Setting an Occupational Exposure Limit for Diesel Engine Exhaust in Canada: Challenges and Opportunities

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Executive Summary

Diesel engine exhaust (DEE) is one of the most prevalent occupational exposures in Canada. CAREX Canada estimates that approximately 897,000 Canadians are exposed to DEE in their workplace. The Occupational Cancer Research Centre in Ontario has used these estimates to calculate that approximately 560 lung cancers and 200 suspected bladder cancers can be attributed to occupational exposure to DEE each year in Canada. This report, which highlights the variability in occupational exposure limits (OELs) that have been adopted in Canada for constituents of DEE, found that few jurisdictions in Canada outside of the mining industry have an OEL for DEE, and none have adopted an OEL that reflects the current state of knowledge. The absence of an evidence-based OEL in Canada is of particular concern because many occupational disease prevention practices rely on the 'benchmark' of meeting a specific standard that an OEL provides.

The purpose of this report is to: understand the regulatory landscape for occupational DEE exposure; learn what experts thought are the key barriers and facilitators to setting and complying with OELs; and make a recommendation on a DEE OEL for Canada. It is designed to be used by people interested in occupational disease prevention. To achieve the project's objectives, the team conducted interviews with key informants and an environmental scan of OELs for DEE. The scan was supplemented by a high-level scan of key policy instruments to determine the basis by which OELs are set in Canada.

Most jurisdictions in Canada set OELs based on the American Conference of Governmental Industrial Hygienists (ACGIH®) *Threshold Limit Values* (TLVs) and *Biological Exposure Indices* (BEIs). Some, however, develop province- and/or industry-specific limits in addition to, or instead of, adopting the TLVs. Although most OELs in Canada are based on ACGIH® recommendations, the edition of the TLVs on which the OELs are based varies widely across and within jurisdictions. Across the country, a number of jurisdictions exclude the mining industry from the application of their occupational health and safety (OHS) legislation. In these jurisdictions, OELs are enacted under mining-specific OHS regulations and/or codes of practice – some which are based on the ACGIH® recommendations, others are province-specific. What is particularly noteworthy and relevant to the development of an OEL for DEE is that, within a given jurisdiction, mining sector OELs are often inconsistent with – and less protective than – those that apply to other industries.

The environmental scan found that OELs exist for various components of DEE (e.g., carbon monoxide, oxides of nitrogen), but there is a regulatory gap for limiting exposure to the carcinogenic fraction, which is mainly found in the particulate matter (PM). Within Canada, no jurisdiction has adopted an OEL for DEE that reflects the current state of knowledge and a consensus has yet to be reached for the exact substance(s) that should be measured to accurately assess exposure to diesel exhaust. At present, the most commonly measured marker of DEE exposure in Canada is respirable combustible dust (RCD).

Elemental carbon has emerged as the best surrogate for measuring diesel exhaust particulate and several international jurisdictions have proposed or adopted OELs based on measurement of elemental carbon. Legally enforceable OELs have been adopted by three countries in Europe (Switzerland, Germany, and Austria), three states in Australia (Queensland, Western Australia, and New South Wales), and New Zealand. The European Parliament adopted an OEL of 50 µg/m^3 of elemental carbon in December 2018, but has incorporated longer transitional periods before the OEL will apply in recognition that the OEL may be difficult to achieve in the short term. Four professional organizations have recommended OELs for DEE (California Department of Public Health, Finnish Institute of Occupational Health, the Health Council of the Netherlands, and the Australian Institute of Occupational Hygiene). None of these are legally enforceable at present. The ACGIH® has placed DEE on its list of agents under study but does not currently recommend a TLV for DEE.

Key informants identified **five key challenges and barriers** to the development and implementation of a DEE OEL: uncertainty in the science, slow regulatory processes, economic impact, inconsistencies in the selected marker of exposure, and measurement and analytical issues. Other barriers identified were in relation to the OHS landscape in Canada and the fact that provincial reliance on the ACGIH® threshold limit values means that jurisdictions will wait until the ACGIH® issues a recommended limit for DEE. The interviewees identified the following **six key facilitators** that they perceive are necessary (or highly desirable) for the implementation of a DEE OEL in their jurisdiction: proof of achievability, strong scientific rationale, a national working group, availability of up-to-date measurement techniques and data, and a consensus recommendation.

The absence of an ACGIH® recommendation on DEE appears to be one of the principal reasons why there is currently no OEL for DEE in Canada. The provincial reliance on the TLVs likely means that many jurisdictions will wait until the ACGIH® issues a recommended

limit for DEE before adopting or developing their own OEL. The wide variability *between* jurisdictions in the edition of the TLVs on which the OELs are based, coupled with the siloing of who has responsibility for OHS (e.g., for mining *vs*. all other industries) within individual provinces, means that it is unlikely that a consistent OEL will be adopted across the country once the ACGIH® issues a TLV recommendation. The consequence of this will be that some provinces will have more protective OELs than others and within individual provinces, some industries will have more protective OELs than others. In either case, there will be uneven protection across the country for workers exposed to DEE.

In considering whether or not to adopt an OEL for DEE, jurisdictions will be faced with not only factoring in the scientific evidence, but also weighing social policy factors, such as the economic impact of implementation. While more than half of the key informants indicated that this will likely impede the development and adoption of an OEL, they did not appear to think it was an insurmountable barrier. Indeed, many offered suggestions on strategies that might ease the impact, facilitate uptake, and smooth the process of implementation. Several jurisdictions who have already adopted a legally enforceable OEL for DEE have implemented a number of these strategies and their experience could be used as a model for action here in Canada.

Current scientific evidence supports the need for a more protective OEL for DEE in Canada. As this report illustrates, many jurisdictions around the world have adopted or are in the process of adopting a legally binding OEL for DEE in most workplaces that is in n the range of 0.05 to 0.1 mg/m^3 (or, 50 to 100 µg/m^3). Nearly all of these jurisdictions have moved to a standard based on elemental carbon measurement. The health-based recommendations recently released by the Health Council of the Netherlands are particularly noteworthy as they reflect the current state of the evidence and are two orders of magnitude lower than other existing OELs for DEE.

Based on evidence of increased lung cancer risk at very low levels, **we recommend that Canadian jurisdictions move towards an OEL based on elemental carbon of 20 µg/m^3 for the mining industry and 5 µg/m^3 for other workplaces to protect worker health**. The higher OEL recommended for the mining industry takes into account the feasibility of implementation in this industry that will have particular challenges and is meant as a interim target in a staged approach to eventually have one harmonized OEL for all workers.

Introduction

Diesel engine exhaust (DEE) is a complex mixture of gases and particulates produced by the combustion of diesel fuel (1). Gaseous compounds can include carbon dioxide, water vapour, oxygen, sulphur and nitrogen compounds, carbon monoxide, and low molecular weight hydrocarbons and their derivatives (2, 3). Diesel particulate matter (DPM) may contain elemental carbon, organic compounds (including polycyclic aromatic hydrocarbons, or PAHs), metals, and other trace compounds (2). Almost all particulate emitted by diesel engines is respirable (i.e. median diameter PM <4 microns), with the majority having diameters less than 1.0 micron (1).

CAREX Canada estimates that approximately 897,000 Canadians are exposed to DEE in their workplace – making it the third most prevalent occupational exposure in the CAREX database. Exposure to DEE causes a range of acute (e.g., eye and throat irritation), allergic, and chronic (e.g., cancer) health effects (2). The International Agency for Research on Cancer (IARC) first classified DEE as a probable human carcinogen in 1989, upgrading it to a known human carcinogen in 2012.

The Occupational Cancer Research Centre (OCRC) used national and provincial cancer statistics, literature reviews on the cancer risks associated with workplace exposures, and CAREX Canada's estimates of historical exposures to calculate the burden of lung and bladder cancer in Canada due to DEE exposure (4). Results showed that occupational exposure to DEE is a significant cause of lung cancer incidence and death, with approximately 560 lung cancers and 200 suspected bladder cancers attributed to occupational exposure to DEE each year in Canada, based on 2011 cancer statistics (5). This amounts to 2.4% of lung cancer cases diagnosed annually (5).

With the exception of the mining industry, few jurisdictions in Canada have an occupational exposure limit (OEL) for DEE and none have adopted an OEL that reflects the current state of knowledge. The absence of an OEL in most jurisdictions in Canada and the lack of consistency that exists across jurisdictions are of particular concern because many occupational disease prevention practices rely on the 'benchmark' that an OEL provides. In other words, an OEL provides a quantitative, achievable criterion that can be used to select appropriate controls, evaluate efficacy, and test compliance, among other factors.

Purpose of the report

The objectives of this report are to understand the regulatory landscape for occupational DEE exposure, to learn what experts thought are the key barriers and facilitators to setting and complying with OELs, and to make a recommendation on a DEE OEL for Canada. It is designed to be used by people interested in occupational disease prevention. This includes (but is not necessarily limited to) provincial and territorial Ministries of Labour and workers' compensation boards, policy analysts, researchers, and those who advocate for occupational health and safety (OHS).

To achieve the project's objectives, an environmental scan of occupational exposure limits for DEE was undertaken. The scan was supplemented by a high-level scan of key policy instruments (i.e., legislation, regulation and practice guidelines) to determine the basis by which OELs are set in Canada. Information for both scans was collected primarily from online sources. To examine the barriers and facilitators to developing an OEL for DEE in Canada, 10 key informant telephone interviews were conducted (between November 27, 2018 and January 31, 2019).

Methodology

Scan methodology

To examine current state of DEE exposure and workplace limits in Canada and internationally, an environmental scan of regulations and literature available online was conducted. Sources for the scan included government websites, legal and regulatory documents and portals, and other relevant publications. The scan was limited to Canada and to jurisdictions with similar workplace and approaches to OHS, including the United States, several European countries, Australia, and New Zealand. Regulations and guidelines, as well as industries that were not covered by existing regulations, were summarized by region.

Key informant interviews

Ten telephone interviews were conducted between November 27, 2018 and January 31, 2019 to better understand the current status of DEE OELs both nationally and internationally and to gather information that could help support the implementation of a DEE OEL in Canada. Participants were chosen based on the following criteria:

1. Pan-Canadian representation, with emphasis on jurisdictions where there has been some momentum towards a DEE OEL
2. International perspective, with emphasis on jurisdictions that are comparable to Canada and where DEE OELs have either been discussed or implemented
3. Inclusion of a broad spectrum of stakeholders (i.e., regulators, researchers, labour, and advocacy)

The interviews ranged from 25 minutes to 40 minutes in length and were conducted by one member of the study team. The interviews were recorded, transcribed, and analyzed for common themes. The interview component of the study received ethical approval from the Cancer Committee of the Health Research Ethics Board of Alberta (certificate #18-0627).

Of the 10 interviews, 6 were with individuals working within Canada and 4 were with individuals from other countries. The interviewees represented the following jurisdictions:

- **British Columbia:** Ministry of Energy, Mines and Petroleum Resources; WorkSafeBC
- **Ontario:** Ministry of Labour; Occupational Health Clinics for Ontario Workers (OHCOW); Occupational Cancer Research Center (OCRC)
- **Quebec:** University of Montreal
- **United Kingdom:** National Health Service
- **The Netherlands:** University of Utrecht
- **Finland:** Finnish Institute of Occupational Health (FIOH)
- **Australia:** Australian Institute of Occupational Hygienists (AIOH)

Background: Diesel engine exhaust

What is diesel fuel?

