Human Health Risk Assessment
151 Bristol Street, Guelph, Ontario

Submitted to: Mezcon Construction Limited
5524 Watson Road North
GUELPH, ON., N1H 6J1

April 2021
NovaTox Project 21-538

NovaTox Inc.
10 Crane Avenue, Unit B, Guelph, Ontario N1G 2R2
Tel 1.877.680.7256 • Fax 1.519.231.0130 • http://novatox.ca

CONTENTS

TABLES

FIGURES

APPENDICES

1. Introduction

NovaTox Inc. (NovaTox) was retained by Mezcon Construction Limited (Mezcon) to complete a risk assessment (RA) for the property located at 151 Bristol Street, Guelph, Ontario (the 'Site'). The Site location is shown on Figure 1.

The RA consisted of a human health risk assessment and is being completed to support the zoning and approval process through the City of Guelph. The RA is completed as a non-regulatory (i.e., due-diligence) submission. Specifically, the RA is designed to support an application to the City of Guelph for a proposed Zoning By-law Amendment, to obtain approval to rezone the lands to allow development of multiple new residential lots.

It is understood that the HHRA will not be used to support the filing of a Record of Site Condition (RSC) under O. Reg. 153/04 (as amended) under the *Environmental Protection Act*, and that the RA will not be submitted to the Ontario Ministry of Environment, Conservation and Parks (MECP) for review. Nevertheless, to facilitate future filing of an RSC for the Site, the RA has been prepared pursuant to O. Reg. 153/04 and has been structured according to the mandatory requirements for RA reports listed under Table 1, Schedule C, and Section 4 of the Regulation.

The specific objectives of the HHRA were to:

- Quantitatively or qualitatively assess the risk from exposure to contaminants of concern (COCs) in soil at the Site to the human receptors that may use the property assuming the Site is to remain as residential land use in the future;
- Qualitatively determine the risk associated with exposure to the COCs in on-Site soil to off-Site receptors in the vicinity of the Site;
- Develop effects-based values for COCs in soil at the Site; and
- Where unacceptable risks are identified to human receptors, propose risk management (RM) measures to mitigate risks associated with COCs present in soil at the Site.

To meet these objectives, the following HHRA approach was adopted and followed:

- A non-Regulatory (i.e., due-diligence) standard risk assessment (i.e., a risk assessment other than the alternative RA approaches identified in O. Reg. 153/04 Schedule C Part II, as amended) was employed for the Site.
- The Site is considered to be Residential, and will remain residential.

The HHRA consisted of identifying the COCs, based on historical evidence and comprehensive Site investigation activities that were completed by Bluewater Geosciences, followed by the identification of appropriate pathways and receptors based on the current and proposed future land use for the Site. The last stage of the RA consisted of developing effects-based values for all the COCs that were screened into the HHRA. Where risks to human receptors were identified, RM measures to ameliorate or eliminate risks were provided.

2. Property Information

The HHRA report relies on the following reports:

1. Bluewater Geosciences (2021a) Phase One Environmental Site Assessment, 151 Bristol Street, Guelph, Ontario. Prepared for Mezcon Construction Ltd. Prepared by Bluewater Geoscience Consultants Inc. Bluewater Project No. BG-767. January 2021.

2. Bluewater Geosciences (2021b) Phase 2 Environmental Site Assessment, 151 Bristol Street, Guelph, Ontario. Prepared for Mezcon Construction Ltd. Prepared by Bluewater Geoscience Consultants Inc. Bluewater Project No. BG-770. February 2021.

All property information in this section was obtained from Bluewater (2021a and 2021b),

2.1. Site Land Use

The Site is located in Guelph, Ontario, on the north side of Bristol Street, east of McGee Street and west of Yorkshire Street South. Emslie Street fronts the Site to the north, and is at a higher elevation compared to Bristol Street. The location and Site layout are shown in Figure 1.

