Guidance for Evaluating Human Health Effects in Impact Assessment:

AIR QUALITY

Health Canada Santé Canada

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1 ACRONYMS

ACRONYM	MEANING
Agency	Impact Assessment Agency of Canada (also known as the IAAC)
AQMP	air quality management plan
AQMS	Air Quality Management System
AZMF	Air Zone Management Framework
B[a]P	benzo[a]pyrene
CAAQS	Canadian Ambient Air Quality Standards
CalEPA	California Environmental Protection Agency
CCME	Canadian Council of Ministers of the Environment
CEAA 2012	*Canadian Environmental Assessment Act, 2012*
CEPA 1999	*Canadian Environmental Protection Act*, *1999*
CI	continuous improvement
CO	carbon monoxide
COPC(s)	contaminant(s) of potential concern
GBA Plus	gender-based analysis plus
HBEL	health-based exposure limits
HHRA	human health risk assessment
HIA	health impact assessment
IA	impact assessment
IAA	*Impact Assessment Act*
IAAC	Impact Assessment Agency of Canada (also known as the “Agency”)
IARC	International Agency for Research on Cancer
IS	impact statement

KCAC	keeping clean areas clean
LSA	local study area
µg/m^3	micrograms per cubic metre
µm	micrometres
mg/m^3	milligrams per cubic metre
MW	molecular weight
NAAQOs	National Ambient Air Quality Objectives
NH_3	ammonia
NO_2	nitrogen dioxide
NO_X	nitrogen oxides
PAHs	polycyclic aromatic hydrocarbons
ppb	parts per billion
ppm	parts per million
$PM_{2.5}$	particulate matter less than 2.5 µm in diameter
PM_{10}	particulate matter less than 10 µm in diameter
RfC	reference concentration
RSA	regional study area
SO_2	sulphur dioxide
TISG	tailored impact statement guidelines
TSP	total suspended particulates
VOC(s)	volatile organic compound(s)
US EPA	United States Environmental Protection Agency
UFP	ultrafine particles
WHO	World Health Organization

2 PURPOSE OF THIS DOCUMENT

This document provides generic guidance on assessing potential human health risks of air quality in federal impact assessments (IAs) of proposed major resource and infrastructure projects in Canada. It presents the principles, current practices and basic information Health Canada looks for when it reviews the impact statement (IS) or other documentation submitted by project proponents as part of the IA process.

The document was prepared to support an efficient and transparent project review process. The foundational information described here should be supplemented appropriately with additional information relevant to proposed projects. The guidance was prepared for the Impact Assessment Agency of Canada (the Agency) and stakeholders involved in the IA process to communicate Health Canada's standards areas of engagement and priorities to help ensure that sufficient evidence is available to support sound decisions. As part of its review, Health Canada may suggest that the Agency, review panels or others collect information not specifically described here in this document to assess the health effects of proposed projects. As the guidance provided here is generic and designed to support the IA process, the scope of Health Canada's review may also be amended to reflect project-specific circumstances.

Health Canada updates guidance documents periodically and, in the interest of continuous improvement, accepts comments and corrections at the following address: ia-ei@hc-sc.gc.ca.

In the same series, the following guidance documents are available:

- *Guidance for Evaluating Human Health Effects in Impact Assessment: COUNTRY FOODS*
- *Guidance for Evaluating Human Health Effects in Impact Assessment: DRINKING AND RECREATIONAL WATER QUALITY*
- *Guidance for Evaluating Human Health Effects in Impact Assessment: HUMAN HEALTH RISK ASSESSMENT*
- *Guidance for Evaluating Human Health Effects in Impact Assessment: NOISE*
- *Guidance for Evaluating Human Health Effects in Impact Assessment: RADIOLOGICAL IMPACTS*
- Please verify that you are reading the most recent version available by consulting the Government of Canada Publications: https://www.publications.gc.ca/site/eng/home.html.

3 INTRODUCTION AND CONTEXT

The key objectives of Health Canada's IA program are to inform and improve understanding of the potential risks to human health associated with proposed projects, to help prevent, reduce, and mitigate negative impacts and foster positive impacts. Health Canada's expert information and knowledge are available to assist the Agency, review panels and others in assessing the potential project-related health effects.

As a federal authority, Health Canada provides specialist or expert information or knowledge in the Department's possession (expertise) to support the assessment of impacts on human health from projects considered individually and cumulatively under the *Impact Assessment Act* (IAA). This complement of expertise may change or evolve over time. The Department provides scientific expertise; it does not play a regulatory role. The use of expertise provided by Health Canada in the IA process will ultimately be determined by the reviewing body(ies).

In comparison to the *Canadian Environmental Assessment Act 2012* (CEAA 2012), the IAA expands the assessment of health to promote a broader understanding of the biophysical environment and supports assessment of the social and economic effects of projects. Among other things, the IAA includes specific requirements to consider positive and negative effects on the health, social and economic conditions of the public, including Indigenous peoples. In addition, the IAA includes the requirement for potentially affected Indigenous groups to be consulted during the planning phase of the project and incorporate Indigenous traditional knowledge, if provided, alongside other evidence. The IAA also requires consideration of the intersection of sex and gender with other identity factors.

Gender-Based Analysis Plus

Gender-based analysis plus (GBA Plus) identifies and analyzes the differential impacts of designated projects on diverse population groups. The "plus" in GBA Plus acknowledges that GBA goes beyond biological (sex[1]) and socio-cultural (gender[2]) differences. It highlights the pathways on which those differences develop and how they intersect with other determinants to shape health and well-being. It guides how we consider sex and gender when we frame, plan for, and implement the IA of designated projects. Gender-based analysis plus includes other individual and social identity factors such as race, religion, social position, income, age, ability, and education; this is called intersectionality[3]. The basic steps to applying GBA Plus include gathering appropriate data, understanding context, and asking analytical questions to determine whether the project is expected to have disproportionate effects on diverse populations. By working through a GBA Plus analysis, experts can better understand the possible differential effects of a project on distinct groups of people, including on disproportionately affected or impacted populations and populations identified by sex and gender. Considering how a program, policy, plan, or product might impact groups differently provides an opportunity for all those involved to help address potential pitfalls before they become a problem or to identify opportunities that would not have been otherwise considered.

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1 Sex refers to physical and physiological features including chromosomes, gene expression, hormone levels and function, and reproductive/sexual anatomy. https://cihr-irsc.gc.ca/e/48642.html

2 Gender refers to the socially constructed roles, behaviors, expressions and identities of girls, women, boys, men, and gender diverse people. https://cihr-irsc.gc.ca/e/48642.html

3 Government of Canada's Approach Gender Based Analysis Plus. https://women-gender-equality.canada.ca/en/gender-based-analysis-plus/government-approach.html

Key GBA Plus considerations in IA of designated projects:

- Does the proposal identify the diverse communities of women, men, and children who will be directly and indirectly affected by the proposed project's activities?
- Are the data about potential impacts disaggregated by sex, age, language and other social identities relevant to the local communities?
- Have the views of the affected women, men, Indigenous peoples and other disproportionately impacted groups been included in the proposed project's design?
- What are the implications of the proposed project's health and socio-economic effects on the well-being of women, men, Indigenous peoples and disproportionately affected populations?
- What types of measures are needed to ensure equitable representation during consultation processes and subsequent stages of the IA?
- What measures are needed to enhance the positive effects or mitigate any adverse effects of the designated project on women, men, children and other disproportionately affected groups?

Identifying the range of concerns and interests of, and impacts on, diverse groups based on social characteristics like gender, age, ethnicity, occupation, and length of residency, for example, can help foster the development of more comprehensive mitigation and enhancement strategies.

A health impact assessment (HIA) is a systematic, objective and yet flexible and practical way of assessing the potential positive and negative impacts of a proposal on health and well-being. In the context of designated projects under the IAA, an HIA aims to characterize the anticipated health effects, both adverse and positive, and the distribution of those effects within the population. The Agency determines the scope of the factors taken into account, including their relevance to the IA, as outlined in the tailored impact assessment guidelines (TISG). The steps of an HIA include screening, scoping, assessment, recommendations, reporting, monitoring and evaluation of the effectiveness of the HIA process, and the impact on decision-making.

Health Canada has been working with key partners and rights holders, including Indigenous organizations, federal partners, provinces/territories, and other key stakeholders, to develop HIA guidance and tools for a more comprehensive assessment of potential health effects of proposed projects. The document provides guidance to scope and address the broader social and economic conditions underlying the health of potentially affected communities and Indigenous peoples. Health Canada has developed an interim HIA Guidance Document to bridge the gap between the IAA coming into force on August 28, 2019 and the planned publication by the Department of the guidance document and complementary material on HIA. The interim guidance document is available upon request at the following address: ia-ei@hc-sc.gc.ca.

Health Canada provides its expertise in human health risks associated with air quality, drinking and recreational water quality, ionizing radiation, electromagnetic fields, noise and country foods when it reviews and provides comments on information submitted by proponents in support of proposed projects. Health Canada also provides general information on the subject of health assessments in relation to proposed projects subject to the federal IA process.

This document concerns the assessment of human health risks associated with air quality. It contains information on the division of roles and responsibilities for issues related to air quality at various levels of government in Canada; health effects associated with air quality; indicators of these effects; and steps in Health Canada's preferred approach to assessing air quality-related health effects.

APPENDIX A provides a checklist for verifying that the key elements of an air quality assessment have been completed and where this information appears in the assessment document.

APPENDIX B lists the Canadian Ambient Air Quality Standards (CAAQS) and National Ambient Air Quality Objectives (NAAQOs) for various ambient air pollutants, current as of the date of publication of this document. The Canadian Council of Ministers of the Environment (CCME)'s State of the Air website also provides key information on air quality across Canada. Definitions and equations for converting units are provided at the end of this appendix.

APPENDIX C provides a sample calculation of additional lung cancer mortality from fine particulate matter ($PM_{2.5}$) recommended for the characterization of health risks of diesel exhaust.