A byproduct of the petroleum refining process, diesel fuel is a mixture of hydrocarbons obtained by distillation of crude oil. During the refining process, the crude oil is converted into various transportation fuels including gasoline, jet fuel, and diesel fuel and other petroleum products (such as liquefied petroleum gas (LPG), heating fuel, lubricating oil, wax, and asphalt) (6). Diesel fuel can only be used in a diesel engine, which is the most efficient type of internal combustion engine or compression ignition engine (6). Heavy trucks, urban buses, and industrial equipment are powered almost exclusively by diesel engines and diesel-powered pick-up trucks and sport utility vehicles have become

increasingly popular (6). Because they are highly efficient, robust, and durable, diesel engines are an appealing alternative for many applications.

What is diesel engine exhaust?

Diesel engine exhaust (DEE) is produced when diesel fuel combusts in a compression ignition engine. A complex mixture of gases and particulates, the composition of DEE depends on a number of factors including the type of engine (heavy or light duty), type of fuel and engine oil, engine speed and load of operation, and presence of emission control systems (1). Gaseous compounds present in diesel exhaust can include carbon dioxide, sulphur and nitrogen compounds, carbon monoxide, and low molecular weight hydrocarbons and their derivatives (1-3), as well as water vapour and oxygen. In comparison with gasoline engine exhaust, DEE contains considerably less carbon monoxide (CO) which makes it possible to run this type of engine in enclosed worksites where gasoline engines cannot be used (7). Diesel particulate matter (DPM) may contain elemental carbon, organic compounds (including polycyclic aromatic hydrocarbons, or PAHs), metals, and other trace compounds (2). Almost all particulate emitted by diesel engines is respirable (i.e., median diameter PM <4 microns), with the majority having diameters less than 1.0 micron (1).

Who is occupationally exposed to DEE in Canada?

CAREX Canada estimates that approximately 897,000 Canadians are exposed to diesel exhaust in their workplace. The two largest industrial groups exposed are truck transportation and transit and ground passenger transportation. The two largest occupational groups exposed are truck drivers and heavy equipment operators. Additional occupations that may be exposed to diesel exhaust from the use of on-road engines include bus and subway drivers, bus garage workers, trucking company workers, forklift operators, firefighters, lumberjacks, toll-booth and parking garage attendants, traffic controllers, car mechanics, taxi drivers, couriers, and other professional drivers (1, 3). Occupations with potential for exposure to non-road diesel engines include railroad workers, underground mine workers (using diesel powered equipment), forestry (loggers), and those in the marine industry (1, 3).

What are the health effects of exposure?

Inhalation is the most important route of occupational exposure to DEE (1). Short-term exposure to DEE has been shown to cause irritation of the eyes, throat, and bronchi, as well as neuro-physiological symptoms such as light-headedness, nausea, and respiratory

symptoms (2). DEE exposure may also initiate allergic reactions or increase immunological response to other allergens (2). Increases in hospital admissions, higher incidence of respiratory symptoms, and decreases in lung function are all associated with exposures to airborne particulate, including diesel particulate matter (DPM) (2). Increased mortality rates are also reported, particularly in the elderly and those with cardiopulmonary conditions (2). Children living in high traffic areas are at particular risk of respiratory symptoms (8).

Although DEE has been suspected of causing cancer in humans since the 1980s, it was not classified as a known human carcinogen until 2012. The International Agency for Research on Cancer (IARC) first determined that DEE was likely to be carcinogenic to humans in 1989, classifying it as a Group 2A carcinogen (*probably carcinogenic to humans*) in Volume 46 of the IARC Monographs (9). In 1998, an advisory group to the IARC Monographs Program suggested that DEE be reevaluated based on a study on underground miners in the United States. Following the publication of that study's results in March 2012, IARC reevaluated its classification of DEE. On June 12, 2012, IARC reclassified DEE as a Group 1 carcinogen (*carcinogenic to humans*). This determination was based on 'sufficient evidence' for lung cancer and 'limited evidence' for bladder cancer in humans (3).

The studies considered in the IARC review used several markers to measure exposure to DEE, including polycyclic aromatic hydrocarbons, oxides of nitrogen, particulate matter (PM), and elemental carbon (EC) (3). Of these, EC has emerged as the best surrogate for measuring exposure to DEE particulate (3, 7, 10). Two key reasons for this are that EC constituted between 30-90% of the PM in older technology engines; and the methods for sampling and analysis of EC are more specific and sensitive than methods available for other particulate types (10).

Background: Legislative and regulatory context for OELs

To understand the reason why no Canadian jurisdiction has yet adopted an OEL for DEE, it is important to first have some context on OELs and on the occupational health and safety (OHS) landscape in Canada. This section of the report defines key terms related to occupational exposure limits and describes how OELs are set around the world and in Canada.

What is an occupational exposure limit?

Occupational exposure limit (OEL) is defined by the International Labour Organization as the "concentration in the air of a harmful substance which does not, so far as may be judged in the light of present scientific knowledge, cause adverse health effects in workers exposed for eight to ten hours a day and 40 hours a week. It is not an absolute dividing line between harmless and harmful concentrations but merely a guide for the prevention of hazards" (11). The Canadian Centre for Occupational Health and Safety (CCOHS) defines it more simply as "the maximum airborne concentration of a toxic substance to which a worker can be exposed over a period of time without suffering any harmful consequences" (12).

OELs are expressed as concentrations, averaged over a specific period of time. The time period may be long-term (i.e., the duration of a work shift, which is typically 8 or 12 hours) or short-term (i.e., 15 minutes). In addition, for some substances, an OEL may also be expressed as a short-term peak concentration that should never be exceeded. Definitions of each type of limit are provided in Table 1. Three units of measure are commonly used: parts per million (ppm), milligrams per cubic metre (mg/m^3), or micrograms per cubic metre ($\mu g/m^3$). OELs reported in mg/m^3 can be converted to $\mu g/m^3$ by dividing the former by 1000.

Table 1: OEL Definitions

OEL category	Definition
Long-term	The concentration of a hazardous substance in the air averaged over the period of time to which it is believed that workers may be repeatedly exposed, day after day, for a working lifetime without adverse effects. The averaging time is generally an 8- or 12-hour workday and a 40-hour workweek.
Short-term	The concentration of a hazardous substance in the air that should not be exceeded over any 15-minute period during a workday. Exposure to this concentration should not occur more than four times per day and there should be at least 60 minutes between successive exposures.
Ceiling	This is the concentration of a hazardous substance in air that should not be exceeded during any part of the work shift.

Note: Definitions adapted from those published by the Canadian Centre for Occupational Health and Safety (12), the American Conference of Governmental Industrial Hygienists (13), the Health and Safety Executive (14), and the National Institute for Public Health and the Environment (15).

How are occupational exposure limits set?

A number of professional organizations around the world develop and publish health- or risk-based exposure limits. The most prominent include: the American Conference of Governmental Industrial Hygienists (ACGIH®) and the National Institute for Occupational Safety and Health (NIOSH) in the United States, and the Scientific Committee on Occupational Exposure Limits (SCOEL) in the European Union. Independent scientific committees established by these organizations review and evaluate the peer-reviewed (and sometimes non peer-reviewed) literature across a range of disciplines (including toxicology, occupational hygiene, occupational medicine, and occupational epidemiology) and make recommendations on the basis of health-related factors only.

Ideally, the OELs are derived based on data from human studies (epidemiological and clinical, where available). However, the absence of high-quality human studies often means that these committees must rely on data from animal studies. Where there is evidence of a clear threshold of toxicity, the general approach[1] to setting OELs involves using that threshold to delineate a reference or toxicity endpoint below which no adverse health effects of exposure are expected. This reference point is referred to as the "No Observed Adverse Effect Level" (NOAEL) or the "Lowest Observed Adverse Effect Level" (LOAEL). To arrive at a recommended safe threshold of exposure (i.e., a health-based OEL), the committees adjust the NOAEL by a safety factor to account for uncertainty in the data and individual susceptibility (15, 16).

In theory, the scientific committees do not take into account factors like technical or analytic feasibility and the economic impact of implementation. These are considered social policy factors and are left to be weighed by policy- and decision-makers in the jurisdictions who elect to adopt their recommendations. The health-based OELs issued by these organizations are not legally binding or enforceable. Rather, they are guidelines designed for use by OHS professionals in making decisions about safe levels of exposure in the workplace. They only become legally enforceable once they are adopted and promulgated into law by agencies with legislative authority to make and enforce OHS legislation, regulations, and policy.

[1] This approach is taken by a number of professional organizations worldwide, including: the ACGIH® TLV Committee, the German MAK Commission, the SCOEL in the EU, the Nordic Expert Group for Criteria Documentation of Health Risks from Chemicals, the Dutch Expert Committee on Occupational Safety, the Occupational Safety and Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH) in the US.

How are OELs set in Canada?

Who has responsibility for setting and enforcing OELs in Canada?

In Canada, responsibility for OHS (which includes the setting and enforcement of OELs) is laid out in labour legislation, which falls under provincial authority. Responsibility for OHS is either held by a single branch of government (typically the Ministry of Labour) or by the agency responsible for the delivery of the workers' compensation system. In some jurisdictions, responsibility is shared between these two entities. Depending on the jurisdiction, OEL provisions are found in either the enabling statute (i.e., the *Occupational Health and Safety Act*[2] or the *Workers' Compensation Act*[3]) or in the subordinate regulations.

Because OHS falls under provincial jurisdiction, the specific industries and workers to which the legislation applies vary across the country. At the federal level, the *Canada Labour Code* applies to workers in the federal government, federal corporations, and federally regulated industries (e.g., aviation, some grain elevators, banks, inter-provincial trucking, shipping, railway and bus companies) (17). Provincial or territorial legislation applies to most other workplaces (17); however, there are some notable exceptions which have implications for the development and adoption of an OEL for DEE. For example, in Prince Edward Island, the Occupational Health and Safety Regulations do not apply to a workplace that is an "agricultural operation conducted on farmland"[4] (18). In British Columbia, *Section 108 of the Workers Compensation Act* states that Part 3 (Occupational Health and Safety) and its regulations do not apply to mines covered under the *Mines Act* (19). As a consequence, OELs are developed, adopted, and enforced by three agencies in British Columbia: the BC Ministry of Energy, Mines & Petroleum Resources – Office of the Chief Inspector of Mines (which has jurisdiction over mines in the province), the federal Labour Program (which is part of the Employment and Social Development Canada

[2] OHS legislation generally sets out the rights and duties of all workplace parties, as well as how workers are to be protected from health and safety hazards (i.e., prescriptive or performance-based requirements; inspection and monitoring requirements; and how laws and regulations are to be enforced).

[3] Workers' compensation legislation delegates authority for the delivery of workers compensation programs and sets out responsibilities in the spheres of prevention (where applicable), rehabilitation, and compensation.