The Site was originally (prior to records) used for agricultural/pastoral purposes. In the 1800s the Site was used as a stone quarry. In 1870 the quarry was reportedly filled in with limestone and mixed fill, and may also have been used as a neighbourhood dump site. In the early 1900s the Site transitioned to being used for residential purposes, and a wood frame house was built. In the 1950s, that original house was demolished and a new house (130 m^2 footprint; with a basement) and detached garage (60 m^2 footprint; slab-on-grade) were constructed. This house and garage remain at the Site but will also be demolished. The adjacent properties comprise a mix of single family and multi-unit residential developments, assumed to be originally constructed in approximately the early to mid-20th century.

2.2. Areas of Potential Environmental Concern

The entire Site is considered to be an Area of Potential Environmental Concern (APEC) due to the Potentially Contaminating Activities (PCAs) of (i) the reported placement of fill materials of unknown quality and (ii) the potential use of the Site as a neighbourhood dumping area.

Two more potential environmental concerns were identified although these do not influence the completion of the RA for the Site:

1. **Designated Substances inside the current structure**: Materials such as asbestos, lead, PCBs, and mercury could be present based on the date of construction (1950s) of the current structure. Bluewater was not able to inspect or verify their presence but state that if building materials are intact, undamaged, and in operating condition, they generally would not be considered to be a health and safety concern for the occupants, nor would they present a risk of significant environmental liability for the current use of the property. These materials will be disposed of accordingly once demolition of the building occurs.
2. **Soil movement**: If the Site is developed in a manner that requires soil to be excavated then a soil sampling and analysis plan may be required to determine the extent to which the soil can be re-used on-Site or must be disposed of off-Site. On-site and Excess Soil Management Regulations under O.Reg. 407/19 would be required to be followed.

2.3. Subsurface Investigation

Bluewater advanced six boreholes at the Site in February 2021. Boreholes encountered surficial materials (topsoil or fill), followed by generally coarse soil material (sand and gravel or mixed silty fill, which was noted to also include miscellaneous material such as topsoil, organics, coal, glass, slag, brick and concrete), followed by bedrock (at 1.05 to 1.35 m below grade, i.e., shallow at all locations). Groundwater was not encountered during the drilling of any of the six boreholes.

Bluewater collected six soil samples (one from each borehole) at the time of drilling. Samples were submitted to an accredited laboratory (ALS Laboratory Group, Waterloo, Ontario) for analysis of inorganics parameters, metals, petroleum hydrocarbon fractions 1 through 4 (PHC F1-F4), polycyclic aromatic hydrocarbons (PAHs), and volatile organic compounds (VOCs) including benzene, toluene, ethylbenzene and xylene (BTEX). The laboratory included a standard internal QA/QC program consisting of the analysis of replicates and surrogate recoveries. The laboratory also analyzed method blanks, matrix spikes, duplicates, and spiked blanks as part of their own internal QA/QC program. Based on a review of the field and laboratory QA/QC, there were no issues that would affect the quality of the laboratory data or the interpretation of the results. The laboratory Certificates of Analysis (CofA) and QA/QC data were provided in the Bluewater report.

2.4. Contaminants of Concern

Soil COCs were identified by comparing maximum measured concentrations to the generic Table 6 SCS applicable to the Site. The choice of SCS was based on the following considerations:

- The current land use is residential;
- The future land use is assumed to remain residential;
- The pH of surface soils is between 5 and 9, and of sub-surface soils is between 5 and 11;
- The soil texture is coarse;
- The Site does not include or is within 30 m of a water body;
- The Site does not include or is adjacent to any areas of natural significance;
- The Site does meet the O. Reg. 153/04 definition of a shallow soil property based on the overburden thickness;
- Risks to human receptors were modeled using reasonable estimates of the maximum chemical concentrations plus 20% to account for sampling variability.

Any chemical detected at the Site that exceeded its Table 6 SCS was considered to be a COC and was required to be assessed within the HHRA.