4 ROLES AND RESPONSIBILITIES

In Canada, the protection and improvement of ambient air quality is a shared responsibility between the federal, provincial and territorial governments. Health-based exposure limits (HBEL) are issued by a variety of agencies for characterizing potential health risks associated with exposure to environmental pollutants. Health Canada has derived a range of HBEL for many substances that should be used when evaluating human health risk in an air quality assessment. When Health Canada has not derived an HBEL for a substance of interest, values derived by the World Health Organization (WHO), the United States Environmental Protection Agency (US EPA), and the California Environmental Protection Agency (CalEPA) are considered acceptable for use. Should none of these agencies have available values, parties may use HBEL from other organizations/jurisdictions such as, but not limited to, provincial ministries of health and/or environment, provided a rationale is included for the selected value(s). For all substances of concern, no matter their origin, supporting documentation for the selected HBEL should be provided. Health Canada encourages readers to consult with provincial, territorial and municipal authorities, as appropriate, to determine or verify which standards exist for specific regions. The CCME's State of the Air website provides key information on air quality across Canada and links to provincial and territorial air quality resources.

4.1 HEALTH CANADA

Health Canada's primary role with respect to air pollution is to identify hazards posed to the Canadian population and to collaborate with others, often Environment and Climate Change Canada, to reduce the identified risks. Health Canada's scientists conduct, evaluate and remain current on domestic and international scientific research on the effects of air quality on human health.

Health Canada is typically asked to undertake reviews of IS or other documentation for a proposed project, subject to federal IA legislation. For example, under the IAA, Health Canada's primary role is to make available project-related specialist or expert information and knowledge in its possession. Health Canada's review of air quality assessments for IA processes is project-specific. Health Canada's expertise in this context focuses on assessing the risks to human health resulting from exposure to air pollutants—using health-based evaluation tools, standards, objectives, guidelines and toxicological reference values. Health Canada reviews the baseline conditions described (i.e., air quality in the existing environment) and the predicted project-related air pollutant concentrations for different assessment scenarios at locations where human receptors may be affected. Health Canada can comment on whether the assessment of effects of air quality on human health undertaken by the proponent was scientifically valid, and may request further information or rationale. Health Canada may make available additional information or knowledge when predicted air quality changes have the potential to affect human health. Health Canada may also comment on the adequacy of mitigation measures proposed to reduce project-related changes and/or health impacts. The Agency, review panels or others conducting the assessment will ultimately determine how the information or knowledge provided by Health Canada will be used in the IA process.

Health Canada does not possess the expertise to verify air quality modelling results and assumes that the assessment has used correct, accepted and/or validated methods. Health Canada relies on the expertise of Environment and Climate Change Canada in the areas of emissions, dispersion (i.e., environmental fate) and atmospheric modelling. Health Canada may also seek Environment and Climate Change Canada's advice on the adequacy of an IA's ambient air quality predictions. If Environment and Climate Change Canada notes errors and/or gaps in the modelling of air quality, revisions may be requested by the Agency, review panels or others to address the errors. If the revised results differ from the originally submitted results, the report needs to be resubmitted to Health Canada for review. Additionally, Health Canada does not currently have the expertise to address or evaluate the potential effects of odour.

4.2 PROVINCES AND TERRITORIES

In general, provinces/territories are responsible for controlling pollution emissions, including air pollutants, from industry and business operations. The provinces manage air pollutant emissions through regulations and their approach to granting (or issuing) permits that describe the allowable levels of emissions of various pollutants from a given facility, including emissions from associated mobile sources. Provinces may also develop or adopt ambient air quality standards or objectives, which are used to inform their processes for issuing pollution emission permits (e.g., using air quality modelling to predict how ambient air quality in a neighbouring community will be impacted by a facility's emissions and how the predicted pollution levels compare to the air quality standard) and other air quality management actions. In 2012, the Ministers of the Environment, with the exception of the Quebec Minister[4], agreed to begin implementing the Air Quality Management System (AQMS), which includes the ambient air quality standards as a key component. Those conducting IAs are encouraged to seek information as early as possible as to which provincial, territorial and/or municipal legislation and regulations concerning ambient air quality may apply to the project.

4.3 AIR QUALITY STANDARDS AND GUIDELINES

The *Canadian Environmental Protection Act*, 1999 (CEPA 1999) is the principal federal legislative tool governing environmental contaminants. It is administered jointly by Environment and Climate Change Canada and Health Canada. The CEPA 1999 enables the Minister of Environment and Climate Change and the Minister of Health to regulate substances and allows the federal government to assess air pollutants and provide targets that can be used in setting goals for reducing health and environmental risks from contaminants of potential concern (COPCs). Part 3 of CEPA allows the federal government to establish environmental standards, objectives and guidelines, including for ambient air quality. The federal government also has the authority to address air pollution caused by the transboundary flow of air pollutants (e.g., across the Canada-U.S. border) and to identify key air pollutants as toxic substances under CEPA 1999.

Under the auspices of the CCME, Health Canada and Environment and Climate Change Canada have been working with provincial/territorial governments and non-governmental stakeholders on the development of the AQMS, designed to be a comprehensive and national approach to improving air quality in Canada. A key element of the AQMS are the

[4] Although Québec supports the general objectives of AQMS, it will not implement the System since it includes federal industrial emission requirements that duplicate Québec's Regulation. However, Québec is collaborating with jurisdictions on developing other elements of the system, notably air zones and airsheds.

health and environment-based CAAQS and their associated management levels. These are benchmarks against which air quality is compared to as the basis for iterative improvements for air quality management across the country. In October 2012, the CCME endorsed CAAQS for $PM_{2.5}$ and ozone for 2015 and 2020. The federal government established these CAAQS as ambient air quality objectives on May 25 2013[5]. The CAAQS, which are to be achieved by 2015 and 2020, are more stringent than the previous Canada-wide Standards, which they replace. Additional CAAQS were endorsed by the CCME for sulphur dioxide (SO_2) in 2016, and nitrogen dioxide (NO_2) in 2017, which are to be achieved by 2020 and 2025. The federal government established these CAAQS as ambient air quality objectives under CEPA on October 28, 2017[6] for SO_2 and on December 9, 2017[7] for NO_2. These CAAQS for SO_2 and NO_2 replace their former National Ambient Air Quality Objectives (NAAQOs). More recently, Environment Ministers announced new ozone CAAQS for 2025[8]. The CAAQS will be periodically reviewed to reflect the latest science and health information. For more information on CAAQS, including the values and management levels along with information on achievement please visit the CCME' State of the Air website.

The AQMS includes the Air Zone Management Framework (AZMF), which provides guidance to jurisdictions on the level of monitoring, reporting and management actions to implement in air zones depending on the level of prevailing concentrations of air pollutants. The AZMF includes four air quality management categories, or levels, denoted by the colours green, yellow, orange and red. Each of these management levels is associated with a corresponding range of concentrations of air pollutants which were established during the CAAQS development process. Prevailing air quality in the red management level corresponds to exceedances of the CAAQS, while prevailing air quality in the green management level corresponds to "clean" air quality.

Key objectives of the AZMF are keeping clean areas clean (KCAC), supporting continuous improvement (CI) in air quality and preventing the CAAQS from being exceeded. Continuous improvement refers to remedial and preventative actions to reduce emissions from anthropogenic sources, toward the long-term goal of reducing overall ambient concentrations of pollutants. KCAC refers to preventative measures that are intended to avoid or minimize increases in overall ambient concentrations of pollutants in air zones that are assigned a green management level. The guiding principles of CI/KCAC are intended to ensure that air quality does not deteriorate but is maintained or improved to the extent practicable. Maintaining or improving air quality minimizes risk to human health and the environment for the benefit of current and future generations. By its very nature, the AZMF stipulates that the CAAQS are not pollute-up-to levels and that proactive actions should be taken to prevent CAAQS exceedances. Furthermore, most CAAQS are not fully protective since health effects have been observed below their numerical values.

Consult the CCME's website for up-to-date information on the AQMS and CAAQS: www.ccme.ca

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5 Canada Gazette Part 1, Volume 147, no 21, May 25, 2013. http://gazette.gc.ca/rp-pr/p1/2013/2013-05-25/pdf/g1-14721.pdf

6 Canada Gazette Part 1, Volume 151, no. 43, October 28, 2017. https://gazette.gc.ca/rp-pr/p1/2017/2017-10-28/pdf/g1-15143.pdf

7 Canada Gazette Part 1, Volume 151, no 49, December 9, 2017. http://gazette.gc.ca/rp-pr/p1/2017/2017-12-09/pdf/g1-15149.pdf

8 Canada Gazette Part 1, Volume 153, no 26, June 29, 2019. http://gazette.gc.ca/rp-pr/p1/2019/2019-06-29/pdf/g1-15326.pdf

5 COMMON AMBIENT AIR POLLUTANTS

5.1 AMBIENT AIR QUALITY AND HEALTH

There is consensus among international and national organizations (e.g., the WHO, the European Union, the International Agency for Research on Cancer [IARC], the US EPA and Health Canada) that air pollution has significant human health impacts. Causal associations have long shown that poor air quality results in respiratory and cardiovascular illnesses, hospitalizations and mortality. More recently, such associations have been demonstrated throughout the range of concentrations experienced by Canadians with the result that some air pollutants (such as $PM_{2.5}$, ozone and NO_2) are regarded at the population level as being non-threshold in their effects. The response of an individual to air pollutants depends on the type of pollutant to which a person is exposed, the degree of exposure and the individual's health status and a range of other factors. Harmful health outcomes attributable to air pollution can range from respiratory symptoms to premature death—encompassing acute irritation and respiratory problems, the development or worsening of existing respiratory and/or cardiovascular diseases, and cancer. These effects can result in higher medication use, increased visits to doctors or emergency rooms and more hospital admissions. Epidemiological studies that make use of administrative databases that track information such as mortality, hospital admissions and emergency room visits have been used to characterize population risk; these studies are now a common tool in assessing the health implications of air quality changes related to environmental pollutants. Based on such studies, there is a growing awareness that air pollutants at concentrations across Canada are associated with morbidity (incidence of disease) and mortality (Health Canada, 2021). The Global Burden of Disease Study recognizes outdoor air pollution in the form of fine particles as one of the top-ten global human health risk factors (GBD 2017 Risk Factor Collaborators, 2018), while IARC (2013, 2014) has identified air pollution as a whole, as well as component particles ($PM_{2.5}$, PM_{10} and diesel exhaust), as causes of cancer.