[4] Agricultural operations defined in the regulations to include the production activity conducted, or service provided, by a bona fide farmer in relation to berry farming; Christmas tree culture; dairy farming; egg farming; grain and oilseed production; orchards; poultry farming; a riding academy or the boarding or breeding of horses; seed production; sod or turf production; vegetable farming; wool, hide, feather or fur production; and the raising of crops or animals for human or animal consumption.

portfolio and has jurisdiction over federal workplaces), and WorkSafeBC (which has jurisdiction over all other worksites that are covered by its legislation).

Most jurisdictions in Canada set OELs based on the ACGIH® *Threshold Limit Values* (TLVs) and *Biological Exposure Indices* (BEIs). Some, however, develop province- and/or industry-specific limits in addition to, or instead of, adopting the TLVs. See Appendix 2 for a summary of who has responsibility for setting and enforcing OELs in Canada, along with a list of the relevant policy instruments (enabling statutes and subordinate regulations/codes) in which the OELs are found, the industries and workplaces in which the OELs apply, and the specific ACGIH® edition on which the OELs are based.

ACGIH®-based OELs

Although most OELs in Canada are based on ACGIH® recommendations, the edition of the TLVs on which the OELs are based varies widely across and within jurisdictions (TLV's are updated by ACGIH® on an annual basis, and edition refers to publication year). The regulations in some jurisdictions clearly set out that the OELs are based on the most recent edition (e.g., the federal *Maritime Occupational Health and Safety Regulations*). In others, the regulations reference specific editions (e.g., Ontario, the 2015 edition; Alberta, the 2006 edition). In others still, the regulations reference a specific edition, but include language that allows for the OELs to be updated annually without the need to go to the legislature for a regulatory amendment. For example, the regulations in British Columbia specify the 2002 edition "as amended from time to time", while those in Prince Edward Island specify the 1985-86 edition "with annual update".

Jurisdiction-specific OELs

In some jurisdictions (e.g., British Columbia and Ontario), the relevant agency with responsibility for setting the OELs has adopted province- or industry-specific limits that are not consistent with ACGIH® recommendations. These jurisdictions generally start with a review of the ACGIH® recommendations, but ultimately adopt limits based on whether they are practicable (i.e., can industry meet them?), technically feasible (i.e., is there a validated sampling method to measure at these new limits?), and enforceable. The ACGIH® is clear that their TLVs are not, in fact, consensus OELs and recommends that jurisdictions consider questions related to implementation as part of their OEL-setting process.

Industry-specific OELs

Across Canada, a number of provinces exclude the mining industry from the application of their OHS legislation. In these jurisdictions, OELs are enacted under mining-specific OHS regulations and/or codes of practice. Some of these OELs are based on the ACGIH® recommendations and others are province-specific. What is particularly noteworthy and relevant to the development of an OEL for DEE is that, within a given jurisdiction, mining sector OELs are often inconsistent with – and less protective than – those that apply to other industries. For example, the OELs set out for the mining industry in British Columbia, New Brunswick, and the Northwest Territories/Nunavut are based on the 1994-95, 1992-93 and 1994-95 TLVs, respectively.

Outcome of the national and international scan of OELs

The environmental scan of the national and international OHS landscape found that OELs exist for various components of DEE (e.g., carbon monoxide, oxides of nitrogen), but there is a regulatory gap for limiting exposure to the carcinogenic fraction, which are mainly found in the particulate matter (10). As noted in the section on health effects, elemental carbon has emerged as the best surrogate for measuring diesel exhaust particulate (7, 10) and several jurisdictions have proposed or adopted OELs based on measurement of elemental carbon. This section of the report provides tabular overviews of OELs adopted by jurisdictions in Canada and abroad for DEE or surrogates of DEE exposure.

Which jurisdictions in Canada have adopted or recommended OELs for DEE?

No Canadian jurisdiction has adopted an OEL for DEE that reflects the current state of knowledge (Table 2). In addition, there is no consensus in Canada on the exact substance(s) that should be measured within DEE to accurately assess exposure.

The most commonly measured marker of DEE exposure in Canada is respirable combustible dust (RCD). Seven jurisdictions (Canada, British Columbia, New Brunswick, Nova Scotia, Yukon, Northwest Territories, and Nunavut) have adopted an OEL of 1.5 mg/m^3 for RCD, based on an 8-hour time-weighted average (8-hour TWA). Three jurisdictions (Ontario, Quebec, and Saskatchewan) use total carbon as the marker of DEE exposure. Ontario and Quebec have adopted an OEL of 0.4 mg/m^3 (based on an 8-hour TWA) for mining, while Saskatchewan recently amended its provincial mining regulations to include an OEL of 160 $\mu g/m^3$, which equates to 0.16 mg/m^3 (20). Newfoundland and Labrador is the only jurisdiction in Canada that uses elemental carbon as the marker of

DEE exposure, with an adopted OEL of 0.4 mg/m^3 (based on an 8-hour TWA). In March 2018, the Ministry of Labour in Ontario issued a proposal for consultation to lower its OEL to 160 µg/m^3 (which equates to 0.16 mg/m^3) for mining and additional industries (including construction, transportation, and warehousing) (21). This proposal was based on the limit that has been adopted by the Mine Safety and Health Administration (MSHA) in the United States (22). The consultation ended in May 2018; however, with a change in the provincial government later that year, the proposal for a reduced OEL has yet to be adopted.

Three jurisdictions (Alberta, Manitoba, and Prince Edward Island) have not adopted OELs for the particulate component of DEE. However, under its mining regulations, Manitoba has specific provisions regarding the allowable levels of exposure to some of the gaseous components of DEE (23) and under its *Occupational Health and Safety Code,* Alberta has an OEL for diesel fuel, as total hydrocarbons (24).

Table 2: Adopted or recommended OELs for DEE in Canada

Jurisdiction	OEL	Marker of exposure	Notes/Policy instrument reference
CAN	8-hr TWA: 1.5 mg/m^3	Respirable combustible dust	
BC	8-hr TWA: 1.5 mg/m^3	Respirable combustible dust	Applies to mines and to to any underground working which is not a mine within the meaning of the *Mines Act*.
SK	8-hr TWA: 0.16 mg/m^3	Total carbon[5]	Applies to mines, as defined by the Mines Regulations, 2018.
MB	8-hr TWA: 25 ppm STEL: 100 ppm	Carbon monoxide	Applies to a mine, as defined by the Mines Regulation.
	Ceiling limit: 1 ppm 8-hr TWA: 25 ppm	Oxides of nitrogen: Nitrogen dioxide Nitrous oxide	
ON	8-hr TWA: 0.4 mg/m^3	Total carbon	Current OEL; applies to all mines, mining plants, and mining development in Ontario. Method: NIOSH 5040.
	8-hr TWA: 0.16 mg/m^3	Total carbon; respirable dust	Proposed OEL. Would apply to workplaces in which Regulation 833 applies. Method: NIOSH 5040.
QC	8-hr TWA: 0.4 mg/m^3	Total carbon	Applies to a mine, as defined by the mining OHS regulations. Method: NIOSH 5040.

[5] Documentation indicating the particle size fraction (i.e., inhalable, thoracic, or respirable) for the marker of exposure was not available.

Jurisdiction	OEL	Marker of exposure	Notes/Policy instrument reference
NL	8-hr TWA: 0.4 mg/m^3	Elemental carbon	Applies to underground mines. Measured as per NIOSH Method 5040.
NB	8-hr TWA: 1.5 mg/m^3	Respirable combustible dust	Applies to underground mines.
NS	8-hr TWA: 1.5 mg/m^3	Respirable combustible dust	Applies to non-coal mines.
YK	8-hr TWA: 1.5 mg/m^3	Respirable combustible dust	Applies to mines, as defined under the OSH regulations.
NWT	8-hr TWA: 1.5 mg/m^3	Respirable combustible dust	Applies to mines.
NU	8-hr TWA: 1.5 mg/m^3	Respirable combustible dust	Applies to mines.

Which international jurisdictions have adopted or recommended OELs for DEE?

Across the international jurisdictions scanned, a number of jurisdictions have proposed or adopted OELs for DEE based on the measurement of elemental carbon (Table 3). Legally enforceable OELs have been adopted by three countries in Europe (Switzerland, Germany, and Austria), three states in Australia (Queensland, Western Australia, and New South Wales), and New Zealand. In all jurisdictions except Germany and the underground mining sector in Austria, the OEL is 100 µg/m^3 of elemental carbon (based on an 8-hour TWA). The OEL for Austria's underground mining sector is three times higher than this level. Germany adopted an OEL of 50 µg/m^3 of elemental carbon (based on an 8-hour TWA) in 2017, although it does not become effective in underground mines until 2022. The European Parliament adopted an OEL of 50 µg/m^3 of elemental carbon (based on an 8-hour TWA) in December 2018. The legislative resolution acknowledged that the OEL may be difficult to achieve in the short term and incorporated longer transitional periods before the OEL will apply. The OEL comes into effect on the 21st of February 2026 for underground mining and tunnel construction and on the 21st of February 2023 for all other industries (25).

No jurisdictions in the US have adopted OELs for DEE based on elemental carbon. The Occupational Safety and Health Administration has not adopted an OEL for diesel particulate; rather, it has enacted OELs for some of the gaseous constituents (nitrogen dioxide and carbon monoxide). The Mining Safety and Health Administration (MSHA) adopted an OEL of 160 µg/m^3, based on total carbon, in 2008. It applies in underground metal and non-metal mines.

Four professional organizations have recommended OELs for DEE (California Department of Public Health, Finnish Institute of Occupational Health, the Health Council of the

Netherlands, and the Australian Institute of Occupational Hygiene). All but California's are based on measurement of elemental carbon. The Australian recommendation is 100 µg/m^3 (8-hour TWA), while the Dutch and Finnish recommendations are at least an order of magnitude lower. None of these are legally enforceable at present.

The ACGIH® has placed DEE on its list of agents under study, but does not currently recommend a TLV for DEE. The ACGIH® first proposed a TLV of 0.15 mg/m^3 (or, 150 µg/m^3, 8-hour TWA) for DEE (on the basis of diesel particulate matter) in its 1995-1996 Notice of Intended Changes (NIC). At that time, it assigned a designation of A2 (suspected human carcinogen). That proposed limit was later lowered to 0.05 mg/m^3 (or, 50 µg/m^3, as total DPM) and was replaced in 2002 with a proposed TLV of 0.02 mg/m^3, expressed as elemental carbon. The proposed carcinogenicity classification remained as A2. The ACGIH® withdrew diesel exhaust particulates from the NIC in its 2003 edition of *Threshold Limit Values for Chemical Substances and Physical Agents*. The following year, the ACGIH® was named as a defendant in lawsuits filed in the US District Court in Macon, Georgia that sought to enjoin the ACGIH® from taking action on publishing or revising TLVs on several substances, including diesel particulate matter (26). On November 26, 2004, the court upheld the ACGIH®'s right to publish TLVs under the First Amendment of the US Constitution (26). DEE was placed on the "Under Study" list in 2016 (16) and remains there as of January 1, 2019 (27).