Soil COCs are summarized in Table 2-1 and include:

- **Metals and Inorganics**. The maximum concentration of eight metals was reported in BH-2 (west corner of the site), at a depth of 0.3 - 1.35 m below grade. Four of the metals (antimony, barium, cadmium, copper) are COCs only at BH-2. Three of the metals (arsenic, mercury, zinc) also exceed their Table 6 SCS at BH-4 (0 - 1.05 m below grade). One metal (lead) also exceeds its Table 6 SCS at both BH-4 and BH-6 (0 - 1.35 m below grade). Metals were non-detectable or otherwise below their Table 6 SCS in soil samples collected from BH-1, BH-3, and BH-5.
- **Polycyclic Aromatic Hydrocarbons (PAHs)**. The only location where PAHs (7 on total) were identified as exceeding their Table 6 SCS was BH-6 (south corner of the site), at a depth of 0 - 1.35 m below grade. The soil sample collected from BH-5 had detectable concentrations of some PAHs but they were all below Table 6 SCS. PAHs were non-detectable in soil samples collected from BH-1 and BH-3. (*Note: the contribution to total risk from 6 other PAHs will also be assessed even though they are not individually identified as COCs; explained in latter sections of the HHRA*).

Table 2-1: Identification of Contaminants of Concern in Soil

Parameter	Maximum concentration (µg/g)	Table 6 SCS [a] (µg/g)	COC	Rationale
Metals				
Antimony	41.7	7.5	**Yes**	**Max. > Table 6 SCS**
Arsenic	54.4	18	**Yes**	**Max. > Table 6 SCS**
Barium	733	390	**Yes**	**Max. > Table 6 SCS**
Cadmium	3.9	1.2	**Yes**	**Max. > Table 6 SCS**

Parameter	Maximum concentration (µg/g)	Table 6 SCS [a] (µg/g)	COC	Rationale
Copper	251	140	**Yes**	**Max. > Table 6 SCS**
Lead	871	120	**Yes**	**Max. > Table 6 SCS**
Mercury	1.14	0.27	**Yes**	**Max. > Table 6 SCS**
Zinc	2,610	340	**Yes**	**Max. > Table 6 SCS**
PAHs				
Acenaphthene	<0.05	7.9	No	RDL < Table 6 SCS
Acenaphthylene	0.274	0.15	**Yes**	**Max. > Table 6 SCS**
Anthracene	0.138	0.67	No	Max. < Table 6 SCS
Benz[a]anthracene	0.888	0.5	**Yes**	**Max. > Table 6 SCS**
Benzo[a]pyrene	1.08	0.3	**Yes**	**Max. > Table 6 SCS**
Benzo[b]fluoranthene	1.37	0.78	**Yes**	**Max. > Table 6 SCS**
Benzo[ghi]perylene	0.929	6.6	No	Max. < Table 6 SCS
Benzo[k]fluoranthene	0.386	0.78	No	Max. < Table 6 SCS
Chrysene	0.839	7	No	Max. < Table 6 SCS
Dibenz[a h]anthracene	0.17	0.1	**Yes**	**Max. > Table 6 SCS**
Fluoranthene	1.41	0.69	**Yes**	**Max. > Table 6 SCS**
Indeno[1 2 3-cd]pyrene	0.766	0.38	**Yes**	**Max. > Table 6 SCS**
Pyrene	1.43	78	No	Max. < Table 6 SCS

[a]Table 6 SCS are the same as Table 2 SCS for soil.

3. Human Health Risk Assessment (HHRA)

Risk is assessed using methodology developed by the Ontario Ministry of the Environment, Conservation and Parks (MECP) and other health and environment authorities in Canada (e.g., Health Canada) and internationally (e.g., U.S. EPA). The process follows a step-wise approach that identifies, characterizes, and integrates these elements of risk. Specific requirements for risk assessment in Ontario are provided in Ontario Regulation 153/04, as amended, under Ontario's *Environmental Protection Act* (RSO 1990, Chapter E19). Mandatory reporting requirements are listed in Table 1, Schedule C, and Section 4 of the Regulation. Additional best practice guidelines are found in the Ministry's Procedures Document ('*Procedures for Use of Risk Assessment under Part XV.1 of the Environmental Protection Act*; October 2005; Ontario MOE, 2005).

NovaTox notes that this RA is not being submitted for MECP review. However, the preferred MECP format was followed to ensure comprehensiveness of the report.