5.2 PARTICULATE MATTER

The general term "particulate matter" (PM) can be defined as particles (solid or liquid, or a mixture of both) less than 100 micrometres (µm) in diameter. Particles of 10 µm or less in diameter are referred to as PM_{10}. Particles of 2.5 µm or less in diameter are referred to as $PM_{2.5}$ or fine PM. Particles intermediate in size (i.e., $PM_{10-2.5}$) are generally known as the coarse fraction of PM_{10}. All three size designations (PM_{10}, $PM_{10-2.5}$ and $PM_{2.5}$) have been demonstrated to affect various aspects of human health, such as the respiratory and cardiovascular systems. The fine (smaller) particles pose a greater risk to human health, as they can be inhaled deeply into the lungs and into the blood. Despite the overlap between each of these size fractions (i.e., the PM_{10} size fraction includes the $PM_{2.5}$ size fraction), there is also variation in the deposition patterns within the lungs because of differences in the physical and chemical composition (WHO, 2003). Particulate matter can be primary or secondary in nature; primary particles are emitted directly from a source, while secondary particles form in the air during chemical and physical processes from precursors gases such as SO_2, NO_2 and volatile organic compounds (VOCs).

Health Canada (2022a) conducted an extensive review of the literature on the health effects of $PM_{2.5}$, succeeding two previous analyses on this subject (Environment Canada and Health Canada, 2012; Health Canada, 2013a). That latest assessment concluded that there were distinguishable effects for both short- and long-term exposures, and that the evidence, while highlighted by epidemiological studies of associations in the Canadian (and other) population for premature mortality and hospital admissions, was supported by evidence from controlled exposure studies using both animal and human models providing a clear causal chain at Canadian exposure levels. For instance, short-term (hours to days) exposure to $PM_{2.5}$ can cause serious heart and lung events like heart attacks, heart failure, stroke, asthma attacks and premature death. Effects also include increased emergency room visits and hospitalizations for cardiovascular and respiratory problems. Long-term (months to years) exposure to $PM_{2.5}$ can cause premature death, and can likely cause lung cancer, and heart and lung diseases. Exposure to $PM_{2.5}$ may also lead to neurological and developmental outcomes. Additionally, the evidence pointed to adverse effects that are indicative of non-threshold relationships at the population level. The WHO *Air Quality Guidelines* (2021) also provided an extensive review of the scientific literature describing the relationship between ambient PM and various health endpoints. These guidelines note that a threshold could not be identified below which no adverse effects on health occur but provide a series of interim targets and guidelines for both PM_{10} and $PM_{2.5}$ for 24-hour and annual periods. The CAAQS for PM also recognize that there is no population health threshold for human health effects; therefore, any increase in exposure will result in an incremental population risk (Environment Canada and Health Canada, 2012). Health Canada has concluded that the risk associated with $PM_{2.5}$ is higher than the health risks associated with coarse PM or total suspended particulates (TSP) and constitutes the bulk of the health impact associated with PM, though there may be effects resulting from exposure to particles in the 2.5 to 10 µm range. Total suspended particulates, while having no specific health effects beyond that of $PM_{2.5}$ and PM_{10}, can have soiling effects that may be of concern to communities, and may contribute to deposition of substances that have consequences for soil and country foods quality, and thus should be assessed.

Given there is no level of exposure below which there is no risk to population health, everyone's health can be affected by $PM_{2.5}$. Children, older adults, smokers, people carrying certain gene variants (e.g., antioxidant enzyme) and those with pre-existing cardiovascular and respiratory conditions (e.g., asthma) are at greater risk (Health Canada, 2022a). In addition, those engaged in greater levels of outdoor activity are more likely to be exposed for lengthier periods and are thus more vulnerable to the effects of PM.

Ultrafine particles (UFPs) refer to very small, usually reactive particles with a diameter smaller than 0.1 µm that achieve widespread deposition within the respiratory tract. Therefore, by definition, $PM_{2.5}$ (and PM_{10}) includes UFPs. The results of studies on UFPs are not entirely consistent, and the scientific literature in this field is evolving rapidly. Therefore, Health Canada does not currently make specific conclusions on the potential health effects of UFPs. Rather, Health Canada encourages their inclusion in an assessment of $PM_{2.5}$ and a discussion of the predicted levels in all air quality assessments.

Diesel exhaust is a mixture of gases, particles, and many different chemicals. Exposure to diesel exhaust can cause lung cancer, adverse respiratory effects, and is likely causal in the development of adverse cardiovascular and immunological outcomes (Health Canada, 2016c). Diesel exhaust is recognized as a human carcinogen by a number of international risk assessment organizations (Health Canada, WHO [IARC], US EPA and CalEPA). **Diesel particulate matter** is the particulate component of diesel exhaust and can be an important contributor to ambient $PM_{2.5}$ levels. It is also commonly used as a metric to reflect exposure to diesel exhaust.

5.3 GROUND-LEVEL OZONE

Ozone is a pollutant at ground-level (tropospheric ozone) while being of benefit in the stratosphere by attenuating UV radiation. Unlike most other pollutants, ozone is not directly emitted from any source in appreciable quantities. Rather, most ozone is formed through chemical processes in the atmosphere that act on precursor substances, especially nitrogen oxides (NO_X) and VOCs, which are emitted from various industrial, transportation and societal activities. The slower reacting methane and carbon monoxide (CO) also contribute to ozone formation, especially background ozone. Nevertheless, there are some natural sources of ozone precursors, and stratospheric ozone can occasionally intrude into the troposphere. As a result, ozone presents challenges in IAs, requiring complex modelling efforts on scales that are larger and not suitable with the structure of the project assessment. While quantitative analyses are preferred, a qualitative approach may be acceptable in evaluating the impact of precursor emissions on the formation of ozone, taking into account the processes specific to the region in question. Ozone has been conclusively determined to exert a range of adverse effects on human health at concentrations commonly found in Canada. Like PM, entry into the body is through the lungs, but unlike PM, it is not further absorbed into the body and thus most of its effects are confined to that organ and are largely respiratory in nature. There are indications that ozone can exert effects beyond the lung through physiological mechanisms, but to date effects on asthmatics and others with respiratory disease have formed the bulk of the adverse findings.

As for PM, ozone is regarded by Health Canada and other agencies as a substance without a threshold for effects at the population level. Health Canada (2013a) conducted an extensive review of the literature on the health effects of ground-level ozone, succeeding previous analysis on this subject (Health Canada and Environment Canada, 1999). That analysis concluded that ozone was causally associated with a number of adverse respiratory outcomes ranging from respiratory symptoms up to and including premature mortality. With regard to the timeframe for effects, it was concluded that while there were some indications of effects from long-term exposures, the bulk of the evidence related to effects from short-term exposures. Similar to PM, the evidence is highlighted by epidemiological studies of associations in the Canadian (and other) population for hospital admissions and premature mortality, bolstered by evidence from controlled exposure studies using both animal and human models. The WHO *Air Quality Guidelines* (2021) provide some interim targets and a guideline for short-term exposures to ozone.

Overall, scientific evidence indicates that ozone is associated with acute-exposure mortality and a range of (largely respiratory) human health endpoints, such as reduced pulmonary function, increased asthma exacerbation and respiratory symptoms leading to increased likelihood of physician visits and visits to hospitals (Health Canada, 2013a). The CAAQS for ozone were developed on the basis that there is no population health threshold for human health effects; therefore, any increase in exposure will result in an incremental population risk (Environment Canada and Health Canada, 2012).

The evidence base for ozone implicates those with pre-existing respiratory conditions as being more at-risk from exposure. In addition, those engaged in greater levels of outdoor activity are more likely to be exposed for lengthier periods and are thus more vulnerable to the effects of ozone exposure.

5.4 NITROGEN DIOXIDE

Nitrogen dioxide is a pollutant generally associated with transportation, but emitted from virtually all types of combustion activities. Nitrogen dioxide has been conclusively determined to exert a range of adverse effects on human health at concentrations commonly found in Canada. As for PM and ozone, entry into the body is through the lungs, with the main target for adverse effects being the respiratory system. There is an emerging body of evidence that indicates NO_2 could be linked to a much wider range of effects, though additional research and analysis is needed to properly characterize these effects.

As for PM and ozone, Health Canada regards NO_2 as a substance without a threshold for effects at the population level. Health Canada (2016a) conducted an extensive review of the literature on the health effects of NO_2. Evidence developed in that assessment indicates that NO_2 is causally associated with acute-exposure mortality and several respiratory human health endpoints. In addition, long-term exposure to NO_2 is associated with the development of adverse respiratory conditions, supporting the development of both acute- and chronic-term air quality objectives. The WHO *Air Quality Guidelines* (2021) set guidelines for both short- and long-term exposures to this pollutant. The CAAQS for NO_2 were developed on the basis that, for both short- and long-term effects, there is no population health threshold for human health effects; therefore, any increase in exposure will result in an incremental population risk.

The evidence for NO_2 implicates those with pre-existing respiratory conditions as being more at-risk from exposure. In addition, those engaged in greater levels of outdoor activity are more likely to be exposed for lengthier periods and are thus more vulnerable to the effects of exposure.

