (only apply to miners) based on Debia et al. 2017:

Ratio TC / EC	95% CI
1.6	0.48 – 5.5
Ratio RCD / EC	95% CI
1.8	0.44 – 7.1

TC – total carbon, **EC** – elemental carbon, **RCD** – respirable combustible dust.

This means that the MSHA OEL of 0.16mg/m^3 TC equates to 0.1 mg/m^3 EC

Debia et al. 2017, Diesel engine exhaust exposures in two underground mines, International Journal of Mining Science and Technology Volume 27, Issue 4, July 2017, Pages 641-645

Diesel exhaust exposure lung cancer risk calculator

Exposure to diesel exhaust is a known lung carcinogen with an unacceptable level of risk even below a lifetime exposure below the current occupational exposure (Regulation 854 – Mines and Mining Plants under OHSA. Section 183.1(5) time-weighted average limit for DPM in underground mines at **0.4 mg/m^3** (total carbon).

Consultation through the MLTSD 3 years ago (March 2018), was made to lower this limit and apply a revised limit to all workplaces and not just mining – this limit has still to be reduced. A limit for elemental carbon (EC) will apply.

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The International Agency for Research on Cancer (IARC) has concluded that Diesel Engine Exhaust (DEE) is a cause of lung cancer (Group 1: carcinogenic to humans). CAREX Canada estimates that approximately 897,000 Canadians are currently exposed to diesel engine exhaust at work. Approximately 2.4% (OCRC) to 6% (Vermeulen et al 2014) of annual lung cancer deaths may be due to DEE exposure. Combined data from three U.S. occupational cohort studies including more than 40,000 workers in the trucking and mining industries (Vermeulen et al 2014) have provided a powerful estimate of the risk of lung cancer based on the level and duration of exposure to DEE. The truckers' study Garshick et al. (2012) and miners' studies Silverman et al. (2012), (Attfield et al. 2012), (Stewart et al. 2010) combined, allows for a determination of the risk of lung cancer based on the level of exposure to diesel particulate matter (DPM). DPM measured as elemental carbon (EC) is the best surrogate of exposure.

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Meta analysis

Through **meta-analysis**, researchers can combine studies, essentially making them into one big study, which may help show an effect. Additionally, a meta-analysis can help increase the accuracy of the results. This is also because it is, in effect, increasing the size of the study.

This is why the trucker's study has been combined with the miner's study!

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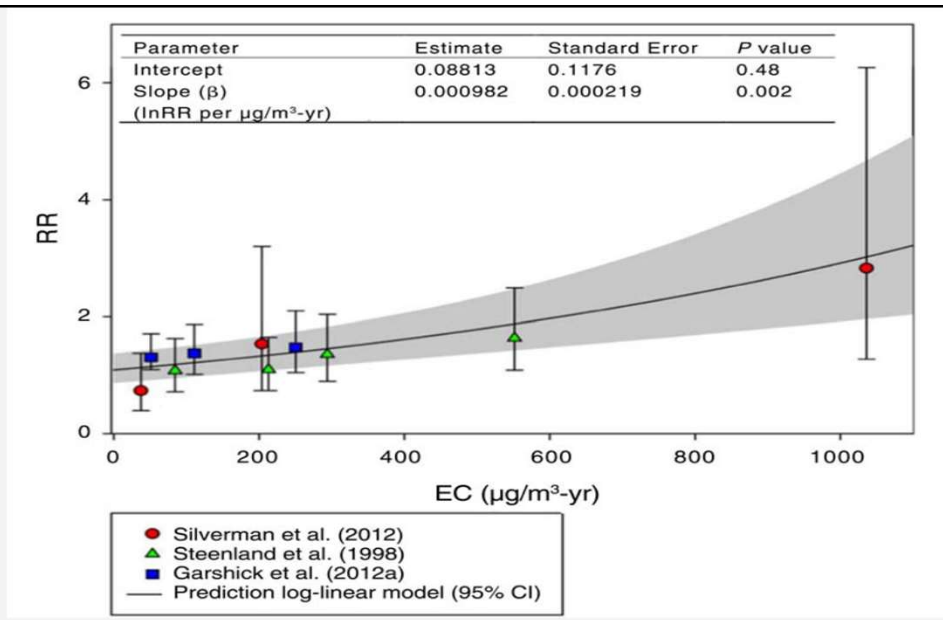