3.1. Problem Formulation

The first step in HHRA is referred to as the problem formulation; it identifies the human receptors at the Site and the potential pathways by which they could be exposed to COCs (summarized in a conceptual site model (CSM; Section 3.1.1) and specifies the objectives of the HHRA (Section 3.1.2).

3.1.1. Human Health Conceptual Site Model

The human health CSM provides an integrated representation of how all environmental media and all human receptors at a site are connected with one another. The CSM was developed in accordance with O. Reg. 153/04 (as amended) Schedule C, Part I, Clause 3(8)(b), and summarizes (i) the primary environmental media that serve as sources of COCs, (ii) the secondary environmental media that contain COCs as a result of release mechanisms and contaminant fate-and-transport pathways, (iii) the human receptors located on, in, and off the RA property (including the critical receptor that will form the basis of the human health effects-based values), (iv) the receptor exposure points (i.e., environmental exposure media such as soil, water, and air), and (v) the routes of exposure (i.e., biological routes such as ingestion, dermal contact, and inhalation by which receptors could potentially take up COCs).

The human health CSM is illustrated in Figure 2 (without risk management measures) and Figure 3 (after implementation of risk management measures).

3.1.2. Risk Assessment Objectives

3.1.2.1. Objectives of the HHRA

The objectives of the HHRA were to (i) assess health risks for human receptors that may be exposed to contaminated media at the Site, and (ii) establish human health-based values for COCs at the Site.

Additional information required by O. Reg. 153/04 (as amended) Schedule C, Table 1 is provided below.

(a) Property Use

The current and future use of the property is classified as *Residential*.

(b) Receptors and Exposure Pathways

Receptors that are quantitatively assessed in the HHRA include (i) residents, (ii) outdoor workers, and (iii) construction workers. Receptors that are qualitatively assessed include residential visitors. Receptors are discussed in detail in Section 3.2.1.

Exposure pathways that are assessed in the HHRA include soil contact pathways (dermal contact, incidental ingestion, particulate inhalation-followed-by-coughing/ingestion) and soil inhalation pathways (particulates inhaled-and-retained-in-the-lungs). Exposure pathways are discussed in detail in Section 3.2.2.

(c) Determination of Quantitative vs Qualitative Assessment of Risk

Contaminants in soil at the site that could potentially pose a risk to human health were identified in Section 2 by screening the maximum detected concentration of each parameter against its respective SCS. Each parameter that was detected at least once at a concentration exceeding its SCS was identified as a COC and was assessed with regard to its potential to pose a human health risk. However, not all COCs or exposure pathways require quantitative assessment to determine whether or not they pose a human health risk; depending on the component values used to derive the SCS, some COCs and exposure pathways can be assessed qualitatively.

COCs and exposure pathways requiring quantitative assessment were identified by screening the ‘reasonable estimated maximum’ (REM) concentration of each COC against its respective human health-based component value that factored into the derivation of the SCS. The REM represents the reasonable upper limit of maximum Site concentrations and is calculated as the measured maximum concentration plus 20% to account for variability in sampling and/or analysis. The use of the REM ensures that the assessment of potential health risks is conservative.

The determination of soil COCs requiring quantitative assessment *via the HHRA exposure pathways standardized by the MECP* (i.e., direct oral/dermal contact with soil; soil inhalation pathways) is provided below in Section 3.1.2.4.

All quantitative aspects of this HHRA are provided in Appendix B, which is separated into Parts B1 (inputs), B2 (equations), B3 (output/calculations).

(d) Approach Used for the HHRA

A non-regulatory Risk Assessment other than those identified in O. Reg. 153/04 as amended, Schedule C, Part II was used.

3.1.2.2. Ability of Data to Meet Objectives of the HHRA

(a) Data Quality Objectives as Specified in the Sampling Program Reports

The data used for the RA are summarized in Appendix A.

All laboratory analysis completed in the Phase Two ESA were completed at an accredited laboratory. AGAT Laboratories is accredited to ISO/IEC 17025 by the Canadian Association for Laboratory Accreditation Inc. (CALA) and/or Standards Council of Canada (SCC) for specific tests listed on the scope of accreditation. AGAT Laboratories (Mississauga) is also accredited by the Canadian Association for Laboratory Accreditation Inc.