Table 3: Adopted or recommended OELs for DEE in other jurisdictions

Jurisdiction	OEL	Marker of exposure	Notes
United States			
US (MSHA)	8-hr TWA: 160 µg/m^3	Total carbon; respirable dust	Since 2008. Applies to underground metal and non-metal mines. Method: NIOSH 5040.
US (California)	8-hr TWA: 20 µg/m^3	Diesel particulates[6]	Recommended limit. Not legally enforceable.
Europe			
EU	8-hr TWA: 50 µg/m^3	Elemental carbon[6]	Adopted December 2018 (becomes effective in 2026 in underground mining and construction tunnels and in 2023 in other industries). Legally enforceable.

[6] Documentation indicating the particle size fraction (i.e., inhalable, thoracic, or respirable) for the marker of exposure was not available.

Jurisdiction	OEL	Marker of exposure	Notes
Switzerland	8-hr MAK: 100 µg/m^3	Respirable elemental carbon	Since 2012.
Finland	8-hr TWA: 5 µg/m^3 8-hr TWA: 20 µg/m^3	Respirable elemental carbon	Recommended: general workplaces. Recommended: mines, underground construction.
Netherlands	8-hr TWA: 0.011 µg/m^3 8-hr TWA: 1.03 µg/m^3	Respirable elemental carbon	Recommended: target risk level. Recommended: prohibition risk level.
Germany	8-hr TWA: 50 µg/m^3	Respirable elemental carbon	Set in 2017. Does not apply to underground mines until 2022.
Austria	8-hr TWA: 300 µg/m^3 8-hr TWA: 100 µg/m^3	Elemental carbon/respirable aerosol	Underground mines (since 2011). All other industries (since 2011).
Australia & New Zealand			
Australia	8-hr TWA: 100 µg/m^3	Submicron elemental carbon	Recommended OEL. Adopted by Queensland, Western Australia, New South Wales.
New Zealand	8-hr TWA: 100 µg/m^3	Inhalable elemental carbon	Enacted 2016.

Notes:
MSHA = Mine Safety and Health Administration
MAK = Maximale Arbeitsplatzkonzentration (maximum workplace concentrations)

Company- and industry association-specific OELs for DEE

BHP Billiton (BHP), a resource extraction and processing company headquartered in Australia, has adopted an OEL of 30 µg/m^3 and is working to reduce exposures further through innovation and prevention by design (28). Over the next 5 years, BHP will aim for further significant reductions in exposure through advancements in electrification and transitioning from traditional diesel to battery electric equipment (28).

The OEL was adopted by BHP following the completion of a review by the Institute for Occupational Medicine (IOM) that BHP had commissioned to assess the relevant and related literature on DEE emissions and to advise whether there were sufficient data available to develop exposure-response curve(s) (29). BHP and the IOM agreed to make a summary of the report publicly available to "support informed discussion, debate and decision-making by all key stakeholders about management of diesel exhaust emissions" (29). The report presents a summary of "the critical analysis that was performed to develop the most appropriate exposure-response curve, the key assumptions that underpin it, potential sources of bias and their impact, limitations and the margins of error around the risk estimates" (29).

Based on their review of three well-conducted epidemiological studies of DEE-exposed workers and the derived exposure-response relationships, the IOM concluded that there is a "marked elevation in lung cancer risk" from DEE even at relatively low levels of exposure (29). The authors acknowledged that it may be impractical to set a meaningful health-based OEL for workplace exposure but concluded that the evidence was "strong enough to support recommending controlling exposures to diesel exhaust particulate to the lowest level that is technically achievable" (29). The report concludes with the following recommendation:

> *In using the exposure-response relationships to decide the level at which to set a limit, it would be appropriate to review existing levels of occupational exposure and the opportunities for exposure reduction. The limit value should be set low enough to drive an overall reduction in exposure to diesel exhaust particulate and to lead to a meaningful reduction in cumulative exposure (measured as EC in mg/m^3·years) across the exposed population. Ideally, a long-term programme of planned reductions in exposure should be in place to ensure ongoing improvement in exposure control and an associated reduction in the risk of lung cancer in the workforce.* (29)

Perspectives of selected Canadian and international jurisdictions

Interviews were conducted with ten key informants in Canada (British Columbia, Ontario, and Quebec), Europe (Finland and the Netherlands), the United Kingdom, and Australia. As noted earlier in this report, participants were principally chosen on the basis of whether an OEL for DEE had been discussed or implemented in their jurisiction.

The input received has been synthesized under the following three headings:

1. What are the perceived barriers to developing and implementing an OEL for DEE?
2. What are the perceived facilitators to developing and implementing an OEL for DEE?
3. What lessons would help Canada implement an OEL for DEE?

What are the perceived barriers to developing and implementing an OEL for DEE?

The interviewees identified five key challenges and barriers to the development and implementation of a DEE OEL: uncertainty in the science, slow regulatory processes, economic impact, inconsistencies in the selected marker of exposure, and measurement

and analytical issues. Other barriers identified were in regards to the OHS landscape in Canada and the fact that provincial reliance on the ACGIH® threshold limit values means that jurisdictions will wait until the ACGIH® issues a recommended limit for DEE.

1. **Uncertainty in DEE OEL numbers/lack of consensus:** Seven of the interviewees mentioned uncertainty in the science or a lack of consensus on a recommended number as a challenge to the development of DEE OELs. Interviewees noted that some employer groups or associations will bring their own scientists or reports to the table and they will often disagree with the science, which then leads to political uncertainty for the decision maker. In Canada, there is also a huge amount of disparity in the numbers. Some jurisdictions say it should be 5 µg/m^3 (0.005 mg/m^3) and others 160 µg/m^3 (0.160 mg/m^3). The interviewees acknowledged that the goal is to come to a consensus as to which number is the best, but this has been a difficult process.
2. **Slow progress in setting and legislating a DEE OEL:** Five of the participants mentioned that the process to set and then legislate an OEL in their jurisdiction is often a very long and slow process. This was noted by respondents in Canada, Australia, Finland, at the EU level, and in the Netherlands. Two of the interviewees also alluded to the fact that another reason things are progressing slowly is that no one wants to take the lead. One interviewee described the situation in Canada: "Unfortunately there doesn't seem to be any appetite for taking lead on anything in Canada. And people are really more derivative than anything so they look for somebody else doing something first that they can copy. And that's unfortunate. I think we could actually be taking more of a lead." Some professional organizations (like the AIOH) and agencies with a national OHS mandate (like the FIOH) have taken the lead in recommending a target OEL for DEE exposure. This strategy has been particularly successful in Australia as three Australian states have adopted the AIOH recommendation.
3. **Economic impact:** Six of the interviewed individuals flagged the economic impact of setting and implementing a DEE OEL – and the resulting cost that industry will incur – as a challenge. One interviewee mentioned, "There would be lobbying to not set an OEL, because if an OEL is set then maybe there will be quite a bit of expenditure on things like after-treatment devices." Often these economic considerations carry a lot of weight in the decision making and can influence decision makers not to make a change. One interviewee mentioned that these monetary issues may need to be mitigated through some financial support or perhaps a phase-in plan to minimize the cost.

4. **Indicator of exposure:** Five of the interviewees mentioned that the exposure indicator used to measure DEE is not always the same and that there is some uncertainty as to what is the best indicator. The debate about whether the limit should be in total carbon or in elemental carbon is illustrated by one respondent's comment that "in Europe, we also had a lot of discussion on what is the best indicator." It was suggested that elemental carbon may be the better indicator and may be easier to measure ("we should be looking at elemental carbon consistently and the level should be the same for mining and other industries") and that the measurement units need to be consistent. One interviewee mentioned that Switzerland uses particle count to measure DEE and it may be a good idea to learn from the Swiss and perhaps set a limit based on mass as well as particle count.
5. **Measurement technology and data:** Four of the participants mentioned measurement technology and the lack of measurement data as a perceived barrier. Respondents flagged the necessity of having measurement or testing technology that is able to evaluate compliance (otherwise an OEL cannot be enforced), with some noting that there are now some real-time sampling devices available to do the measurements: "You really need something that is a real-time sampling device and that's been a hurdle for diesel exhaust but now that we have a couple of them on the market that hurdle is surpassed. And we can now look at real-time monitoring for diesel exhaust. So that changes the whole game." One interviewee mentioned the lack of measurement data in many countries: "They do not have measurement data and they do not know what kind of levels are existing at the workplaces." These data are important because they indicate current DEE levels and what has to be done to make the workplaces safer for workers.
6. **Other barriers:** Some provinces rely on the ACGIH® to determine their limits, so they wait until the ACGIH® makes a recommendation before they will even consider a change: "The challenge is that we have a bit of an uneven landscape here in Canada for occupational exposure limits and it's totally dependent on the ACGIH® moving." Further, the ACGIH® depends to a great extent on volunteers and has limited capacity to produce TLVs and BEIs. In Canada there are only provincial limits, as opposed to a nationally-applicable limit. It was mentioned that an independent scientific committee in Canada would be helpful in the reviewing and developing of proposals: "I don't know of any province that really has that kind of independent scientific committee. It does take resources to do that, which I am not sure the current environment we're going to see it in any of the major provinces."

What are the facilitators to developing and implementing an OEL for DEE?

The interviewees identified six key facilitators that they perceive are necessary (or highly desirable) for the implementation of a DEE OEL in their jurisdiction. They include: proof of achievability, strong scientific rationale, a national working group, availability of up-to-date measurement techniques and data, and a consensus recommendation.

1. **Proof that a limit is achievable with guidance/resources:** Seven participants mentioned that it is important to have examples or proof that limits can be achieved. Resources or guidance on how to achieve the limit is important and would be very helpful. One participant mentioned, "I think it is a combination of being able to demonstrate that limits would be achievable. Also that resources are available to help companies comply with such limits or to be able to know where or provide resources to be able to reduce the level of exposure at their worksites". According to a few of the interviewees, these type of resources are available: "In Australia, it's been shown with the monitoring data that we can get below 0.1 [mg/m^3] and there are a variety of things I've mentioned; the publication the AIOH produced which goes through best practices for reducing diesel particulate exposure in underground mining per se and BHP [an Australian mining company] have written their own on it as well which is readily available."
2. **Strong rationale based on science:** Four participants mentioned that it is important to base the rationale for a DEE OEL on strong scientific evidence: "So I think the main thing is … making your case very strongly, having really good showing of the science, but what's important is not just the science, but showing what would the outcomes be. So if we have this many workers exposed we believe that lowering this limit would eliminate this many deaths. That's a strong case, right?"
3. **National committee:** Four participants identified that having one national organization or committee lead in Canada would be helpful in developing and implementing a DEE OEL nationally. This type of committee could help individual provinces set and implement a limit, as well as provide information, recommendations and assistance for provincial harmonization. It would demonstrate that there is pan-Canadian momentum. Australia was flagged as an example of this approach: "We need a Canadian working group on occupational exposure limits. For example, in Australia they have Safe Work Australia, which is a national body. They don't have any influence in the legislation, but they do set model codes and guides and they also have a national exposure setting process as well. So all of the states just basically adopt what

is set at a national level. Also I think OHAO [Occupational Hygiene Association of Ontario] may be able to play a part in that. And I would think there are organizations like CAREX and others that could help feed into that as well."