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SOURCE: Vermeulen R, Silverman DT, Garshick E, Vlaanderen J, Portengen L, Steenland K. 2014b. Exposure–response estimates for diesel engine exhaust and lung cancer mortality based on data from three occupational cohorts. Environ Health Perspect 122:172–177.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

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DPM measured as elemental carbon (EC) is the best surrogate of exposure.

A tool (risk calculator) developed by the Occupational Health Clinics for Ontario Workers Inc. (OHCOW), can be used as a guide to communicate the risk from DEE exposure. This should provide a heightened awareness about the risk of lung cancer from exposure, as well as further provide the impetus for both lowering the occupational exposure limit (OEL) and provide a catalyst for improved controls around exposure reduction.

The tool requires an estimate of exposure, as EC (NIOSH 5040) (CDC) and duration of exposure.

Where the only measures available are total carbon (NIOSH 5040) or Respirable Combustible Dust (RCD) conversion factors are discussed in line with Debia et al. 2017. An example is provided with recent (anonymous) EC exposure data, from a survey of mines across Ontario, representative of the years 2013 to 2018.

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Also noted:

> *"Estimated numbers of excess lung cancer deaths through 80 years of age for lifetime occupational exposures of 1, 10, and* ***25 μg/m³ EC*** *were 17, 200, and* ***689 per 10,000****, respectively. For lifetime environmental exposure to 0.8 μg/m³ EC, we estimated 21 excess lung cancer deaths per 10,000. Based on broad assumptions regarding past occupational and environmental exposures,* ***we estimated that approximately 6% of annual lung cancer deaths may be due to DEE exposure****"* (Vermeulen et al. 2014).

Refer to previous (2020 and 2021) OHCOW webinars:

- Exposure to diesel exhaust what is the health risk (OHCOW 2020).
- Diesel Exhaust Exposure and Health Risk in Transportation and the Community (OHCOW 2021).

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For an exposure of say 0.1 mg/m^3 of EC which is 3 to 4 times lower than the current OEL and close to what is being proposed by the MLTSD then the relative risk (RR) of lung cancer can be calculated using the following calculator:

Diesel Exhaust Lung Cancer Risk Calculator

years of exposure	25	years
average respirable elemental carbon (REC) exposure (in µg/m^3)	100	µg/m^3
15-year lagged cummulative respirable elemental carbon exposure (in µg/m^3-yrs)	1000	µg/m^3 - years
model estimated relative risk (RR) =	**2.92**	
95% confidence interval:	1.51	5.64

(model based on 0-1000 µg/m^3-yrs range)

model taken from: Vermeulen R, Silverman DT, Garshick E, Vlaanderen J, Portengen L, Steenland K. 2014. "Exposure-response estimates for diesel engine exhaust and lung cancer mortality based on data from three occupational cohorts". Environ Health Perspect 122:172–177; http://dx.doi.org/10.1289/ehp.1306880
http://jnci.oxfordjournals.org/content/suppl/2012/01/28/djs034.DC1/Supp_methods_and_tables_4-30-12.pdf

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This means that for 25 years of exposure with an average elemental exposure of 0.1 mg/m^3 (100 µg/m^3) the relative risk someone exposed to that level is 2.9 (1.5 – 5.6). If the OEL is set at this level then it will be expected that there will be ongoing compensation claims well into the future.