All of the certificates of analysis documented in the Phase Two ESA received (as per sub-Section 47(2)(b); i.e., provision of lab C of As) are deemed to comply with sub-Section 47(3), and a certificate of analysis was received for each sample submitted. The lab C of As are attached in the Phase Two ESA report.

(b) Other Relevant Information

Overall, the QA/QC program did not indicate any potential problems with data quality, and demonstrates that the data is useful, appropriate, and accurate for use in determining whether the site meet the applicable SCS, and in meeting the overall objectives of the RA investigation. On this basis overall, it is the professional opinion of the risk assessor (a qualified person; QP_{RA}) that adequate soil data have been obtained from the site for the purpose of enabling the completion of the HHRA component of the RA. The data are sufficient for thorough characterization of the COCs and of the physical characteristics that may govern the potential exposure pathways. No data quality issues were identified that would significantly affect the completion of the HHRA or the ability to draw inferences about overall risks to human health at the Site.

3.1.2.3. Variability and Uncertainty in the Data

(a) How Data Variability and Uncertainty Affected Setting of HHRA Objectives

To account for potential sampling variability, the maximum plus 20% of the concentration of the COC was used in the quantitative RA investigation.

(b) How Data Variability and Uncertainty Affected Ability to Meet HHRA Objectives

Note that to ensure that a conservative assessment of potential health concerns for human and ecological receptors is evaluated, the RA has considered potential analytical variance as a result of the sampling programs completed above. On this basis, we have developed ‘reasonable estimated maximum’ (REM) estimates for each parameter screened in to the RA that are used to assess the maximum measured concentration in addition to consideration of analytical variability. The REM estimate is represented by the maximum concentration plus 20% to account for sampling variability. The REM (maximum plus 20%) has been applied for all COCs that are qualitatively and quantitatively evaluated in the HHRA component.

3.1.2.4. Determination of Quantitative vs Qualitative Assessment of Risk for Soil COCs (Standardized MECP Exposure Pathways)

A total of 15 COCs were identified in soil by comparing maximum-detected concentrations to MECP Table 6 SCS. This section summarizes the secondary component value screening that was undertaken to determine which soil COCs required *quantitative* human health assessment. The component value screening is shown in Table 3-1 (also Appendix B1(a)) and can be summarized as follows:

- Of the 15 soil COCs, 9 were identified as requiring quantitative assessment (8/9 by contact pathways; 1/9 by inhalation pathways), and the remaining 6 were identified as being able to be assessed qualitatively.
- Lead typically cannot be quantitatively as its oral TRV is considered to be outdated (the human health component value for lead of 120 µg/g is not risk-based but is the Ontario background soil concentration). For the purposes of this HHRA, NovaTox used a TRV that is considered by Health Canada to be acceptable for federal RAs (discussed further in the Toxicity Assessment).

Table 3-1: Screening of Soil COCs for Quantitative Evaluation in HHRA

			Contact			Inhalation		
COC	Max. conc. (µg/g)	REM conc. (µg/g)	S1 (µg/g)	S2 (µg/g)	S3 (µg/g)	Resid. S-IA (µg/g)	S-OA (µg/g)	Assessment
Antimony	41.7	50.0	***7.5***	63	63	–	–	***Contact***
Arsenic	54.4	65.3	***0.95***	***1.3***	***47***	–	–	***Contact***
Barium	733	880	3,800	32,000	8,600	–	–	Qual.
Cadmium	3.9	4.68	***0.69***	7.9	7.9	–	–	***Contact***
Copper	251	301	600	5,600	5,600	–	–	Qual.
Lead	871	1,045	***120***	***120***	***120***	–	–	Qual.
Mercury	1.14	1.37	9.8	67	670	***0.25***	36	***Inhalation***
Zinc	2,610	3,132	5,600	47,000	47,000	–	–	Qual.
Acenaphthylene	0.274	0.33	7.8	9.6	360	0.45	96	Qual.
Benz[a]anthracene	0.888	1.07	***0.78***	***0.96***	36	65	330	***Contact***
Benzo[a]pyrene	1.08	1.30	***0.078***	***0.096***	3.6	820	170	***Contact***
Benzo[b]fluoranthene	1.37	1.64	***0.78***	***0.96***	36	5,500	2,000	***Contact***
Dibenz[a h]anthracene	0.17	0.20	***0.078***	***0.096***	3.6	33,000	430	***Contact***
Fluoranthene	1.41	1.69	7.8	9.6	360	250	2,500	Qual.
Indeno[1 2 3-cd]pyrene	0.766	0.92	***0.78***	0.96	36	46,000	4,000	***Contact***