4. **Measurement methods/data:** Four individuals mentioned that having current measurement methods and labs to analyze the measurements is an important step in the implementation of a DEE OEL. It was noted that there are sampling devices that can be used to measure compliance if an OEL is set: "We have a way of measuring it, we have both of course NIOSH 5040 which is a fairly easy method to use and the labs have validated it." Another important aspect of these sampling devices is the resulting measurement data that can be used to show that lower levels are achievableIn Finland, we would have supported a lower limit value, because we have measurement data, at least some measurement data, which shows it is possible to get lower levels even in underground mines and in tunnel work ."
5. **A recommended OEL:** Four interviewees felt that they need a limit or number to move forward in their jurisdictions. Without it, no one will put the necessary controls in place to help to reduce exposure to the workers: "Once we have a number we are happy with and that will happen at the occupational hygiene level, among the hygienists, among the researchers. What is the best number, what is the most practical number that can be used, that's going to be low enough to pick up significant exposures and high enough that you are not going to be forcing employers to implement things that may or may not be as protective as everyone thinks they are or they are overprotective and very expensive."
6. **Controls:** Four of the participants mentioned the importance of controls in discussing the achievability of a new DEE OEL. There is overall agreement that controls are available that would reduce exposure, such as newer generation diesel engines, diesel particulate filters, or non-diesel equipment. But the only way to make sure they are applied is to have a regulation: "There is lots of new equipment available certainly on-road, and even off-road now, progress has been made in terms of engine design and other technical advances that we could be pushing the adoption of. And that's not going to come as fast without some kind of regulation."
7. **Other facilitators:** Interviewees also alluded to other factors that would facilitate the development of an OEL for DEE, including an assessment of economic impact and the inclusion of a broader coalition of groups to help make the call for change heard. The more voices the better, "But I think that that pressure is going to have to come from a coalition of different groups and primarily a push by organized labor would be a way to

start that. But there are other groups as well that should be in. We could combine that as a kind of combined effort to lower levels in workplaces and in the broader environment to get a broader coalition of groups together to push."

What lessons would help Canada implement an OEL for DEE?

When asked if they had any lessons to share that could help Canada implement a DEE OEL, interviewees offered the following insights:

1. **Scientific evidence:** Six interviewees mentioned that the process starts with strong science: "But it all starts with the scientific due diligence". This is the first step in building a strong rationale for a limit.
2. **Phase-in period:** Three participants identified having a phase-in plan or staggered plan for implementation as important. It will take time for companies to comply completely with a new limit, but a staged approach would help. This should be offered as an option to companies: "You are going to have to have a phase-in period to get there which is a normal way of approaching it."
3. **Examples of success/best practice:** Four interviewees agreed that learning from companies who are making the changes and have been successful at implementing limits is very important. BHP was mentioned numerous times and should likely be used as an example: "If I was to sort of look at the leading company that have reduced the level like I said, I would say BHP Billiton are out there," and "They were very big on getting good management commitment. Their leaders would actually, the health and safety leaders, would present to the board and talk to the board about what it meant to the company. So I think that really provided the impetus for a lot of change within the company. And I think they are probably an excellent model to look at. I also think putting people up as leaders from industry, other industries are more likely to listen to those leaders because they have actually gone through the process and they can look at the feasibility for example." Also, when introducing a new limit it is helpful to portray the change as a beneficial situation: "The other key one is making sure that you have together a best practice package for actually maintaining/implementing controls. As I said the key one is if you can introduce things that have a win, win for the people who have management of the issue."
4. **Inter-provincial harmonization:** It is beneficial to work with other provinces on this issue: "In the case of the diesel OEL it's helpful for us if we have other provinces that are looking at it or adopting it, it gives us some justification. So we've been doing a lot of work with Alberta and Saskatchewan and Manitoba trying to synchronize OELs to

bring them up to similar levels [of protection]." One participant gave an example of this strategy working very well when they were trying to lower the OEL for silica dust. This type of strategy can justify to stakeholders why this limit is needed: "It makes it a lot easier to make your case to stakeholders that this is a good thing to do when you have other provinces doing it and access to all of their documentation and information they have to prove your point."

5. **Other lessons:** One individual advised that having stakeholder involvement earlier in the process may be helpful. Another participant mentioned that it is important not to mix up community and workplace exposure: "People need to get the concept that you don't mix up community exposure with workplace exposure. There's often lower concentrations when we do community studies that are causing effects of some sort or another compared to what you'll see in the occupational environment."

Discussion

The results of the key informant interviews suggest that while Canadian jurisdictions recognize that workers must be better protected from exposure to DEE, they perceive a number of obstacles that either have impeded or will potentially impede the adoption of a health-based OEL for DEE. Amongst the challenges and obstacles identified were the following: perceived scientific uncertainty and a lack of consensus about the best marker of exposure, the slow pace of regulatory change, resistance of employers at the perceived costs of implementation, the uneven OHS landscape that exists within Canada, and the absence of an ACGIH® TLV for DEE.

Since each jurisdiction in Canada relies on the TLVs to set OELs, the absence of an ACGIH® recommendation on DEE appears to be one of the principal reasons why there is currently no OEL for DEE in Canada. Although the ACGIH® added DEE to its list of agents under study in 2016, it has yet to issue a TLV recommendation. The provincial reliance on the TLVs likely means that many jurisdictions will wait until the ACGIH® issues a recommended limit for DEE before adopting or developing their own OEL. The wide variability *between* jurisdictions in the edition of the TLVs on which the OELs are based, coupled with the siloing of who has responsibility for OHS (e.g., for mining *vs*. all other industries) *within* individual provinces, means that it is unlikely that a consistent OEL will be adopted across the country once the ACGIH® issues a TLV recommendation. The consequence of this will be that some provinces will have more protective OELs than others and within individual provinces, some industries will have more protective OELs than others. In either case, there will be uneven protection across the country for workers exposed to DEE.

Diesel engine exhaust contains up to 1,800 chemicals, making it a complex mixture that is challenging to monitor. Its composition can change with the type of engine, operating conditions, fuel formulation, and emission control systems. The adoption of an OEL for DEE will require decisions on what is the appropriate marker of exposure, as well as what is the best method of sampling and analysis. The literature suggests that there are several potential chemicals or substances on which an OEL could be based, including: airborne particulate matter, polycyclic aromatic hydrocarbons, carbon monoxide, or elemental carbon (16). Despite the lack of certainty about the exact component, the findings of our scan indicate there is an emerging consensus that the best marker of exposure is **elemental carbon** (30).

Several key informants perceived the lack of a real-time sampling device as a barrier to the adoption of an OEL for DEE. However, because real-time measurement technology does not allow for extrapolation to an 8-hour OEL, it is not a necessary requirement for establishing an OEL for DEE. A well-established sampling and analytical method for DPM, as elemental carbon, already exists in North America. This method[7], first issued by the National Institute for Occupational Safety and Health (NIOSH) in May 1996 and subsequently updated in March 2016, should form the basis for evaluating compliance with any OEL that is proposed for DEE (30).

The findings of the environmental scan indicate a trend towards the adoption and implementation of more protective OELs for DEE. The health-based recommendations recently released by the Health Council of the Netherlands are particularly noteworthy as they reflect the current state of the evidence and are two orders of magnitude lower than other existing OELs for DEE. The concentrations of the derived OELs correspond to a "target risk level" of 4 extra lung cancer deaths per 100,000 and a "prohibition risk level" of 4 extra lung cancer deaths per 1,000, due to 40 years of occupational exposure (10). The Dutch committee reviewed studies in workers who had been exposed to emissions from diesel engines with no effective emission reduction systems to arrive at a target risk level of 0.011 µg/m^3 and a prohibition risk level of 1.03 µg/m^3 (10). Both are 8-hour time-weighted average concentrations and both are based on respirable elemental carbon (10). There are also many exposure experts and other scientists who recommend the use of the *precautionary principle*, which involves "taking preventive action in the face of

[7] Method 5040 is available in the NIOSH Manual of Analytical Methods, 5th Edition.

uncertainty; shifting the burden of proof to the proponents of an activity; exploring a wide range of alternatives to possibly harmful actions; and increasing public participation in decision making" (31). This could be a valuable strategy for DEE, since it is a complex exposure to define and measure, a large number of people are exposed, and the population-level impacts are likely to be very large.

In considering whether or not to adopt an OEL for DEE, jurisdictions will be faced with not only factoring in the scientific evidence, but also weighing social policy factors, such as the economic impact of implementation. While more than half of the key informants indicated that this will likely impede the development and adoption of an OEL, they did not appear to think it was an insurmountable barrier. Indeed, many offered suggestions on strategies that might ease the impact, facilitate uptake, and smooth the process of implementation. Examples included:

- developing resources, tools, or guidance documents on how to achieve the proposed limit;
- demonstrating that the limit is achievable with real-world monitoring data (preferably that have been collected in their industry or jurisdiction);
- creating opportunities for employers to learn from or be mentored by companies who have successfully achieved the limits;
- creating a communication strategy that highlights why meeting the limits is a win-win opportunity; and
- implementing the OEL in a phased or staggered approach, as is done in the European Union.

Several jurisdictions who have already adopted a legally enforceable OEL for DEE have implemented a number of these strategies and their experience could be used as a model for action here in Canada. BHP Billiton's experience – in developing and adopting an OEL that is as low as technically feasible (and that is, at least in theory, a more precautionary approach), combined with the work they are doing in partnership with the International Council on Mining and Metals to reduce exposures further through innovation on cleaner vehicles and advancements in electrification – could be highlighted as a model of what a forward-thinking company and industry association can achieve.

Finally, the work required to set and implement a diesel OEL by companies, associations, or legislative bodies will inevitably require human and financial resources, and this should not be overlooked as an important consideration that will contribute to the success of prevention initiatives.

Recommendations

Priorities for prevention

Preventing workplace exposure to diesel exhaust will require employers, workers, industry associations, and professional organizations to work toward limiting emissions, through education and training, hazard assessment, engineering controls (such as enclosed cabs, high efficiency filters, ventilation to control emissions in the workplace, local exhaust ventilation on tailpipes in shops with idling vehicles, and ensuring vents are unblocked), and best practices. Ultimately, the most effective approach will be to eliminate the harmful emissions associated with diesel fuel combustion, by replacing older engines with low emission engines, or switching to alternatives such as electric. The following key priorities for prevention emerged from a 1-day symposium hosted by CAREX Canada in March 2016 (32).

1. Adopt and implement an occupational exposure limit for DEE.
2. Lobby for legislation and incentives to reduce or eliminate the use of diesel fuel. Examples include: requiring all vehicles in enclosed, underground mines to switch to electric; expanding the requirement for electric engines above ground wherever possible (e.g., in smaller equipment like tractors and electric share power for trucks); supporting the development of commercially available devices that run on zero emission sources such as electric motors, at affordable price; and, supporting the replacement of diesel engines with LNG-powered engines.
3. Use new monitoring technology to change driving practices and offer incentives to develop new, improved technology to drive change in driving practices.
4. Educate employees about the effects of DEE and promote the use of safer replacements, where available. Also provide incentives for switching to more environmentally friendly equipment.
5. Link occupational exposures to particular tasks within each industry and use the information to inform prevention priorities and controls. Linking occupational exposure estimates to engine size, type, and age would generate useful information for regulatory agencies to prioritize emission standards and develop programs to substitute/eliminate diesel fuel.
6. Develop a communications and outreach strategy to raise awareness and to communicate data on the burden of cancer associated with DEE exposure to industry,

workers, and the public. Share information with occupational associations and communities, particularly on the way exposures cause cancer, to promote prevention and good driving practices.