5.5 SULPHUR DIOXIDE

Sulphur dioxide is a pollutant generally formed in combustion and industrial processes. It was widespread in the past but is now much reduced due to regulations on the sulphur content in fuels. Very high concentrations were largely associated with point sources and can still be found in Canada in association with such sources (e.g., close to some types of industrial facilities and in areas of oil and gas extraction). As for PM, ozone and NO_2, entry into the body is through the lungs, and its adverse effects appear confined to the respiratory system, acting as an irritant and interfering with some basic pulmonary functions.

Unlike the other pollutants for which CAAQS have been developed, it has been concluded that SO_2 may have a threshold for effects. Health Canada (2016b) conducted an extensive review of the literature on the health effects of SO_2 in support of the development of a CAAQS. Evidence developed in that assessment indicates that SO_2 is causally associated with acute-exposure morbidity for respiratory endpoints. The WHO *Air Quality Guidelines* (2021) set guidelines for 24-hour and 10-minute periods, reflecting the impact of short-term spikes in concentration on those with pre-existing respiratory conditions. Evidence to date indicates that the primary concern with SO_2 exposure is associated with the exacerbation of respiratory conditions such as asthma. Effects of long-term exposure are not expected at most current concentrations in Canada (Health Canada, 2016b).

The acute-exposure CAAQS for SO_2 were developed on the basis that this pollutant has an effect on those with pre-existing respiratory disease, but that there is likely to be a threshold for effects based on results from controlled human exposure studies. It is important to note that the SO_2 CAAQS (for both 2020 and 2025) reflect management targets and do not represent a "no-effect" level, i.e., there are effects at and below the level of the CAAQS. The likely threshold aspect of SO_2 is reflected in the green management level for the 1-hour CAAQS and, as for the other CAAQS pollutants, should be referenced in assessments. Those with asthma are regarded as a sensitive population for the effects of this pollutant. It is important to note that there is a long-term (annual) CAAQS for SO_2 based on environmental effects.

5.6 SECONDARY POLLUTANTS

Pollutants such as ground-level ozone and secondary $PM_{2.5}$ are formed in the atmosphere through the reaction of gaseous precursors; in the case of ozone, the presence of sunlight is required for these reactions to occur. Project-related emissions may contribute to secondary pollutant formation. Including predicted concentrations of secondary pollutants from project-related emissions in an air quality assessment provides a more comprehensive estimate of project-related effects; a qualitative discussion of precursors and secondary pollutant formation (especially ozone and secondary $PM_{2.5}$) is helpful in the absence of a quantitative assessment. Secondary pollutants may be important elements of an air quality assessment, especially when the secondary pollutant precursors (e.g., NO_X, ammonia [NH_3], SO_2, VOCs) are emitted from project activities. Particulate matter and ozone precursor pollutants need to be managed—both in terms of mitigating their own associated health risks and with regard to their contribution to the formation of secondary pollutants. As examples, ground-level ozone is formed from reactions involving NO_X and VOCs, and $PM_{2.5}$ is formed from complex reactions involving NO_X and VOCs and SO_2, as well as other substances, including NH_3.

In the case of $PM_{2.5}$, both primary and secondarily formed particles are regarded as being of equal toxicity and should be given equal consideration in any assessment. While it is expected that different sources of $PM_{2.5}$ (both primary and secondary) may have different toxicities, the scientific literature to date has not identified any source or characteristic of $PM_{2.5}$ that indicates that it should be assessed in a manner different from PM in general.

5.7 OTHER AMBIENT AIR POLLUTANTS

The use of equipment such as engines and generators, as well as other industrial processes, may lead to increased levels of PM and fuel combustion by-products (e.g., PM, NO_X, SO_2, CO, polycyclic aromatic hydrocarbons [PAHs], VOCs, metals, diesel exhaust/particles).

Polycyclic aromatic hydrocarbons are relatively non-volatile compounds of low solubility in water. These compounds are mostly adsorbed to PM, on which they are transported. Some PAHs are known to be carcinogenic (e.g., benzo[a]pyrene, or B[a]P) (Government of Canada, Environment Canada and Health Canada, 1994), as are some VOCs, such as acetaldehyde (Health Canada, 2017), formaldehyde (Health Canada, 2006), benzene (Health Canada, 2013b) and 1,3-butadiene (Environment Canada and Health Canada, 2000).

On-road and off-road vehicles and equipment are a key source of air pollutant emissions due to engine exhaust, evaporative emissions, tire wear and brake wear. Primary emissions include $PM_{2.5}$, UFPs, NO_2, CO, and VOCs, as well as other pollutants such as 1,3-butadiene, benzene, formaldehyde, acetaldehyde, acrolein, PAHs and metals. In addition, mobile source emissions contribute to the formation of secondary $PM_{2.5}$ and ozone in the atmosphere. Equipment used in large development projects can be a significant source of diesel engine exhaust. Diesel exhaust causes lung cancer and adverse respiratory effects, and is likely causal in the development of adverse cardiovascular and immunological outcomes (Health Canada, 2016c).

Many of the pollutants emitted from vehicles and equipment may be produced by other activities during construction and operation of a facility being evaluated in an IA. Additional air pollutants of concern beyond these include hydrogen sulphide, toxic metals (e.g., cadmium, lead, mercury, manganese, arsenic and nickel), polychlorinated biphenyls, dioxins and other persistent organic compounds.

Each project should strive to characterize all the substances potentially emitted by activities related to the project; identify appropriate HBEL; and provide as comprehensive an analysis of human health risks as possible, including analysis of important uncertainties in relation to exposure scenarios. Health Canada has derived a range of HBEL for many substances that should be used when evaluating human health risks in an air quality assessment. When Health Canada has not derived an HBEL for a substance of interest, values derived by the WHO, the US EPA, and the CalEPA, are considered acceptable for use. Should none of these agencies have available values, parties may use HBEL from other organizations/ jurisdictions, such as, but not limited to, provincial ministries of health and/or environment, provided a rationale is included for the selected value(s).

6 CONDUCTING AN AIR QUALITY ASSESSMENT FOR AN IMPACT ASSESSMENT

Section 6 provides general information about the assessment of project-related changes in ambient air quality in IAs and the potential impacts of these changes on human health. In general, an assessment begins by characterizing the project study area and identifying the people who may be impacted by changes to the environment due to the project. This includes considering the manner of exposure (e.g., inhalation). Next, the possible COPCs are identified and characterized. The existing environment is described, and the emissions and COPCs generated from the project activities are predicted using scenarios and modelling software. The predicted COPC concentrations should be analyzed in relation to appropriate air quality standards (e.g., CAAQS) or to the provincial and territorial standards if these are more stringent. After estimating the changes in air quality, the assessment should examine and consider the risks to human health due to these changes. Mitigation measures may be recommended to reduce the potential changes to air quality and impacts on human health. Measuring COPC levels during the project may assist with implementing or modifying mitigation measures.

6.1 DEFINE SPATIAL AND TEMPORAL BOUNDARIES

"Regardless of whether direct measurement or environmental modelling is used, both spatial and temporal variability need to be characterized. Spatial definition of the site is particularly important for the application of any microenvironment analysis. Temporal definition of the site is needed to address changes in chemical concentrations over time" (Health Canada, 2010).

Spatial boundaries identify and define the area(s) to be considered in the air quality assessment, including local and regional boundaries. The spatial boundaries of air quality effects are project-specific. Depending upon the amount and types of emissions, a project may affect air quality over a larger or smaller area. Often, a local study area (LSA) and a larger regional study area (RSA) are delineated for the assessment. Maps, diagrams and figures should be used to illustrate the boundaries and distances to project site(s). It is good practice to consider adjacent land use if the ecosystem is sensitive; if the land is or will be used for residential purposes; or if on-site contamination is migrating off-site and potentially impacting adjoining properties (Health Canada, 2010).

It is good practice to focus a discussion of potential human health impacts on locations where people could be most affected, such as those nearest to the emission sources or those who may be exposed to the highest concentrations of COPCs. The latter point is particularly important if there is high variability in air quality within the spatial boundary identified. However, care must be taken to identify those area(s) where there are people who may experience less exposure—but who are at potential greater risk as a result of higher sensitivity.. Note that Health Canada is generally interested in all exposures. Medium- and long-range transport is usually evaluated to the extent that it is bounded by the LSA and RSA. Health Canada encourages the evaluation and discussion of long-range transport, if it is important for a particular project.

This step of defining boundaries and identifying areas of particular concern, as described above, may be conducted in conjunction with the receptor identification step (Health Canada, 2010).

Temporal boundaries address the timing and lifespan of the potential impacts of the project, and may be described based on the various project phases (i.e., construction, operation, modification, decommissioning and abandonment). It is good practice to clearly determine the most appropriate temporal scales and descriptions of air quality data (e.g., seasonal or annual variation, 24-hour maximum and averaging times, such as 8-hour, 1-hour, etc.)—particularly when the IA will include a comparison of measured or predicted values for air pollutants to existing standards or guidelines. To enable the evaluation of the impacts of project-related air quality changes on human health over time, it is important that the temporal scales provided in both the modelling predictions and health effects assessment are consistent.

To better characterize the types of exposure experienced by humans near the project site(s), it is good practice to differentiate between acute and chronic exposures when describing potential air quality impacts on humans.

6.2 IDENTIFY AND CHARACTERIZE HUMAN RECEPTORS

The identification and description of all existing and reasonably foreseeable human receptors that may be affected by project-related air emissions, including individuals temporarily exposed during specific uses of the areas (e.g., cabins, recreational use, seasonal occupancy, transient use), are necessary for an assessment of potential air quality impacts on human health. Local information on the frequency of use of temporary habitations, as well as frequency of seasonal and transient use may be of help in better characterizing the health implications of a project, especially in areas where such use is a common cultural feature. It is good practice to select the most sensitive or exposed individuals in determining these potential impacts. Some individuals are more susceptible to contamination exposure due to the following:

- Physiology (e.g., newborns, children, pregnant or breastfeeding women and elderly people);
- Health status (e.g., immune-compromised persons, and persons suffering from heart disease, respiratory conditions or allergies);
- Behaviour (e.g., amount of time spent outdoors); and
- Lifestyle (e.g., smoking, Body Mass Index (BMI) and exercise status).