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Utilizing the same diesel exhaust lung risk calculator at the front of the **locomotive** (Jeong et al. 2015) (**balance crew exposures**) resulted in the following:

Diesel Exhaust Lung Cancer Risk Calculator

years of exposure	25	years
average respirable elemental carbon (REC) exposure (in µg/m^3)	22	µg/m^3
15-year lagged cummulative respirable elemental carbon exposure (in µg/m^3-yrs)	220	µg/m^3 - years
model estimated relative risk (RR) =	**1.36**	
95% confidence interval:	0.98	1.88

(model based on 0-1000 µg/m^3-yrs range)

Relative risk (RR) of lung cancer 25 years of exposure @ 22 µg/m3 = 1.36 (0.98 – 1.88)

Jeong C-H, Traub A, Evans E 2015, Exposure to ultrafine particles and black carbon in diesel-powered commuter trains. Atmospheric Environment, Vol. 155, April 2017. pp. 46 – 52.

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claims in Ontario (2009-2018)

Primary Causal Agent	Compensated	Expected*
Asbestos	1,291	7,850
Defoliants and herbicides	38	---
Crystalline silica	23	2,000
Benzene	21	125
Solar & ultraviolet radiation	24	14,000
Coal Tar	14	[950 for all PAHs]
Foundry emissions	13	
Coke oven emissions	11	
Nickel & sinter plant emissions	18	800
Welding fumes	9	1000
Uranium [presumed to be radon]	8	600
Exhaust gases - diesel	7	1700

* Expected based on the Burden of Occupational Cancer Project Towards a cancer-free workplace

Challenges for workers compensation

Compensated claims for cancer from exposure to diesel exhaust 2009 – 2018 : **Accepted 7, expected 1700**

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Exposures international and Canada

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Exposure data from the literature

Pronk et al. 2011

International

Description	Agent	Duration	n	AM (SD)	GM (GSD)	Location	Year	Ref
Underground								
Production (NM/NI)	EC_S	1->4	13	163 (141)	84 (4.3)	US	2001–2002	
Production (NM)	EC_R	NI	6 (a)	148 (136)	85 (3.5)	UK	2004(p)	(Leeming, et al., 2004)
Production (NM)	EC_R	>4	343	202 (32–144)	111 (1.4–4.8)	US	2002(p)	(Cohen, et al., 2002)
Production (NM)	EC_S	>4	38	219 (65–193)		US	1997(p)	(Stanevich, et al., 1997)
Production (C)	EC_R	>4	4	241[e]	202 (1.8)	Estonia	2002 (p)	(Boffetta, et al., 2002)
Production (M)	EC_R	>4	15	637 (75–508)		US	1999	(McDonald, et al., 2002)
Production (NI)	EC_I	<1–4	12	538 (512)		US	2007 (p)	(Burgess, et al., 2007)
Maintenance (NM)	EC_S	>4	8	53 (46)		US	1997(p)	(Stanevich, et al., 1997)
Maintenance (NM)	EC_R	>4	269	144 (17–462)	66 (1.7–4.6)	US	2002(p)	(Cohen, et al., 2002)

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https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3073453/#!po=28.8732

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Australia

Estimation of quantitative levels of diesel exhaust exposure and the health impact in the contemporary **Australian mining industry**

Results Personal EC measurements (n=8614) were available for 146 different jobs at 124 mine sites. The mean estimated EC exposure level in 2011 for underground occupation groups ranged from 18 to 44 µg/m^3.

Peters, S. and de Klerk, N. and Reid, A. and Fritschi, L. and Musk, A. and Vermeulen, R. 2016. Estimation of quantitative levels of diesel exhaust exposure and the health impact in the contemporary Australian mining industry. Occupational and Environmental Medicine. 74 (4): pp. 282–289.

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Underground diesel loader operators had the highest exposed specific job: 59 µg/m3.

A lifetime career (45 years) as an underground miner, experiencing exposure levels as estimated for 2011 (44 µg/m^3 EC), **was associated with 38 extra lung cancer deaths per 1000 males.**

https://espace.curtin.edu.au/handle/20.500.11937/3693

Peters, S. and de Klerk, N. and Reid, A. and Fritschi, L. and Musk, A. and Vermeulen, R. 2016. Estimation of quantitative levels of diesel exhaust exposure and the health impact in the contemporary Australian mining industry. Occupational and Environmental Medicine. 74 (4): pp. 282–289.