A recommended health-based OEL for Canada

Current scientific evidence supports the need for a more protective OEL for DEE in Canada. As illustrated by the environmental scan, several jurisdictions around the world have adopted or are in the process of adopting a legally binding OEL for DEE in most workplaces that is in the range of 50 to 100 µg/m^3 of respirable EC (which equates to 0.05 to 0.1 mg/m^3). Nearly all of these jurisdictions have moved to a standard based on elemental carbon measurement. As noted elsewhere in this report, elemental carbon is a more specific measure of diesel particulate matter than total carbon, which can be confounded by cigarette smoke or other combustion products (33). Based on evidence of increased lung cancer risk at very low levels (34), **we recommend that Canadian jurisdictions move towards an OEL based on respirable elemental carbon of 20 µg/m^3 for the mining industry and 5 µg/m^3 for other workplaces to protect worker health**. The higher OEL recommended for the mining industry takes into account the feasibility of implementation in this industry that will have particular challenges, and is meant as a first step in a staged approach to eventually have one harmonized OEL for all workers.

The creation of a national committee and early stakeholder engagement, as recommended by the key informants, could foster support for the adoption and implementation of an OEL at these levels, as well as build momentum towards a harmonized exposure limit within and between jurisdictions across the country. For this committee to be successful, it must be appropriately resourced and have a central secretariat or organizing body to support its work. Ideal candidate organizations to take on this role include CAREX Canada and the Canadian Centre for Occupational Health and Safety (CCOHS).

We further recommend that jurisdictions introduce an OEL for DEE in a structured, phased approach similar to the transitional arrangements allowed for by the European Commission. This will allow industries time to address any technological challenges and associated costs, as well as implementing appropriate control technology and collecting baseline exposure data. Available monitoring data suggests that with appropriate support, it will be feasible for industries to achieve the recommended OELs. For example, exposure

levels for truck, bus, and taxi drivers generally range from 1 to 10 µg/m^3 elemental carbon, while mechanics are exposed to approximately 20 to 40 µg/m^3 elemental carbon (35).

Conclusion

Diesel engine exhaust is one of the most prevalent occupational exposures in Canada. CAREX Canada has estimated that approximately 897,000 Canadians are exposed to DEE in their workplace. The Occupational Cancer Research Centre in Ontario has used these estimates to calculate that approximately 560 lung cancers and 200 suspected bladder cancers can be attributed to occupational exposure to DEE each year in Canada. These are preventable. This report, which highlights the variability in OELs that have been adopted in Canada for constituents of DEE, found that no jurisdiction in Canada has adopted an OEL that reflects the current state of knowledge. The absence of an OEL is of particular concern because many occupational disease prevention practices rely on the 'benchmark' that an OEL provides.

Appendix 1: The IARC classification process

The Monographs Program of the International Agency for Research on Cancer (IARC) identifies and evaluates environmental causes of cancer. Since 1971, more than 1000 agents have been evaluated and of those 400 have been identified as carcinogenic, probably carcinogenic or possibly carcinogenic to humans (36). The types of agents the Monographs Program assesses include chemicals, complex mixtures, occupational exposures, physical agents, biological agents and personal habits (36). IARC works with international experts to identify and evaluate agents suspected of causing cancer. A working group of independent experts carries out the evaluation of suspected agents and the assessment is done based on available scientific evidence. After gathering for eight days and reviewing the scientific evidence they classify the agent into one of 5 groups: Group 1 or the agent is carcinogenic to humans, group 2A or the agent is probably carcinogenic to humans, group 2B or the agent is possibly carcinogenic to humans, group 3 or the agent is not classifiable as to its carcinogenicity to humans, or Group 4 or the agent is probably not carcinogenic to humans (36).

Appendix 2: Legislative & regulatory context for OELs in Canada

Table 4: Who's responsible for setting and enforcing OELs in Canada, by jurisdiction

Jurisdiction	Responsible Authority	Enabling Statute, Subordinate Regulations	Scope of Application
Federal	Setting OELs: Employment and Social Development Canada – Labour Program Enforcing OELs: Employment and Social Development Canada – Labour Program	Canada Labour Code	Part II of the Labour Code applies "(a) on or in connection with the operation of any federal work, undertaking or business other than a work, undertaking or business of a local or private nature in Yukon, the Northwest Territories or Nunavut; (b) by a corporation established to perform any function or duty on behalf of the Government of Canada; and (c) by a Canadian carrier, as defined in section 2 of the *Telecommunications Act*, that is an agent of Her Majesty in right of a province." Also applies to "federal public administration and to persons employed in the federal public administration to the extent provided for under Part 3 of the *Federal Public Sector Labour Relations Act*" and to "any person who is not an employee but who performs for an employer to which this Part applies activities whose primary purpose is to enable the person to acquire knowledge or experience, and to the employer, as if that person were an employee of the employer"
		Canada Occupational Health and Safety Regulations	All federal workers, except those employed (a) on trains while in operation; (b) on aircraft while in operation; (c) on ships; (d) on or in connection with exploration or drilling for or the production, conservation, processing or transportation of oil or gas in frontier lands (subject to Part II of the *Oil and Gas Occupational Safety and Health Regulations*); or (e) on or in connection with a work or undertaking that is excluded from the application of the Act by an order made pursuant to section 123.1 of the Act.
		Aviation Occupational Health and Safety Regulations	Workers employed on board aircraft while in operation and persons granted access to those aircraft by the employer
		Maritime Occupational Health and Safety Regulations	Applies to workers employed (a) on vessels registered in Canada; (b) on un-commissioned vessels of Her Majesty in right of Canada; and (c) in the loading or unloading of vessels.
		Oil and Gas Occupational Safety and Health Regulations	Other than Part II, applies to workers employed on or in connection with exploration or drilling for or the production, conservation, processing or transportation, other than transportation through an interprovincial pipeline, of oil or gas in Canada lands, as defined in the *Canada Oil and Gas Act*.

Jurisdiction	Responsible Authority	Enabling Statute, Subordinate Regulations	Scope of Application
			Part II applies to workers employed in Canada lands, as defined in the *Canada Oil and Gas Act*, on or in connection with the transportation of oil or gas through an interprovincial pipeline. Regulations do not apply to workers employed in the operation of ships or aircraft.
		On Board Trains Occupational Health and Safety Regulations	Workers on trains while in operation and in respect of all persons granted access to such trains by the employer. Note: Part 7 (which sets out OEL provisions) does not apply to the handling or transportation of dangerous goods to which the *Transportation of Dangerous Goods Act, 1992* and its regulations apply.
British Columbia	Setting OELs: WorkSafeBC - Policy, Research & Regulation Division Enforcing OELs: WorkSafeBC - Prevention Services	Workers Compensation Act, Part 3, Occupational Health and Safety Occupational Health and Safety Regulation, Part 5, Controlling Exposure	All workplaces except mines covered under Mines Act and industrial camps covered under Public Health Act
	Setting OELs: Ministry of Energy, Mines & Petroleum Resources – Office of the Chief Inspector of Mines Enforcing OELs: Ministry of Energy, Mines & Petroleum Resources – Office of the Chief Inspector of Mines	Mines Act Health, Safety and Reclamation Code 2017	All mines during exploration, development, construction, production, closure, reclamation and abandonment
Alberta	Setting OELs: Ministry of Labour – Occupational Health & Safety (OELs reviewed by	Occupational Health and Safety Act Occupational Health and	Every occupation, employment, business, calling or pursuit over which the Legislature has jurisdiction, except farming and ranching operations specified in the regulations and private dwellings

Jurisdiction	Responsible Authority	Enabling Statute, Subordinate Regulations	Scope of Application
	Director of Occupational Hygiene) Enforcing OELs: Ministry of Labour - Occupational Health & Safety	Safety Regulation Occupational Health and Safety Code	
Saskatchewan	Setting OELs: Ministry of Labour Relations and Workplace Safety Enforcing OELs: Ministry of Labour Relations and Workplace Safety – Occupational Health and Safety Division, WorkSafe Saskatchewan	S-15.1 - The Saskatchewan Employment Act O-1.1 Reg 1 - The Occupational Health and Safety Regulations O-1.1 Reg 2 - The Mines Regulations	All workplaces, except those covered under federal OHS legislation.
Manitoba	Setting OELs: Department of Growth, Energy & Trade – Labour & Regulatory Services – Workplace Safety & Health Enforcing OELs: Department of Growth, Energy & Trade – Labour & Regulatory Services – Workplace Safety & Health	Workplace Safety and Health Act Workplace Safety and Health Regulation Operation of Mines Regulation	All provincial and federal workplaces (defined as building, site, workshop, structure, mine, mobile vehicle, or any other premises or location whether indoors or outdoors in which one or more workers, or self-employed persons, are engaged in work or have worked)
Ontario	Setting OELs: Ministry of Labour - Health & Safety Policy & Program Development	Occupational Health and Safety Act Reg. 833: Control of Exposure to Biological or	All workplaces, which the Act defines to mean any land, premises, location or thing at, upon, in or near which a worker works, except private residences, farming operations (except as prescribed), persons employed as teachers (as defined under the *Education Act*) or a member/teaching assistant of academic staff at a university or related institution.

Jurisdiction	Responsible Authority	Enabling Statute, Subordinate Regulations	Scope of Application
	Branch Enforcing OELs: Ministry of Labour - Occupational Health & Safety Branch	Chemical Agents Reg. 490/09: Designated Substances	
Quebec	Setting & Enforcing OELs: CNESST – Santé et sécurité du travail	chapter S-2.1 Act respecting occupational health and safety chapter S-2.1, r. 13 Regulation respecting occupational health and safety	All workplaces, which the Act defines to mean any place in or at which a person is required to be present out of or in the course of work, including an establishment and a construction site (terms that are also defined under the Act).
Newfoundland & Labrador	Setting & Enforcing OELs: ServiceNL – OHS Branch	Occupational Health and Safety Act Occupational Health and Safety Regulations	All workplaces, which the Act defines as a place where a worker or self-employed person is engaged in an occupation and includes a vehicle or mobile equipment used by a worker in an occupation. Regulations apply to all employers and self-employed persons and workers and other persons to whom the Act applies except where the context of the regulations indicates otherwise.
New Brunswick	Setting & Enforcing OELs: WorkSafeNB – Compliance & Regulatory Review	Occupational Health and Safety Act General Regulation - Occupational Health and Safety Act Underground Mine Regulation - Occupational Health and Safety Act	All places of employment, which the Act defines as “any building, structure, premises, water or land where work is carried on by one or more employees, and includes a project site, a mine, a ferry, a train and any vehicle used or likely to be used by an employee”. Exceptions: private homes and places of employment exempted by the regulations. The Underground Mine Regulation defines “underground mine” as a mine where the workings extend below ground level and are not generally visible from the surface except for shafthead buildings or portal houses.
Nova Scotia	Setting OELs: Department of Labour & Advanced Education – Occupational Health & Safety Division	Occupational Health and Safety Act Workplace Health and Safety Regulations Underground Mining	Act applies to (a) every agency of the Government of the Province; and (b) all matters within the legislative jurisdiction of the Province. The Act defines “workplace” to mean any place where an employee or a self-employed person is or is likely to be engaged in any occupation and includes any vehicle or mobile equipment used or likely to be used by an employee or a self-employed person in an occupation.