It is important to clearly describe the location and distance from the project site(s) of all potential human receptors (permanent, seasonal or temporary)—taking into consideration the different types of land uses (e.g., residential, recreational, industrial); and identifying all sensitive people (e.g., in schools, hospitals, retirement complexes or assisted care homes). Note that the types of residents and visitors in a particular area will depend on land use, and may include members of the general public and/or members of specific population subgroups (e.g., Indigenous peoples, campers, hunters).

In the context of IAs, consideration is generally given to human exposure to potential contaminants in ambient air, as specific information on indoor air pollution sources and concentration is often unknown. Furthermore, for key air pollutants (e.g., $PM_{2.5}$, NO_2), ambient concentrations are considered a good indication of total personal exposure in epidemiological studies that are used to derive HBEL. More detailed risk assessments may require that receptor exposure to COPCs be calculated by taking into consideration time spent outdoors versus indoors. As building envelopes are rarely completely airtight, infiltration of air pollution occurs at different rates. An acceptable approach for risk assessment purposes is to assume that receptors are exposed to the same COPC concentrations indoors as they are outside of the building.

To identify the human receptors that may be affected by project-induced air quality changes, it is useful to provide a map illustrating, through isopleths (contour lines showing constant concentration levels) or other means, the predicted pollutant concentrations for those COPCs approaching or exceeding appropriate guidelines and/or standards overlaid with the receptor locations in the LSA and RSA. Consider that the dispersion of substances into air can affect receptors that are either in close proximity to or at considerable distances from the source. Air pollutants can travel long distances (i.e., from meters to hundreds of kilometers) and affect communities and receptors even though they are far away from the initial source. If any humans or residences are omitted from the air quality assessment, an evidence-based rationale for their exclusion should be provided.

Note that occupational exposure and health issues are typically under provincial or territorial jurisdiction, but where project workers live on-site, they may be considered "general population" while they are off-duty for the purpose of the assessment.

6.3 DESCRIBE EXPOSURE PATHWAYS

Exposure to air pollutants, such as PM, gaseous chemicals or chemicals adsorbed to PM, occurs primarily via inhalation, which is the main pathway considered in an air quality assessment.

Another potential exposure pathway is the consumption of vegetation, dairy products, meat or game meat from crops or animals that have been exposed to elevated concentrations of airborne contaminants through air deposition onto produce, fodder and grazing crops. Health Canada possesses the expertise to review the predicted human health impacts of this mode of contamination, but does not have the ability to verify modelling results that are predictive of this exposure pathway (as discussed in Section 4.1). It is good practice to employ prediction models obtained from published or other sources that have received peer or regulatory endorsement. Modelling results may indicate that, over time, the chemical concentration of contaminants in environmental media may increase (e.g., accumulation over time in soils, bioaccumulation and bio-concentration) due to emissions of airborne contaminants.

6.4 IDENTIFY CONTAMINANTS OF POTENTIAL CONCERN

Contaminants of potential concern are chemicals whose concentration(s) may become elevated in ambient air as a result of project-related activities, and which have the potential for adverse health impacts based on documented scientific evidence or suspected causal relationships.

The COPCs to be characterized for a proposed project will be detailed in the TISG. It is good practice to include an inventory of all emissions and potential COPCs resulting from the proposed project in an air quality assessment. All sources should be considered, including project-related processes, on-site vehicle usage and fugitive emissions. All phases of the proposed project should also be considered (e.g., construction, operation, modification, decommissioning and abandonment). The inventory should include the following (as applicable):

- Common air pollutants, (i.e., sulphur oxides/SO_2, nitrogen oxides/NO_2, PM including total PM, PM_{10}, and $PM_{2.5}$, VOCs, CO, NH_3, ground-level ozone, and secondary PM);
- Air pollutants on the *List of Toxic Substances* in *Schedule 1* of CEPA 1999;
- Diesel exhaust/Diesel PM; and
- Other contaminants as appropriate (e.g., heavy metals and PAHs).

As discussed in Section 5, it has been concluded that PM, ozone and NO_2 are non-threshold substances, meaning that health effects may occur at any level of exposure. Health Canada has concluded that the majority of PM-associated risk comes with exposure to very fine particles, particularly $PM_{2.5}$ (Health Canada, 2013a; 2022a). IARC recently classified PM as carcinogenic to humans (IARC, 2013; 2014). Health Canada suggests that when assessing the potential health effects of PM, ozone and NO_2, there is acknowledgement that there is no threshold below which there is no adverse health effect. Therefore, health risks exist below the CAAQS and proposed mitigation measures should not be confined to meeting the standards, but should also be targeted towards reducing population exposure to air pollutants associated with the proposed project.13

Various sources of information can help identify COPCs that may be emitted from proposed projects. These sources include the following: the environmental impact statement (under the former Act, i.e., CEAA 2012) or the impact statement and TISG (under the IAA), risk assessments, and air modelling studies or monitoring data for other similar projects; Environment and Climate Change Canada's National Pollutant Release Inventory; the US EPA; and the Agency for Toxic Substances and Disease Registry.

6.5 ASSESSMENT SCENARIOS AND OTHER CONSIDERATIONS

As good practice, an air quality assessment includes information on baseline conditions and predicted increases in airborne concentrations of COPCs associated with the project, along with appropriate comparisons to applicable standards and guidelines, and discussions of potential impacts and risk to human health due to the predicted changes in air quality.

6.5.1 Assessment Scenarios

Health Canada encourages the inclusion of four assessment scenarios in the air quality assessment, namely: *i) baseline*; *ii) project alone*; *iii) baseline plus project*; and *iv) cumulative or future development,* as appropriate. These scenarios are described below. Additional "development or application" cases or scenarios may be assessed for comparative purposes. Assessment scenarios for *v) decommissioning or abandonment* phases may also be relevant.

i. Baseline Conditions (Pre-project or Base Case Scenario)

The existing baseline levels of air pollutants must be adequately described in order to establish the extent of possible air quality changes related to future project activities (and thus, the subsequent potential impacts on human health). Baseline conditions are the current levels of air pollutants in the RSA, including existing sources, and are usually reported in concentrations, with units of micrograms per cubic metre ($\mu g/m^3$) or parts per billion (ppb). Comparing predicted COPC concentrations for the project activities to this type of baseline provides information on the sole impact of the project (i.e., project alone scenario), and the project contributions to air quality; it does not, however, consider the predicted contributions of already-approved developments in the area.

In some project assessments, baseline conditions are reported as concentrations of air pollutants from baseline plus approved but not-yet-built developments. These baseline conditions have higher COPC concentrations than a baseline that excludes approved developments. Comparing predicted COPC concentrations for the project activities to this type of baseline does not present as clear a picture of the contributions of the proposed project alone; it may also contain additional uncertainties associated with the predicted emissions of the approved developments. However, the use of this baseline in the application/development scenario will yield predictions that are higher than the contributions of the project alone, and this may result in additional mitigation measures or more intensively applied mitigation measures to reduce the impacts of the project. It is good practice to clearly describe if the baseline conditions include—or exclude—approved but not-yet-built facilities or developments.

In areas where industrial activity is prevalent, the baseline concentrations of air pollutants may be elevated compared to surrounding undisturbed or less-developed areas. In these cases, it is important to discuss the effect of these higher baseline concentrations of air pollutants in the context of project activities during the construction, operation or decommissioning phases.

When describing the existing environment, it may be useful to use actual data available from air quality monitoring networks or stations, including regional or air zone air quality monitoring programs, and monitoring initiated by the proponent or other companies in the project area. Note that Environment and Climate Change Canada, as well as provinces and territories, collects air quality measurements across Canada through monitoring networks, although there may be limitations to the applicability of the data (e.g., the distance from the project site to monitors may be substantial). Ambient air quality data for specific monitoring stations can be requested from Environment and Climate Change Canada and may also be available from provincial authorities. Emissions data from local facilities reported to the National Pollutant Release Inventory may also be useful in characterizing the current study area. While not a preferred approach, should the proponent be unable to obtain local monitoring data to characterize air quality baseline conditions for the project, data from other monitoring stations located in similar environments may be used instead, provided a rationale is included explaining how these substitute data are representative of the air quality in the project area.

ii. Project Alone Scenario

Even if the predicted effects of a proposed project may be low, there will be some impacts. Therefore, it is good practice to report the anticipated project emissions in a project alone scenario (i.e., not added to the baseline concentrations). The project alone scenario provides a clear description of the project's contribution to regional air quality. These data may be predicted using air quality and atmospheric dispersion modelling software—or, provided appropriate justification exists, estimated using measurements obtained from other project operations of a similar type and scale and with comparable meteorological and geographical context. Health Canada relies on the expertise of Environment and Climate Change Canada in the areas of emissions, dispersion and atmospheric modelling.

It is important to report the emissions from the project alone, as in the following situations:

- In urban or near-urban areas;
- In those regions subject to continuing development; and
- When the assessment includes application scenarios that comprise existing and future facilities.

When discussing predicted concentrations for this scenario, the importance of the values for each project phase (e.g., what percentage of the project is construction versus operation?) should also be considered. For instance, a construction phase may last 1–2 years, producing types of emissions that would not be released during the project's operation phase.

iii. Baseline + Project Scenario (Application or Development Case)

It is good practice to report the development case as the combination of the baseline conditions and the predicted concentrations of COPCs associated with the project (i.e., the project alone scenario). This scenario is key to the determination of air quality impacts of a project, as it estimates the potential future air quality conditions that would exist if the project is approved and proceeds.

iv. Cumulative or Future Development Scenario(s) (Baseline + Project + Future Projects)

Cumulative effects are the environmental effects of the proposed project in combination with effects from existing and reasonably foreseeable future projects within the same area of influence. An assessment of cumulative effects is required under the IAA (refer to Section 7 of this document).