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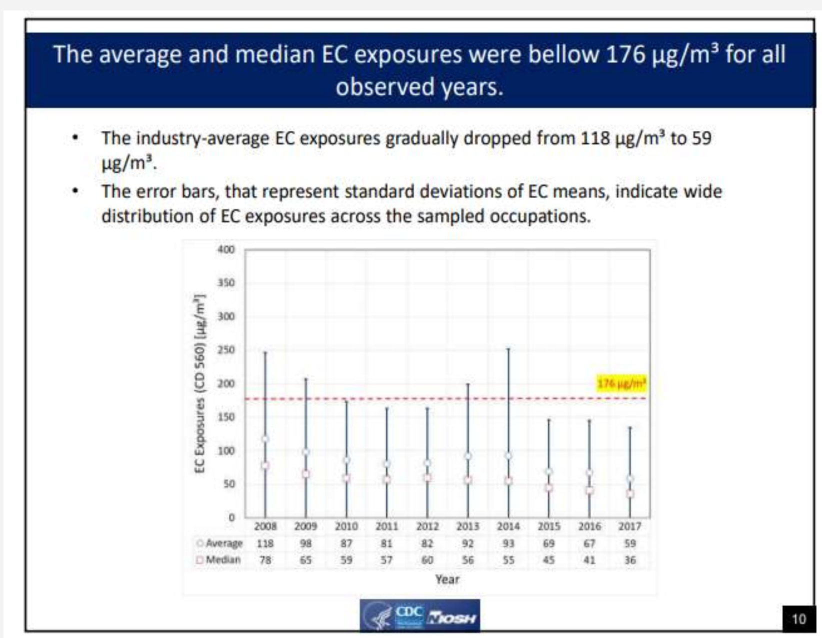
United States

(Bugarski 2018)



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https://mdec.ca/2018/S8P2_Aleksandar_Bugarski.pdf

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Canada

Years	Average / GM EC mg/m^3
1999 to 2003	0.20
2004 to 2005	0.10
2014 to 2018	**<u>0.03</u>** (maximum 0.65)

(Gorman Ng M 2022 The Canadian Association of Research in Work and Health CARWH 2022 conference)

<u>Information shared from Gary Bonnell NRC (2005) MDEC</u>

Why – older tier engines, not fitted with DPF perhaps?

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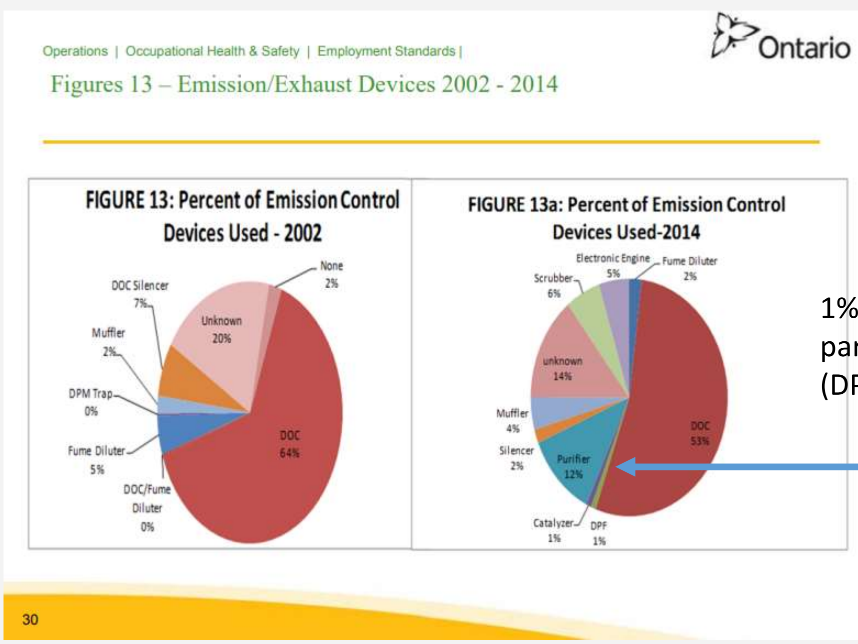