Jurisdiction	Responsible Authority	Enabling Statute, Subordinate Regulations	Scope of Application
	Enforcing OELs: Department of Labour & Advanced Education – OHS Division, Compliance & Inspection Services	Regulations	Regulations apply to all workplaces to which the *Occupational Health and Safety Act* applies, unless exempted by the Act or the regulations
Prince Edward Island	Setting OELs: Workers Compensation Board Enforcing OELs: Workers Compensation Board – Occupational Health & Safety Services (Enforcement)	Occupational Health and Safety Act Chapter 0-1 Occupational Health and Safety Act, General Regulations	Act applies to all workplaces within the legislative jurisdiction of the province, except those exempted by regulation. The Act defines workplace to mean "a place where a worker is or is likely to be engaged in an occupation and includes a vehicle, fishing vessel or mobile equipment used or likely to be used by a worker in an occupation" The Occupational Health and Safety Regulations do not apply to a workplace that is an agricultural operation conducted on farmland. Agricultural operations defined to include the production activity conducted, or service provided, by a bona fide farmer in relation to berry farming; Christmas tree culture; dairy farming; egg farming; grain and oilseed production; orchards; poultry farming; a riding academy or the boarding or breeding of horses; seed production; sod or turf production; vegetable farming; wool, hide, feather or fur production; and the raising of crops or animals for human or animal consumption; but does not include the production of agricultural byproducts or of manufactured derivatives from agricultural raw material; the breeding or raising of pets other than horses; or aquaculture.
Yukon	Setting & Enforcing OELs: Workers' Compensation Health and Safety Board	Occupational Health and Safety Act Occupational Health Regulations Occupational Health and Safety Regulations	Act applies to "employment on or in connection with the operation of any work, undertaking, or business other than a work, undertaking, or business that is under the exclusive jurisdiction of the Government of Canada", except for work performed by the owner or occupant in or about a private residence.
Northwest Territories & Nunavut	Setting OELs: Workers Safety & Compensation Commission (WSCC) – the Commissioner Enforcing OELs:	Safety Act RSNWT 1988 Occupational Health and Safety Regulations Oil and Gas Occupational Safety and Health Regulations	All worksites, which the Act defines to mean a location where a worker is, or is likely to be, engaged in work, or a thing at, on, in or near which a worker is, or is likely to be, engaged in work. The Occupational Health and Safety Regulations do not apply to mines (as defined in section 1 of the *Mine Health and Safety Act*) or to the exploration, production and conservation of oil and gas

Jurisdiction	Responsible Authority	Enabling Statute, Subordinate Regulations	Scope of Application
	Workers Safety & Compensation Commission (WSCC) – Chief Safety Officer	Mine Health and Safety Act Mine Health and Safety Regulations	resources. The Act defines "mine" to include (a) a place where the ground is mechanically disturbed or an excavation is made to explore for or to produce minerals, other than a place where persons use only hand tools to explore for minerals; (b) machinery, equipment and material used in connection with a mine; (c) buildings and shelters used in connection with a mine, other than bunkhouses, cook houses and related residential facilities; (d) a place where mining activities such as exploratory drilling, excavation, processing, concentrating, storage, waste disposal and work associated with mine site reclamation are carried out; (e) a mine under construction; and (f) a closed mine; (mine)
Nunavut	Setting OELs: Workers Safety & Compensation Commission (WSCC) – the Commissioner Enforcing OELs: Workers Safety & Compensation Commission (WSCC) – Chief Safety Officer	Safety Act RSNWT (Nu) Occupational Health and Safety Regulations Mine Health and Safety Act Mine Health and Safety Regulations	All worksites, which the Act defines to mean a location where a worker is, or is likely to be, engaged in work, or a thing at, on, in or near which a worker is, or is likely to be, engaged in work. The Occupational Health and Safety Regulations do not apply to mines (as defined in section 1 of the Mine Health and Safety Act) or to the exploration, production and conservation of oil and gas resources. The Act defines "mine" to include (a) a place where the ground is mechanically disturbed or an excavation is made to explore for or to produce minerals, other than a place where persons use only hand tools to explore for minerals; (b) machinery, equipment and material used in connection with a mine; (c) buildings and shelters used in connection with a mine, other than bunkhouses, cook houses and related residential facilities; (d) a place where mining activities such as exploratory drilling, excavation, processing, concentrating, storage, waste disposal and work associated with mine site reclamation are carried out; (e) a mine under construction; and (f) a closed mine; (mine)

Table 5: Canadian OEL policy instruments and basis for their adoption, by jurisdiction

Jurisdiction	Policy Instrument(s)	OELs based on
Federal	Canada Occupational Health and Safety Regulations Section 10.19 - Control of Hazards Occupational Health and Safety and Compliance	ACGIH® *Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs)*, as amended from time to time; Excluded substances: airborne grain dust, airborne flour dust, and airborne asbestos fibres
	Aviation Occupational Health and Safety Regulations Section 5.16 - Control of Hazards	ACGIH® *Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs)*, as amended from time to time. Excluded substances: airborne asbestos fibres
	Maritime Occupational Health and Safety Regulations Section 238 - Enclosed Working Areas Section 255 - Control of Hazards	Most recent edition of the ACGIH® *Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs)* Excluded substances: airborne grain dust, airborne flour dust, and airborne asbestos fibres
	Oil and Gas Occupational Safety and Health Regulations Section 11.23 - Control of Hazards	ACGIH® *Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs)*, as amended from time to time Excluded substances: airborne grain dust (respirable and non-respirable), airborne asbestos fibres
	On Board Trains Occupational Health and Safety Regulations Section 7.23 - Control of Hazards	ACGIH® *Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs)*, as amended from time to time. Excluded substances: airborne asbestos fibres
British Columbia	Workers Compensation Act, Part 3, Occupational Health and Safety Occupational Health and Safety Regulation, Part 5, Controlling Exposure Policy Item R5.48-1 RE: Occupational Exposure Limits Guideline 5.48-1 Table of exposure limits - Background information Table of adopted TLVs and exposure limits developed by exception Mines Act Health, Safety and Reclamation Code 2017	All provincially regulated workplaces except mines: Ceiling limit, short-term exposure limit, or 8-hour TWA limit prescribed by ACGIH®, except as otherwise determined by the Board. OELs determined by the Board are listed in the table of adopted TLVs and exposure limits developed by exception. ACGIH® defined by Section 5.1 of the *OHSR* to mean publication entitled *Threshold Limit Values and Biological Exposure Indices, dated 2002*, as amended from time to time Mines: ACGIH® "Threshold Limit Values and Biological Exposure Indices", 1994-1995 edition. Excluded substances listed, with adopted OELs, in Table 2.1 of Code.
Alberta	Occupational Health and Safety Act Occupational Health and Safety Regulation Occupational Health and Safety	OELs based largely on the 2006 ACGIH® Threshold Limit Values (TLVs) for Chemical Substances. Section 60 of the *Occupational Health and Safety Act* allows an occupational health and safety officer to enforce an exposure limit from another jurisdiction or organization if

Jurisdiction	Policy Instrument(s)	OELs based on
	Code OHS Code - Schedule 1, Table 2 Occupational Health and Safety Code - Explanation Guide	there is no OEL.
Saskatchewan	S-15.1 - The Saskatchewan Employment Act O-1.1 Reg 1 - The Occupational Health and Safety Regulations O-1.1 Reg 2 - The Mines Regulations - Part XVI, Division 2	Table 21 of the O-1.1 Reg 1 - The Occupational Health and Safety Regulations lists "contamination limits" for substances to which employers must control exposure Section 346 of the Mines Regulation sets out that no diesel engine can be used underground if the carbon monoxide in the undiluted exhaust emissions of a diesel engine exceeds 1,500 ppm of air; the concentration must be measured before the exhaust passes through the exhaust gas scrubber required by section 347
Manitoba	Workplace Safety and Health Act Workplace Safety and Health Regulation - Section 36.5 Operation of Mines Regulation	ACGIH® *Threshold Limit Values and Biological Exposure Indices.* Section 1.1 of the Mines Regulation sets out that "hazardous" is defined in relation to a substance or physical agent as "a substance or physical agent having…a threshold limit value (i) in the case of a gas or vapour, below 500 ppm, (ii) in the case of fumes, below 500 mg/m^3, and (iii) in the case of dust, below 10 mg/m^3 of total dust less than 1% quartz, or 5 mg/m^3 respirable dust;" When a diesel engine is operated underground, the employer is required under Section 15.1(5)(e) to perform air monitoring for carbon monoxide and oxides of nitrogen at the operator's position and to immediately shut down the equipment if the results exceed the TLVs.
Ontario	Occupational Health and Safety Act Reg. 833: Control of Exposure to Biological or Chemical Agents Reg. 490/09: Designated Substances	"Adopted Values" shown at pages 11 to 61 of the publication entitled *2015 Threshold Limit Values for Chemical Substances and Physical Agents & Biological Exposure Indices* published by ACGIH® Ontario-specific OELs are listed in Table 1 of Reg. 833: Control of Exposure to Biological or Chemical Agents and Table 1 of Reg. 490/09: Designated Substances. All OELs currently adopted in Ontario can be found on the MOL website (Current Occupational Exposure Limits for Ontario Workplaces Required under Regulation 833)
Quebec	chapter S-2.1 Act respecting occupational health and safety chapter S-2.1, r. 13 Regulation respecting occupational health and safety chapter S-2.1, r. 14 Regulation	Permissible exposure values for gases, dusts, fumes, vapours or mists listed in Schedule I of chapter S-2.1, r. 13 Regulation respecting occupational health and safety Section 102 of chapter S-2.1, r. 14 Regulation respecting occupational health and safety in mines stipulates "When internal combustion engines are used for operating