Cumulative effects for air quality may be assessed as one scenario, often called the cumulative or future development scenario. Typically, this scenario includes the baseline conditions and predicted changes in COPCs from the project—plus the predicted contributions of COPCs from facilities that are approved but not yet operating, and/or other proposed or likely developments within the study area. The IA may also assess additional future development or application case scenarios for comparative purposes, and to provide additional information on potential future ambient air quality. To model predicted changes in air quality, emissions data from existing projects can be combined with predicted emissions from reasonably foreseeable future projects (estimated from industry averages).

When considering a cumulative effects assessment for air quality, note that the evaluation of multiple sources of a COPC from the project (e.g., diesel PM from generators and truck-traffic emissions) is considered to be the project-specific scenario and does not constitute a cumulative effects assessment.

v. Project Decommissioning or Abandonment Scenario

If applicable to the project, anticipated changes in air quality due to decommissioning or abandonment of the project facilities should be considered and discussed in the air quality assessment. The COPCs to consider will depend on the specific post-project activities undertaken—but are likely to resemble those generated in the construction phase. Identify the duration of decommissioning activities, and the measures that may be incorporated to monitor and control PM and other emissions generated from heavy machinery during demolition. Special consideration is advised when decommissioning or abandonment activities of contaminated soils introduce additional COPCs to ambient air. If applicable, it is good practice to provide information related to monitoring and mitigation measures during the decommissioning phase to ensure acceptable air quality is maintained.

6.5.2 Considerations

It is good practice for the air quality assessment to consider the following points for all scenarios:

- Include a map clearly showing the study area(s) and receptor locations. For COPCs with concentrations predicted to approach or exceed guidelines and/or standards, include maps illustrating the predicted concentrations and the location of the human receptors.
- Provide an evidence-based rationale for the omission of any COPCs from the assessment. (Note that the absence of an applicable screening guideline is not a sound rationale for excluding a COPC from further assessment.)
- Provide the predicted or estimated COPC concentrations for the maximally exposed population, for the most sensitive receptors and at the point of maximum impingement.[9]
- Report data in concentrations (µg/m^3 or ppb) (see equations for converting units at the end of *APPENDIX B*) that are determined or predicted for time periods corresponding to the applicable health-based standards, guidelines or objectives (e.g., 30-minute, 1-hour, 8-hour, 24-hour and annual intervals). Health-based reference concentrations[10] (RfCs) for COPCs will provide guidance on the appropriate averaging times for COPC concentrations (e.g., if there is a 1-hour RfC, then 1-hour averaging of concentrations should be reported and compared).

[9] A point of impingement is a technical term used in dispersion modelling of air pollutants—it is the pollutant concentration measured when the plume from a source reaches the ground or a building. Maximum point of impingement concentrations are the maximum level projected by the air quality model. Point of impingement concentrations are used in provincial regulations of industrial sources (rather than top-of-stack levels).

[10] Reference Concentration: An estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious non-cancer health effects during a lifetime (US EPA).

- It is necessary to consider both **acute (short-term) and chronic (annual/long-term) exposures** for some COPCs. Annual average concentrations for COPCs with chronic health effects should be provided. For some COPCs capable of causing toxic effects following short-term exposures, average or maximum 24-hour values may not provide adequate information to address potential health risks. Consider SO_2, for example, where 10-minute, 1-hour, or in some cases 8-hour short-term exposures, are more relevant than 24-hour or long-term exposures in terms of toxicity and health effects.
- To enable a comparison of predicted data to health-based standards and guidelines, report air pollutant concentrations in $\mu g/m^3$ or ppb, rather than reporting only the emission rates, such as tonnes/year.
- While a comparison with the CAAQS can be used to inform on the impact of a project on air quality, CAAQS should not be used to determine the health impacts of a project, as these standards are not solely based on health. Other factors, such as environmental effects, historical trends and future projections of ambient concentrations, achievability and feasibility were considered in the derivation of the CAAQS.
- When benchmarking predicted air quality levels against the CAAQS or other standards/guidelines/targets, it is important to consider not just the numerical target but also other defining characteristics. For CAAQS, this includes the averaging time period and the statistical form (see Table B1 in *APPENDIX B*). For $PM_{2.5}$, NO_2 and SO_2, there are separate CAAQS aimed at reducing the effects of short-term and long-term exposure. The CAAQS are not a "pollute up-to" level and population health effects occur at levels below the CAAQS. For non-CAAQS substances, other aspects of the standards/guidelines require consideration (e.g., for carcinogens, the target concentration associated with an acceptable risk level).
- Ozone itself is rarely emitted from project activities, although its precursors often are. The effect of a proposed project on ground-level ozone levels should not be dismissed because the predicted change will be "very small." Ideally, the project's contribution to regional formation of ground-level of ozone will be modelled and included in assessments. If not, provide a discussion of the regional environment, for example, a description of ozone formation, and the regional emissions and conditions that influence its formation. Compare the predicted ozone levels against the CAAQS. As with $PM_{2.5}$ and NO_2, health effects of ozone exposure occur at all levels.
- Discuss the emission of precursors to urban smog and ground-level ozone (e.g., NO_2, SO_2, VOCs). If secondary pollutants (e.g., ground-level ozone and secondary-formed PM) are not being considered in an air quality assessment, include a thorough, evidence-based rationale for their exclusion. If a quantitative assessment is not possible, it is useful to include a qualitative assessment that analyzes the likely directional impact—based on precursor emissions and the local air quality regime.
- Reference the air quality management level for the project area, as stated in the latest air zone report by the province or territory, in addition to the CAAQS, during the IA process. A map of current air zones across the country is provided on the CCME's State of the Air website along with links to air zone reports published by the provinces and territories. Proponents may find the information contained in these reports helpful in the conduct of their assessments.

6.6 DETERMINE THE HUMAN HEALTH IMPACTS OF CHANGES TO AIR QUALITY

To assess the impact of a project on air quality, predicted concentrations for each assessment scenario should be compared to appropriate and relevant air quality guidelines and/or standards. Health Canada recommends that modelled predictions be compared to the most stringent federal, provincial or territorial air quality standards applicable to the given area. In some cases, although they are not based on health effects alone, the CAAQS will be the most stringent levels for key air pollutants, especially for longer-term projects with emissions after 2025.

The CAAQS are generally calculated for specific multi-year averages and for a particular statistical form so that extreme and unpredictable events do not drive risk management. Therefore, when comparing predicted COPC concentrations with the CAAQS, it is preferable to use the same metrics. For example, in the case of hourly NO_2 concentrations, the proponent should provide the 3-year average of the annual 98th percentile of the daily-maximum 1-hour average concentrations (see Table B1 in *APPENDIX B*). However, if the proponent is not able to provide data that would compare to a full CAAQS timeframe, Health Canada suggests using model results for at least one calendar year to allow for a basic comparison with the CAAQS statistical form. If predicted concentrations or levels of COPCs remain well below the CAAQS or applicable criteria or guidelines, then further assessment may not be necessary. However, it is important to identify and comment on the project's overall contribution of pollutants to the local area regardless of whether the predicted values are well below the standards or criteria. This is especially important in relation to pollutants for which CAAQS have been derived ($PM_{2.5}$, ozone, SO_2 and NO_2). While the CAAQS are the main reference point for air quality, analysis of local air quality in relation to the air zone management levels for each pollutant would provide additional context in evaluating the impact of a project.

For non-threshold contaminants, or when the predicted COPC concentrations approach or exceed applicable air quality guidelines and standards, it is suggested that modelled concentrations be compared to **health-based** air quality values, when available (e.g., WHO *Global Air Quality Guidelines*[11], Health Canada health-based air quality objectives[12]). The assessment should include a discussion of the potential impacts of these exceedances on human health.

Determination of the health impacts of project emissions should consider all existing and reasonably foreseeable human receptors that may be affected by project-related air emissions, including individuals temporarily exposed during specific uses of the areas (e.g., cabins, recreational use, seasonal occupancy, transient use). As noted in Subsection 6.2, information on the frequency of use of temporary habitations, as well as frequency of seasonal and transient use may be of help in better characterizing the health implications of a project, especially in areas where such use is a common cultural feature.

In some cases, it may be prudent to proceed to a further level of assessment—using a detailed quantitative human health risk assessment (HHRA).

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[11] World Health Organization. (2021). WHO global air quality guidelines: particulate matter ($PM_{2.5}$ and PM_{10}), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. https://apps.who.int/iris/handle/10665/345329. Licence: CC BY-NC-SA 3.0 IGO.

[12] Health Canada. (2023). Health-based air quality objectives (HBAQOs). https://www.canada.ca/en/health-canada/services/air-quality/outdoor-pollution-health/standards-objectives/health-based-air-quality-objectives.html

It is good practice to conduct a quantitative HHRA in the following situations:

- The assessment predicts that COPC values approach or exceed applicable guidelines or standards.
- The project contributes to local air pollutant levels (e.g., the project is the dominant source of pollutant "X" in the area).
- The project is proposed for a region that is already experiencing environmental pressures from other development projects.

Note that in some cases, contaminants bound to PM (e.g., metals) may pose unacceptable risk to human health at low levels of PM concentrations—making further assessment necessary to determine if an unacceptable risk may occur.

A detailed quantitative HHRA generally yields more refined conclusions of risk, especially for complex projects with various activities. An HHRA considers the hazards and risks of multiple COPCs, toxicities and exposure pathways, including country foods. In keeping with the precautionary principle, a quantitative HHRA should assess COPCs that are known as carcinogens or suspected carcinogens (i.e., where there may be limited information on carcinogenicity in humans, but strong evidence based on animal studies). The IARC provides information and classification on the carcinogenic risks of various substances.

For simultaneous exposure to multiple COPCs, risks should be assumed to be additive for the pollutants having a similar effect, target organ and mechanism of action.