1% diesel particulate filters (DPFs) (2014)

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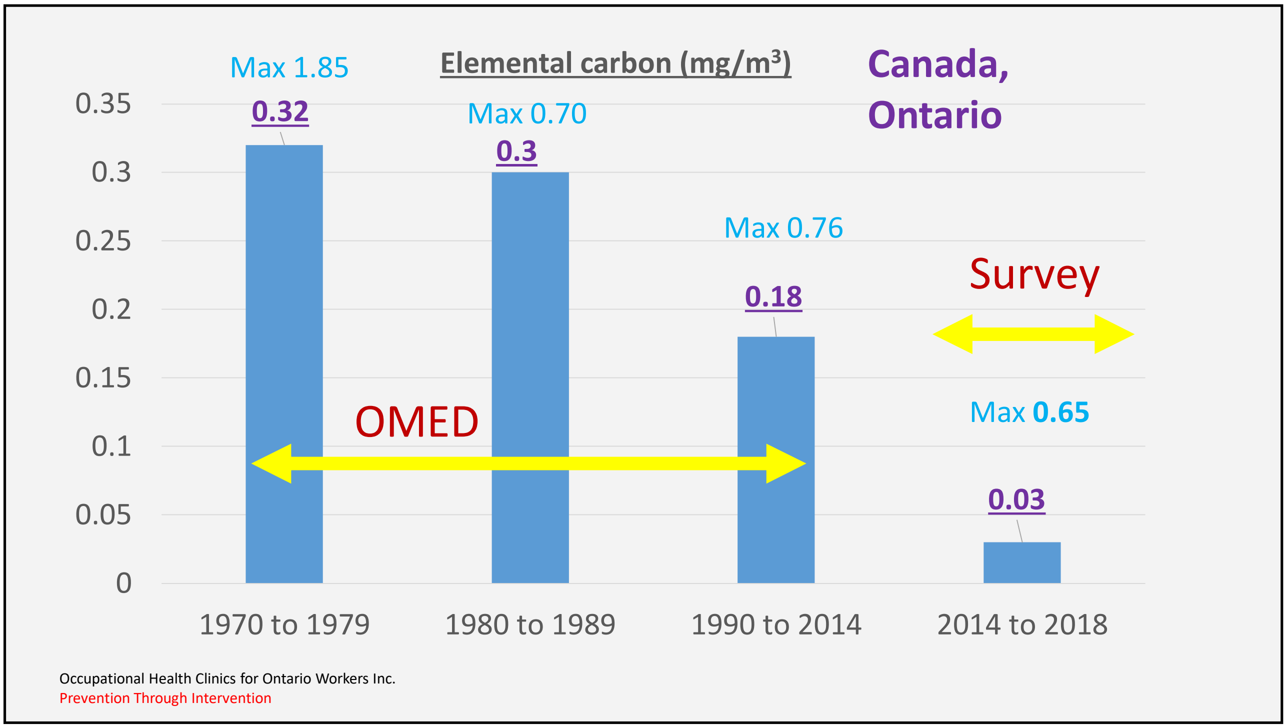
Elemental carbon (mg/m³)
Canada, Ontario
Max 1.85
0.32
Max 0.70
0.3
Max 0.76
0.18
Survey
Max 0.65
0.03
OMED
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1970 to 1979
1980 to 1989
1990 to 2014
2014 to 2018
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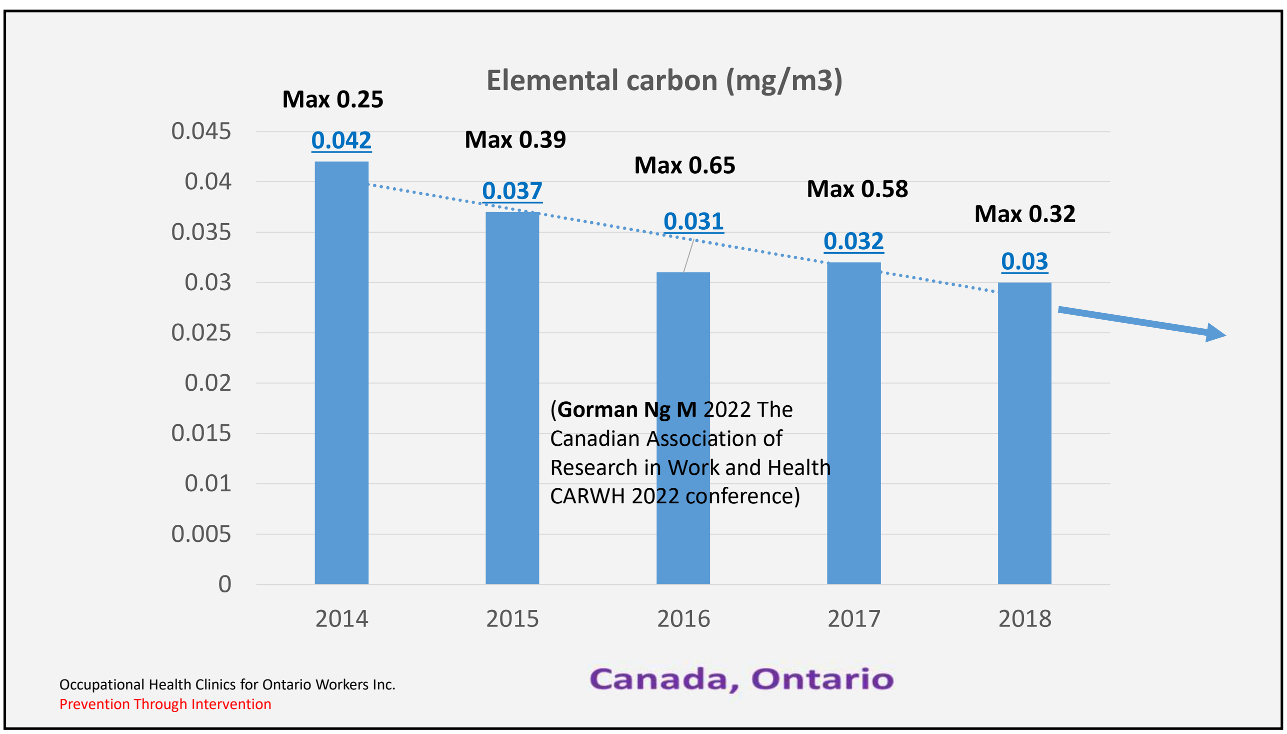
Elemental carbon (mg/m3)
Max 0.25
0.042
Max 0.39
0.037
Max 0.65
0.031
Max 0.58
0.032
Max 0.32
0.03
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
(Gorman Ng M 2022 The Canadian Association of Research in Work and Health CARWH 2022 conference)
2014
2015
2016
2017
2018
Canada, Ontario
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Diesel Exhaust Lung Cancer Risk Calculator