Notes:
1. Contact indicates contact pathways were identified as requiring quantitative assessment; assessment will include incidental ingestion of soil, dermal contact with soil, and inhalation of soil particulates that are coughed and ingested.
2. Inhalation indicates inhalation pathways were identified as requiring quantitative assessment; assessment will include inhalation of vapours and inhalation of soil particulates that are retained in the lungs; risk will also be assessed for receptors inhaling vapours in trench air (component values are not available for this pathway).
3. Qual. indicates qualitative assessment only.
4. Refer to Appendix B1(a) for component values related to odour and leaching, and for free-phase threshold.

– indicates no value available (e.g., non-volatile COCs do not have inhalation component values; other selected COCs lack component values).

Bold/italic – component value exceeded by REM concentration.

3.2. Exposure Assessment

The exposure assessment step characterizes and quantifies the extent to which people could actually be exposed to COCs at the Site. Receptors that were identified in the CSM are described in detail in Section 3.2.1 with regard to biological characteristics (e.g., body weight, skin surface areas, rates of ingestion and inhalation, life expectancy) and behavioural characteristics (e.g., time spent at the site). Exposure pathways that were identified in the CSM are described in detail in Section 3.2.2 with regard to which pathways are complete or incomplete for each receptor. Receptor and exposure pathway information is integrated in Section 3.2.3 to quantitatively estimate the amount of COC to which each receptor is exposed (expressed on a dose basis for ingestion and dermal exposures, or a concentration basis for inhalation exposures). Finally, uncertainties related to the exposure assessment are discussed.

We note that exposure to polycyclic aromatic hydrocarbons (PAHs) can cause both non-carcinogenic and carcinogenic effects. Non-carcinogenic risks are assessed individually for each PAH identified as a COC. However, carcinogenic risks must be assessed by considering all 13 PAHs that are classified as carcinogens by MECP, regardless of how many individual carcinogenic PAHs were screened in as COCs. This is because the 13 carcinogenic PAHs have a common mode of action and display additive carcinogenicity. Cancer risks are assessed by considering the potency of each PAH relative to benzo[a]pyrene, which is the most well-characterized of the PAHs. The relative potency (expressed as a unitless fraction called a Toxic Equivalence Factor or TEF) can be accounted for in the toxicity assessment step or the exposure assessment step of the HHRA. This RA accounted for the relative potency of each PAH in the exposure assessment, by calculating a benzo[a]pyrene equivalent concentration for each individual carcinogenic PAH, and then summing these to determine the level of total carcinogenic PAHs. The calculations for PAHs in soil are provided in Appendix B1a.

3.2.1. Receptor Characteristics

The human health CSM identified the following human receptors that have the potential to experience health risks at the Site: residents (Section 3.2.1.1), residential visitors (Section 3.2.1.2), outdoor workers (Section 3.2.1.3), and construction workers (Section 3.2.1.4). Off-Site receptors are discussed in Section 3.2.1.5.