6.6.1 Characterization of carcinogenicity for specific substances

Characterization of carcinogenicity of diesel exhaust. A discussion and quantitative evaluation of the health risks of diesel exhaust is recommended by Health Canada when diesel emissions are a key source of air pollution from a project. Diesel exhaust causes cancer and non-cancer adverse health effects (Health Canada, 2016c; IARC, 2014). When assessing non-cancer effects from diesel exhaust exposure, please refer to the guidance values found in Health Canada (2016c).

To characterize the carcinogenic risk of diesel exhaust from a project, the proponent can make use of information in Health Canada (2022b), which provides a quantitative assessment of the relationship between ambient $PM_{2.5}$ exposure and lung cancer risk. Specifically, this report quantifies the increase in risk of lung cancer mortality (over the baseline rate in the Canadian population) due to $PM_{2.5}$, based on Canadian studies of ambient exposure to $PM_{2.5}$ in the general population. The pooled risk estimate provided in the report, which combines hazard ratios of several cohort studies, is considered appropriate to characterize risks from diesel PM given the contribution of diesel exhaust to ambient $PM_{2.5}$ and that the carcinogenicity of diesel exhaust has generally been evaluated based on the respirable PM fraction (Health Canada, 2016c; IARC, 2014). Furthermore, this approach is considered appropriate to use in the context of IAs as it is based on Canadian studies. For guidance in applying the risk estimate from Health Canada (2022b), consult APPENDIX C.

In cases where a quantitative assessment is not deemed necessary because diesel sources associated with the project contribute only a limited amount of emissions, it is recommended that the proponent provide a robust qualitative assessment of the carcinogenic risk of diesel exhaust associated with the project. This should include different elements to ensure transparency:

i) identification of the main sources of diesel exhaust for the project and recognition of the relative importance of diesel exhaust as a source of air pollution for the project;

ii) recognition that diesel exhaust has been declared a human carcinogen by governments and international agencies including Health Canada, WHO (IARC), the US EPA and the CalEPA; and

iii) the rationale for not undertaking a quantitative analysis of diesel exhaust carcinogenic risk for the project.

Characterization of carcinogenicity of PAHs for non-diesel sources. Polycyclic aromatic hydrocarbons at any given site are likely to be a diverse compositional range of non-carcinogenic and carcinogenic PAHs of varying potency. It is recommended to assess the cancer risks of human exposures to all potentially carcinogenic PAHs in mixture rather than a single surrogate substance. A mixture analysis (weighted approach) allows for determining the cancer risks of PAHs based on B[a]P Total Potency Equivalents (TPE). Total Potency Equivalents is the ideal approach as risk levels for PAHs are based on toxicity of several components in mixture and not on a single surrogate substance (B[a]P).

6.7 MITIGATION

Mitigation aims to eliminate, reduce or control adverse environmental effects related to a project. Health Canada prefers that all projects attempt to minimize air emissions to the greatest extent possible, regardless of any upper limits referenced in the applicable criteria, guidelines or standards.

Health Canada views mitigation of negative impacts to air quality as important, especially in the following situations:

- The project contribution leads to a deterioration in air quality over existing levels.
- Exceedances or near-exceedances of air quality objectives and guidelines are anticipated.
- The project “load” or contribution to the local air quality is a large proportion of the criteria or guideline value.
- The project is proposed for a region that is already experiencing environmental pressures from other development projects.
- Potential human health impacts are predicted.

Health Canada encourages the use of all available mitigation measures that are technically and economically feasible to limit negative impacts to air quality. The best management activities outlined in *Best Practices for the Reduction of Air Emissions from Construction and Demolition Activities* (Cheminfo, 2005) can be implemented to mitigate air quality effects during the site preparation and construction phase.

Health Canada prefers that mitigation measures also be used in instances when project-related human health impacts are considered minor (in keeping with the AQMS principles of KCAC and CI). If a low-cost mitigation measure exists and its ability to reduce harmful air emissions is well established, Health Canada encourages the implementation of the measure. It is good practice to describe in the IA documentation the mitigation measures to be employed to address any exceedances or near-exceedances of guidelines. If possible, details of modelling studies, monitoring or past experience with a mitigation strategy should be included to outline the anticipated effectiveness of a specific measure. If substantial baseline air quality contamination exists at or near the project site(s), the potential for air quality contamination introduced by project-related activities may necessitate consideration of additional mitigation measures.

An **air quality management plan (AQMP),** often part of an environmental management plan for a project, may form the basis for mitigation measures. Ideally, this plan addresses the management of all potentially harmful emissions from project-related activities. Such a plan may be implemented during the various project phases, to ensure that potentially harmful air pollutants and possible adverse human health impacts are minimized. Air quality management plans often include measures to limit the frequency and duration of people's exposure to COPCs during all phases of the project.

Furthermore, the AQMP often includes adaptive management measures based on the monitoring program results. Adaptive management refers to the planned and systematic process for continuously improving environmental management practices. It provides flexibility to identify and implement new mitigation measures or modify existing ones during the life of a project.[13]

Air quality monitoring is used to ensure that air contaminant levels are within the IA predictions and/or applicable standards, while remaining as low as possible. To accomplish this, the results of the monitoring program should be reviewed periodically (both short and long-term monitoring data) to determine if unexpected trends are being observed and if applicable criteria are being met (see Section 6.8 for more information on monitoring).

The need for corrective actions for on-site emission management or implementation of additional control measures can be determined by comparing monitoring results to trigger levels. The objective of trigger levels is to serve as a signal for the implementation of additional mitigation measures to prevent the deterioration of air quality and exceeding applicable standards. The determination of project-specific trigger levels is thus not only informed by reference guideline values, but also by pre-project baseline concentrations and the analysis of local air quality in relation to the air zone management levels for each pollutant. However, should a decision be made to use the air zone management levels as a guide, it is important to note that when using the CAAQS, their specific statistical form (e.g., 3-year average) may not be appropriate for developing trigger levels for short-term exposure (see Section 6.6 for more information on appropriate comparison with the CAAQS). Other considerations such as public complaints, wind speed, visual observations can also trigger the implementation of mitigation measures.

[13] https://www.canada.ca/en/impact-assessment-agency/services/policy-guidance/adaptive-management-measures-under-canadian-environmental-assessment-act.html

Upon request from the Agency, a review panel or others conducting IAs, Health Canada may review an air quality management plan and provide information or knowledge on the proposed mitigation measures.

6.8 MONITORING

For some projects, air quality monitoring may be advisable to determine the accuracy of predictions; to help verify whether standards are being met; and to assist with implementing or modifying mitigation measures. The extent of monitoring will depend on the project activities, predicted health effects and predictions of COPCs approaching unacceptable concentrations. Monitoring activities may be part of a follow-up program as defined in the IAA.

Health Canada encourages the monitoring of air pollutants when the project is predicted to lead to exceedances or near-exceedances of air quality criteria, standards and/or guidance values, or to contribute significantly to the elevation of COPC levels above baseline concentrations. Monitoring is also advisable if there is a high degree of uncertainty regarding the project's effects on air quality.

The following questions may assist in determining if monitoring is appropriate:

- Is there significant public concern about the possibility of changes in air quality?
- Is there uncertainty about one or more predicted emissions/COPCs as a result of project activities (e.g., due to difficult modelling issues)?
- Is there potential for novel air pollutants to be released, emitted, mobilized or
- modified as a result of project activities?
- Are new technologies, substances and/or monitoring techniques being used for project activities?
- Have any exceedances been predicted for COPCs in any of the assessment scenarios?
- Are there especially sensitive receptors nearby (e.g., children or seniors)?

Health Canada may make available information or knowledge regarding monitoring plans upon request by the Agency, a review panel or others conducting an IA. In regards to monitoring activities, Health Canada prefers that continuous monitors be implemented or a representative number of samples be collected, during different seasons, at locations where potential receptors may be affected. Upon request, Health Canada may also make available information or knowledge on the siting of ambient monitoring stations for regions with an appreciable human presence (e.g., permanent residences, seasonal or temporary residences).

7 ASSESSMENT OF CUMULATIVE EFFECTS

Under subsection 22(1)(a)(ii) of the IAA, an IA must take into account "any cumulative effects that are likely to result from the designated project in combination with other physical activities that have been or will be carried out."

Assessing the cumulative effects of projects is a central element of the IA. The cumulative effects scenario represents the potential environmental effects of the existing baseline plus project scenario in combination with effects from reasonably foreseeable future projects within the same area of influence. Reasonably foreseeable future projects include those that are approved but not yet operating, and/or other proposed or likely developments within the potentially impacted area. The cumulative effects scenario provides an estimate of human health risks in the future when other facilities are also in operation.

Considerations for a cumulative effects scenario in an air quality assessment are discussed in Section 6.5 of this document. If the cumulative effects assessment identifies changes to ambient air quality that exceed project-only effects, Health Canada encourages that further monitoring and/or mitigation measures be considered.

For guidance on assessing cumulative effects, consult the Agency's website for up-to-date guidance materials at Canada.ca/IAAC.

8 FOLLOW-UP PROGRAMS

Under Section 2 of the IAA, a follow-up program is defined as a program for:

a) Verifying the accuracy of the IA of a designated project; and

b) Determining the effectiveness of any mitigation measures.

It may be appropriate to consider a follow-up program for air quality if one of the following applies (note: this is not a comprehensive list and is not a substitute for professional judgment):

- There is uncertainty about the modelling of air pollutant(s) emissions;
- There is uncertainty whether proposed mitigation measures will be effective (e.g., the use of novel technologies or complex systems); or
- The project is located near large population centres, therefore posing a greater potential for exposure and health effects.

Health Canada may make available expert health-related information or knowledge regarding a follow-up program upon request by the Agency, a review panel or others conducting the IA.

For further and up-to-date information on the need or requirements of follow-up programs, contact the Agency.

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APPENDIX A | AIR QUALITY ASSESSMENT CHECKLIST

This checklist can be used to verify that the main components of an air quality assessment have been completed. It is helpful to include this checklist with the IS (or equivalent document) to show where the components of the air quality assessment are located in the document. This is especially helpful if the components are located in more than one section of the document.