years of exposure	**25**	years
average respirable elemental carbon (REC) exposure (in µg/m^3)	**30**	µg/m^3
15-year lagged cummulative respirable elemental carbon exposure (in µg/m^3-yrs)	**300**	µg/m^3 - years
model estimated relative risk (RR) =	**1.47**	
95% confidence interval:	1.02	2.10

(model based on 0-1000 µg/m^3-yrs range)

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

http://jnci.oxfordjournals.org/content/suppl/2012/01/28/djs034.DC1/Supp_methods_and_tables_4-30-12.pdf

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Forest products
Forestry
Mine Rescue
Paper Printing and Converting
Occupational Disease
General
Pandemic
small business

New guideline for reducing diesel particulate matter in underground mines

Monday, February 14, 2022
Two successful examples of control strategies for airborne hazards

Reducing diesel particulate matter in underground mines: Two successful examples

A new guideline document for controlling diesel emissions in underground mines was introduced by the Ontario mining industry technical advisory committee.

"Diesel engine exhaust, including the diesel particulate matter, has been classified as carcinogenic to humans by the World Health Organization," says Keith Birnie, Industrial Hygienist and Ventilation Specialist at Workplace Safety North (WSN) and committee chair and coordinator. "For many years, diesel engines have been the workhorse in a large number of industries including mining, and diesel exhaust exposure presents an inhalation health hazard to workers."

In 2021, mining industry volunteers who make up the WSN Workplace Environment Technical Advisory Committee developed a practical reference document, "Reducing diesel particulate matter in underground mines: Two successful examples," for Ontario mining operations. The guide has information about the hazards of diesel engine exhaust along with examples on controlling diesel emissions, with a focus on diesel particulate matter.

Occupations with potential exposure to diesel emissions include miners, construction workers, heavy equipment operators, bridge and tunnel workers, railroad workers, oil and gas workers, loading dock workers, truck drivers, material handling operators, farmworkers, long-shoring workers, and auto, truck and bus maintenance garage workers.

New WSN Guideline for reducing diesel particulate matter in underground mines

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Underground emissions and miners' personal exposure to diesel and renewable diesel exhaust in a Swedish iron ore mine

https://pubmed.ncbi.nlm.nih.gov/35294627/

Interventions to Reduce Future Cancer Incidence from Diesel Engine Exhaust: What Might Work?

https://pubmed.ncbi.nlm.nih.gov/30352840/

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Conclusions

- Some Ontario mining workers are exposed at levels that may cause lung cancer. From the survey, seventy two percent (70%) of elemental carbon measurements (representing diesel engine exhaust exposure) exceeded the OCRC recommended **health-based exposure limit value** of 0.02 mg/m^3 (or 20 µg/m^3) representing exposures between 2014 and 2018.
- When compared with the **proposed statutory limit of 0.12 mg/m3 (EC)**, 10% exceeded this proposed compliance-based limit. This exceedance will likely be lower in 2022.
- Respiratory protection, along with a respiratory protection program, (CSA94.4) will be required until exposures are reduced as an interim measure.
- The results also **suggest an encouraging trend of annual reductions in exposure levels for EC (10.7% per year)** and progress toward reducing the risk of occupational lung cancer for Ontario miners.

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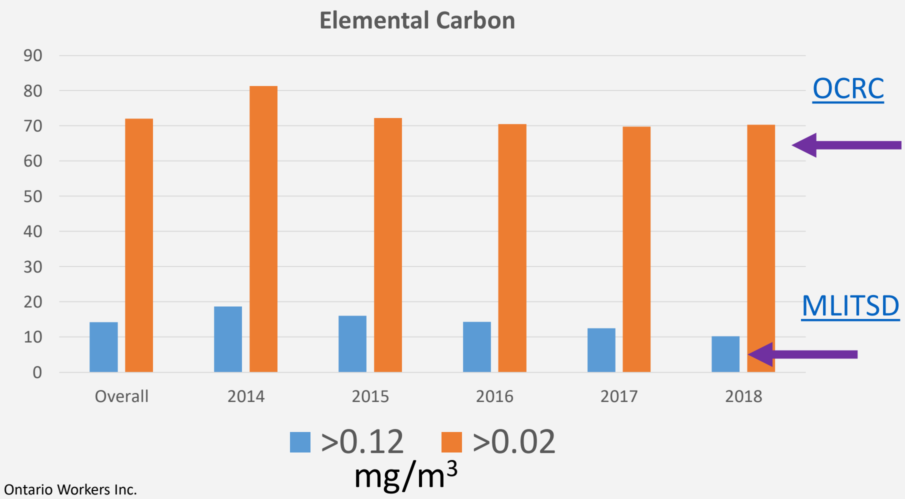
Percent above Occupational Exposure Limits (OELs)

(Gorman Ng M 2022 The Canadian Association of Research in Work and Health CARWH 2022 conference)



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MARC COUSINEAU *20-Nov-1953 - 05-Oct-2021*

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