Jurisdiction	Policy Instrument(s)	OELs based on
	respecting occupational health and safety in mines	equipment in an underground mine, they shall be diesel-type engines and their use shall be subject to observance of the following conditions: (1) the ventilation in places where such engines are used shall be sufficient to dilute the contaminants present in the exhaust gases to weighted average exposure values measured in the worker's respiratory zone; those exposure values shall be: (a) below 0.4 mg of total carbon per cubic metre of air; (b) below the exposure values provided for in Schedule I of the Regulation respecting occupational health and safety (chapter S-2.1, r. 13);"
Newfoundland & Labrador	Occupational Health and Safety Act Occupational Health and Safety Regulations	Ceiling limit, short-term exposure limit or 8-hour time weighted average limit prescribed by ACGIH®, where a threshold limit value has been established by the ACGIH®. "TLV" is interpreted to mean the documentation of threshold limit values for chemical substances and physical agents in the work environment published annually or more frequently by the ACGIH®. The regulations also set out that "a reference to a code or guideline, unless otherwise stated, includes amendments to that code or guideline and a reference shall be presumed to be a reference to the most current code or guideline".
New Brunswick	Occupational Health and Safety Act General Regulation - Occupational Health and Safety Act Underground Mine Regulation - Occupational Health and Safety Act	All provincially regulated workplaces except underground mines: *1997 Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices*, published by the ACGIH®. Exceptions: lead sulfide and formaldehyde. Underground mines: *1992-1993 Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices*
Nova Scotia	Occupational Health and Safety Act Workplace Health and Safety Regulations Underground Mining Regulations	Workplace Health and Safety Regulations: threshold limit values established by the *TLVs and BEIs*, where *"TLVs and BEIs"* means the latest version of the ACGIH® publication of the *Threshold Limit Values and Biological Exposure Indices* Underground Mining Regulations: threshold limit value as set out in the latest version of the publication "TLVs and BEIs" published by the ACGIH® other than a TLV excluded under Section 211. Excluded substances: methane, butane, ethane, propane in coal mines.
Prince Edward Island	Occupational Health and Safety Act Chapter 0-1 Occupational Health and Safety Act, General Regulations	ACGIH® TLVs as prescribed in the publication *Threshold Limit Values and Biological Exposure Indices for 1985-86* (with annual update).
Yukon	Occupational Health and Safety Act Occupational Health Regulations	Permissible concentrations to comply with Section 27 of the Occupational Health Regulations are listed in Tables 8 to 14.

Jurisdiction	Policy Instrument(s)	OELs based on
Northwest Territories	Safety Act RSNWT 1988 Occupational Health and Safety Regulations Oil and Gas Occupational Safety and Health Regulations Mine Health and Safety Regulations	Schedule O of the Occupational Health and Safety Regulations sets out "contamination limits" for substances to which employers in all workplaces to which the Regulations apply must control exposure (in accordance with the provisions of Part 21, Section 314) Part I, Section 1.44 of the Mine Health and Safety Regulations requires managers to ensure appropriate systems are in place to dilute or remove contaminants from all work areas located underground or on the surface to prevent exposure of a worker to contaminants in excess of the values specified in the *2001 Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices*, published by the ACGIH® Part IX, Section 9.02 of the Mine Health and Safety Regulations sets out that employees shall not be exposed to airborne concentrations of chemical or physical substances in excess of those specified in the 1994-1995 *Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices*, published by the ACGIH®
Nunavut	Safety Act RSNWT (Nu) 1988 Occupational Health and Safety Regulations (Nu) Mine Health and Safety Regulations (Nu)	Schedule O of the Occupational Health and Safety Regulations (Nu) sets out "contamination limits" for substances to which employers in all workplaces to which the Regulations apply must control exposure (in accordance with the provisions of Part 21, Section 314). Part I, Section 1.44 of the Mine Health and Safety Regulations (Nu) requires managers to ensure appropriate systems are in place to dilute or remove contaminants from all work areas located underground or on the surface to prevent exposure of a worker to contaminants in excess of the values specified in the *2001 Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices*, published by the ACGIH® Part IX, Section 9.02 of the Mine Health and Safety Regulations (Nu) sets out that employees shall not be exposed to airborne concentrations of chemical or physical substances in excess of those specified in the 1994-1995 *Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices*, published by the ACGIH®

Appendix 3: Environmental Scan of Diesel Engine Exhaust OELs

Canada: In 1990, the Canadian ad hoc Diesel Committee proposed an Occupational Exposure Limit (OEL) of Diesel Particulate Matter (DPM) measured by Respirable Combustible Dust (RCD), which was to not exceed 1.5 mg/m^3 over an 8 hour working shift (37). Many Canadian provinces have used this recommendation to develop legislation for mining industries.

British Columbia: Under Section 22.30 of the *Occupational Health and Safety Regulation*, a non-mine underground worker's exposure to RCD cannot exceed 1.5 mg/m^3 over an 8-hour working shift (38). The Health, Safety and Reclamation Code for Mines in British Columbia also sets a regulatory limit of 1.5mg/m^3 RCD (8-hour, time-weighted average) for the mining industry in British Columbia (39).

Alberta: Alberta does not have a provincial OEL regulation for DEE, however it does have an OEL of 100 mg/m^3 for diesel fuel, as total hydrocarbons (24). Section 60 of the *Occupational Health and Safety Act* allows an occupational health and safety officer to enforce an exposure limit from another jurisdiction or organization if there is no OEL (40).

Saskatchewan: Under Section 14.3 of Saskatchewan's provincial mining regulations (which became effective in April 2019), an employer or contractor must ensure that a worker's personal exposure to DPM in an underground mine does not exceed an airborne concentration of 160 µg/m^3 of total carbon (based on an 8-hour time-weighted average) or equivalent value to 160 µg/m^3 determined by and based on an approved methodology for judging exposure (20).

Manitoba: Manitoba does not have a provincial OEL for DEE in any industries, but their mining legislation does include rules for operating diesel engines underground (23).

Ontario: In 2018, the Ministry of Labour proposed to reduce the OEL for DPM in underground mining from 400 µg/m^3 to 160 µg/m^3 (based on TC) and to introduce a new OEL for other industries (including construction, transportation, and warehousing) of 160 µg/m^3 (based on TC) (21). This change was proposed based on the United States Department of Labor's Mining Safety and Health Administration regulation for DEE, which became effective in underground metal and non-metal mines in May of 2008 (22).

Quebec: Under Section 102 of Quebec's *Regulation respecting occupational health and safety in mines*, the OEL for underground mining is 0.4 mg/m^3 TC (41). There is no regulation for general workplaces.

Newfoundland and Labrador: In 2012, Newfoundland and Labrador adopted an OEL of 0.4 mg/m^3 EC (time weighted average, TWA) for underground mines (42).

New Brunswick: Section 53(5)(e)(iv) of New Brunswick's *Underground Mine Regulation* requires an employer to ensure that an air monitoring plan describes the procedures and corrective measures to be followed in the event that RCD from diesel engines exceeds a time-weighted average of 1.5 mg/m^3 (43).

Nova Scotia: Section 221 of Nova Scotia's *Underground Mining Regulations* sets out that in non-coal mines, the air flow to an active working where diesel engines are operated must keep the airborne concentration of RCD below 1.5 mg/m^3, based on an 8-hour TWA (44).

Prince Edward Island: Prince Edward Island does not have a provincial OEL for DEE (45, 46).

Yukon: Before diesel-powered equipment can be operated in an underground mine or project, Section 15.61 of Yukon's *Occupational Health and Safety Regulations* requires a mechanical ventilation system capable of supplying sufficient air to reduce the airborne concentration of RCD to below a TWA of 1.5 mg/m^3 (47)

Northwest Territories: Under Section 10.62(4)(c) of the Northwest Territories *Mine Health and Safety Regulations*, exposure to RCD from diesel engines cannot exceed 1.5 mg/m^3 (48).

Nunavut: Under Section 10.62(4)(c) of Nunavut's Mine Health and Safety Regulations, exposure to RCD from diesel engines cannot exceed 1.5 mg/m^3 (49).

United States of America: The Mine Safety and Health Administration enforces a DPM limit of 160 µg/m^3 TC (8-hour TWA) for metal and non-metal mines (22). The Occupational Safety and Health Administration, which covers workers in general industry, agriculture, construction, and maritime industries, does not currently have an exposure limit (50).

California has a state-specific recommended OEL for diesel exhaust emissions within all industries of 20 µg/m^3 of diesel particles (51). This limit is based on an assessment completed by California's Environmental Protection Agency's Office of Environmental Health Hazard Assessment, however it is not legally enforceable (51).

ACGIH®: The ACGIH® recommended a limit of 20 µg/m^3 EC (TWA) for diesel exhaust in 2002. This recommendation was withdrawn in 2003. DEE is currently on their "Under Study" list (27).

European Union: The European Union (EU) adopted a limit value for DEE of 0.05 mg/m^3, measured as EC, in December 2018 (52). The limit values set by the EU are legally binding; once published as law, EU member states will have two years to incorporate the DEE limit value into their legislation, with the exception of underground mining and tunnel construction which will have five years.

United Kingdom: The United Kingdom (UK) has identified diesel exhaust as an exposure that requires mitigatory work to reduce the overall cancer burden for UK citizens (53). However, there is currently no OEL in the UK for diesel exhaust emissions (14).

Switzerland: Switzerland has based their national OEL for DEE on the measurement of EC. The Maximale Arbeitsplatz-Konzentration (MAK) [Maximum Work Place Concentration] limit is 0.1 mg/m^3 respirable EC (based on an 8-hour TWA) (54).

Scandinavia: No OEL for DEE was found in Sweden, Denmark, Norway, or Iceland.

Finland: The Finnish Institute of Occupational Health recommends a target level of 5 µg/m^3 respirable EC for general workplaces and 20 µg/m^3 respirable EC for mines and underground construction sites (based on an 8-hour TWA) (55). However, as this is a recommended OEL, it is not enforceable (10).

Netherlands: In 2019, the Dutch Expert Committee on Occupational Safety recommended health-based OELs for DEE, based on predetermined risk levels (target and prohibition) for death from lung cancer based on 40 years of occupational exposure (10):

- 0.011 µg/m^3 respirable EC (8-hour TWA), which corresponds to 4 extra deaths per 100,000 (target risk level)
- 1.03 µg/m^3 respirable EC (8-hour TWA), which corresponds to 4 extra deaths per 1,000 (prohibition risk level)

These recommendations will be used to inform the government's decision on an OEL for DEE.

Germany: In 2017, the German Committee on Hazardous Substances set an OEL for DEE of 50 µg/m^3 respirable EC (10, 56). This limit will not apply to underground mines until 2022.

Austria: The 8-hour TWA OEL for underground mining is 300 µg/m^3 DPM EC/respirable aerosol. For all other industries, the 8-hour TWA OEL is 100 µg/m^3 DPM EC/respirable aerosol (54, 57).

Australia: No national OEL exists for DEE in Australia (58). Safe Work Australia is currently reviewing a number of workplace exposure standards, including DEE (59).

In 2013, the Australian Institute of Occupational Hygienists (AIOH) recommended a level of 100 µg/m^3 submicron EC for DEE (60). Three Australian states (Queensland, Western Australia, and New South Wales) have adopted this recommendation into their guidelines for mining industries (61, 62).

New Zealand: In 2016, New Zealand established a workplace exposure standard of 100 µg/m^3 inhalable EC (8-hour TWA) (63).

Ireland: Limit value - 8 hours, 150 µg/m^3 diesel exhaust, dust respirable[8] (64)

Poland: Limit value - 8 hours, 500 µg/m^3 diesel exhaust, dust respirable (64)

[8] The limits for Ireland and Poland were found on an international occupational exposure limit database (GESTIS International Limit Values), but documentation to confirm these values were not available.

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