OVERALL		
✓	**Item**	
	1. Background concentrations of air pollutants and predicted values of COPCs are presented in concentrations (i.e., reported in µg/m^3 or ppb), not only as emission rates, to enable comparisons to appropriate and relevant air quality guidelines and/or standards.	
	2. All phases of the project activities are considered in the assessment (construction, operation, etc.).	
	3. Assumptions are clearly stated and justified (modelling of worst-case scenarios, etc.).	

DESCRIPTION OF BOUNDARIES, COPCs, ETC.		
✓	**Item**	**Section in IA**
	4. Spatial and temporal boundaries are clearly reported.	
	5. Potential human receptors, with particular attention to Indigenous peoples, are identified and characterized. Distances from the project site(s) to all potential human receptors within the area affected by the project are delineated (using maps if applicable), and different land uses are identified (residential, recreational, Indigenous, etc.).	
	6. All possible COPC emissions as result of project activities are identified.	
	7. Any COPCs not carried forward to assessment are identified and accompanied by a scientific rationale.	

SCENARIOS FOR THE ASSESSMENT		
✓	**Item**	**Section in IA**
	8. The assessment scenarios are clearly described and assumptions are stated, and include *i)* baseline, *ii)* project alone, *iii)* baseline plus project, *iv)* cumulative or future development, and *v)* decommissioning or abandonment.	
	9. Predictions are accompanied by map(s) showing the estimated COPC concentrations and the location of human receptors.	
	10. The assessment discusses the project's contribution to local air quality and considers the importance of the project phases (e.g., the portion of the project that consists of construction activities).	
	11. The assessment includes a discussion of ground-level ozone levels, and any project emissions that are precursors to formation of ozone and urban smog in the area affected by the project.	
	12. Predicted exceedances of air quality objectives/criteria/guidelines/ standards, and/or health-based reference concentrations are identified and their significance is discussed. It should include at least the maximum levels predicted; the number of exceedances of the applicable targets; the magnitude of the predicted exceedances; and other descriptive statistics that more fully describe the air quality scenarios under consideration.	

MITIGATION MEASURES, MONITORING ACTIVITIES AND FOLLOW-UP PLANS		
✓	**Item**	**Section in IA**
	13. The mitigation measures to be employed are described in sufficient detail, including any criteria for the implementation of mitigation.	
	14. The assessment includes a discussion of how the AQMS principles of KCAC and CI will be taken into account in designing mitigation measures, monitoring and follow-up activities.	
	15. The details or a description of monitoring activities (i.e., frequency and duration of monitoring activities, COPCs to be monitored) are provided.	
	16. A description of the air quality portion of the follow-up program is provided, if available.	

APPENDIX B | CANADIAN AMBIENT AIR QUALITY STANDARDS (CAAQS) AND NATIONAL AMBIENT AIR QUALITY OBJECTIVES (NAAQOs)

The values listed in the tables below are valid as of the date of publication of this document. In addition, you will find information and equations for converting units. Readers should consult the appropriate source(s) for the most up-to-date and current air quality criteria, standards, and/or objectives. Readers can also consult the CCME website for the latest updates and information on the implementation of the AQMS, including the CAAQS. The CCME's State of the Air website also provides information on CAAQS achievement by local air zone with links to provincial air zone reports where available.

The CAAQS for $PM_{2.5}$, ground-level ozone, SO_2 and NO_2 are listed in Table B1.

The NAAQOs are listed in Table B2.

Table B1. Canadian Ambient Air Quality Standards

Pollutant	Averaging time	Standard (numerical value)			Statistical form of the standard
		2015[1]	2020	2025	
Ozone*[2]	8-hour	63 ppb	62 ppb	60 ppb[5]	The 3-year average of the annual 4th highest of the daily- maximum 8-hour average concentrations.
Fine particulate matter ($PM_{2.5}$)[2]	24-hour (calendar day)	28 µg/m^3	27 µg/m^3		The 3-year average of the annual 98th percentile of the daily 24-hour average concentrations.
	Annual (calendar year)	10.0 µg/m^3	8.8 µg/m^3		The 3-year average of the annual average of all 1-hour concentrations.
Sulphur Dioxide (SO_2)[3]	1-hour		70 ppb	65 ppb	The 3-year average of the annual 99th percentile of the daily-maximum 1-hour average concentrations.
	Annual (calendar year)		5.0 ppb	4.0 ppb	The average over a single calendar year of all 1-hour average concentrations.
Nitrogen Dioxide (NO_2)[4]	1-hour		60 ppb	42 ppb	The 3-year average of the annual 98th percentile of the daily-maximum 1-hour average concentrations.
	Annual (calendar year)		17.0 ppb	12.0 ppb	The average over a single calendar year of all 1-hour average concentrations.

(1) This is the effective year. (2) Published in Canada Gazette Part 1, May 25, 2013. (3) Published in Canada Gazette Part 1, October 28, 2017. (4) Published in Canada Gazette Part 1, December 9, 2017. (5) Published in Canada Gazette Part 1, June 29, 2019.

* Not usually modelled but provided for information

ppb: parts per billion

µg/m^3: micrograms per metre cubed

Table B2. National Ambient Air Quality Objectives for Canada

Pollutant	Year	Averaging Time	Maximum Desirable Level	Maximum Acceptable Level	Maximum Tolerable Level
Carbon Monoxide (CO)	1996	8 hours	5 ppm	13 ppm	17 ppm
		1 hour	13 ppm	31 ppm	–
Total Suspended Particulates (TSP)	1989	Annual	60 µg/m^3	70 µg/m^3	–
		24 hours	–	120 µg/m^3	400 µg/m^3

Definitions and Equations for Converting Units (mg/m^3 to parts per million)

Milligram per cubic metre (mg/m^3): milligrams of gaseous pollutant per cubic metre of ambient air.

Part per million (ppm): one part per million (by volume) is equal to a volume of a given gas mixed in a million volumes of air.

Part per billion (ppb): one part per billion (by volume) is equal to a volume of a given gas mixed in a billion volumes of air.

Convert concentrations in **ppm to mg/m^3** using the following general equation:

$$Ymg/m^3 = (Xppm) \times (MW) / 24.45$$

Convert concentrations in **mg/m^3 to ppm** using the following general equation:

$$Xppm = (Ymg/m^3) \times (24.45) / (MW)$$

Where:

Ymg/m^3 is the concentration of an element or compound expressed in units of mg/m^3

Xppm is the concentration of an element or compound expressed in units of ppm

24.45 is a constant (unitless) representing the volume (litres) of a mole (gram molecular weight) of a gas or vapour when the pressure is at 1 atmosphere and the temperature is 25°C

MW is the molecular weight of the gaseous pollutant (element or compound) expressed in units of grams/mole. The molecular weight of an element (atomic weight) can be found in the periodic table of elements. The molecular weight of a compound is the sum of the atomic weights of each element comprising the compound.

APPENDIX C | Additional Lung Cancer Mortality from Diesel Exhaust Fine Particulate Matter ($PM_{2.5}$): Recommended Approach and Sample Calculation

Health Canada (2022b) provides a quantitative estimate of the risk of lung cancer associated with exposure to $PM_{2.5}$ in Canada. The pooled hazard ratio (HR) for lung cancer mortality in the Canadian population is 1.127 (95% CI: 1.085, 1.170) per 10 µg/m^3 increase in long-term exposure to ambient $PM_{2.5}$. The slope coefficient (β) for this relationship is 0.01196, as derived below:

$e^{(\beta \times 10\ \mu g/m^3)}$ = pooled hazard ratio per 10 µg/m^3

$e^{(\beta \times 10\ \mu g/m^3)}$ = 1.127

$\beta \times 10\ \mu g/m^3$ = ln 1.127

β = (ln 1.127) / (10 µg/m^3)

β = 0.01196

The additional lung cancer mortality (over the baseline rate) from diesel exhaust $PM_{2.5}$ emissions from a given project can be determined using the equation below, based on the attributable fraction or (HR-1)/HR (Greco et al. 2020):

$$ALCM = \left[\left(e^{\beta \cdot Exposure} - 1\right) \Big/ e^{\beta \cdot Exposure} \right] \cdot Baseline\ rate \cdot Years$$

ALCM = additional lung cancer mortality cases per 100,000 population

β = 0.01196 (slope coefficient from meta-analysis in Health Canada (2022b))

Exposure = estimated diesel exhaust $PM_{2.5}$ concentration from the project (µg/m^3), which includes diesel exhaust $PM_{2.5}$ from all project sources (does not include baseline diesel exhaust $PM_{2.5}$ exposure)

Baseline rate = 45.5 per 100,000 (current Canadian Age Standardized Mortality Rate (ASMR) for lung cancer from Canadian Cancer Society 2020); the Canadian baseline rate is appropriate as the slope coefficient was derived from Canada-wide studies and an updated ASMR of Canada (if available) would be appropriate for use in the calculation

Years = duration of project or project phase

Sample calculation:
Project estimates an exposure from relevant source(s) of 0.067 µg/m^3 over 50 years of operation.

$$ALCM = \left[\left(e^{\beta \cdot Exposure} - 1\right) \Big/ e^{\beta \cdot Exposure} \right] \cdot Baseline\ rate \cdot Years$$

$$ALCM = \left[\left(e^{0.01196 \cdot 0.067} - 1\right) \Big/ e^{0.01196 \cdot 0.067} \right] \cdot 45.5 \cdot 50$$

ALCM = 1.8 additional lung cancer mortality cases per 100,000

While this ALCM estimation provides valuable insight as to the potential lung cancer risk associated with project-related diesel particulate matter emissions, other variables (e.g., comparison of modelled concentrations of COPCs to applicable air quality objectives, guidelines, and standards; elevated PM or diesel baseline concentrations; presence of susceptible sub-populations in the vicinity of the project) must be taken into consideration to assess the full impact of the project.

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