3.2.1.1. Residents

Residents represent people of all age groups who may live at the Site in the future. MECP provides biological and behavioural characteristics for five periods of a person's life as a resident: infants (birth to six months of age), toddlers (six months to five years), children (5–12 years), teenagers (13–19 years) and adults (20–76 years). During one's toddler years is typically when one would be expected to be most at risk from exposure to chemical contaminants, due both to biology/physiology (the toddler has higher intake rates of exposure media than other ages on a per-unit-body-mass basis) and to behaviour (higher mobility than an infant, and a higher rate of hand-to-mouth behaviour than the older age categories, combines to give the toddler more opportunity to be exposed to COCs in the environment). For this reason, the toddler is used as a model receptor and results obtained for the toddler can be considered indicative of non-carcinogenic risk results for other age categories (i.e., if the toddler is not at risk then there is high confidence no other age category is at risk). Risks from carcinogenic COCs are assessed by assuming that a person could be exposed for their entire life, and so considers exposure over the entire 76 year average lifespan. Resident characteristics used in this HHRA are summarized in Table 3-2. As shown, default values recommended by MECP were used for the following:

- body weight;
- skin surface area;
- soil adherence;
- soil ingestion rate; and
- averaging periods.

MECP does not provide a recommended default inhalation rate for residents. NovaTox used values for toddlers and adults from Health Canada (2012) guidance for Preliminary Quantitative Risk Assessment (PQRA; Health Canada 2012).

Residents may be exposed to soil via direct pathways.

The exposure pathways that were assessed are also summarized in the CSM (Figure 2).

Table 3-2: Resident Characteristics and Exposure Parameters

Characteristic		Units	Resident			
			Toddler	Pregnant female [a]	Full-life composite [b]	Reference
Body weight		kg	16.5	63.1	62.44	Table 2-6 of MOE (2011)
Skin	Surface area	cm^2	1,745	3,988	3,977	Table 2-7 of MOE (2011)
	Soil adherence factor	mg/cm^2-day	0.2	0.07	0.09	Table 2-8 of MOE (2011)
Intake rates	Soil ingestion	mg/day	200	50	58.75	Table 2-5 of MOE (2011)
	Inhalation	m^3/hour	0.346	0.692	0.655	Health Canada (2012) PQRA Guidance
Time indoors		hours/day	24	24	22.5	Table 2-16 of MOE (2011)
		days/year	350	365	350	Table 2-14 and Table 2-15 of MOE (2011)
Time outdoors		hours/day	24	24	22.5	Table 2-16 of MOE (2011)
		days/year	273	365	273	Table 2-13 and Table 2-15 of MOE (2011)
Exposure duration		years	4.5	56	76	Table 2-10 of MOE (2011)
Averaging period	Non-carcinogens	years	4.5	56	76	Table 2-11 of MOE (2011)
	Carcinogens	years	76	76	76	Table 2-12 of MOE (2011)

[a] Pregnant female characteristics required for assessment of developmental toxicants.
[b] Values for composite receptor calculated based on pro-rating all other life stages.
na – not applicable (incomplete exposure pathway for this receptor).

3.2.1.2. Residential Visitors

Residential visitors represent people of all age groups who may visit future residential units at the Site. Their characteristics are summarized in Table 3-3. As shown, default values recommended by MECP were used for the following:

- body weight;
- exposure duration; and
- averaging periods.

The greatest potential source of exposure to COCs for residential visitors is inhaling soil and groundwater vapours that have migrated to the indoor environment. They will have negligible exposure to soil since they are either inside the building on-Site or are off-Site; therefore, soil contact pathways (incidental ingestion, dermal contact, inhalation of particulates) are considered incomplete.

Default exposure frequency values are not provided by MECP for such receptors but a conservative estimate would be that a residential visitor would visit the site one hour per day, every day through the year (e.g., seven days per week for 50 weeks per year, equivalent to 350 days per year). Given that the frequency of exposure is much less than that of an actual resident, the results for residents (i.e., the calculated human health-based values) will be health-protective of residential visitors. On this basis, residential visitors are not quantitatively assessed in the remaining sections of the HHRA.

Table 3-3: Residential Visitor Characteristics and Exposure Parameters

Characteristic	Units	Residential visitor			
		Toddler	Pregnant female [a]	Full-life composite [b]	Reference
Body weight	kg	16.5	63.1	62.44	Table 2-6 of MOE (2011)
Time indoors	hours/day	1	24	1	NovaTox assumption

Characteristic		Units	Residential visitor			
			Toddler	Pregnant female [a]	Full-life composite [b]	Reference
		days/year	350	365	350	NovaTox assumption
Exposure duration		years	4.5	56	76	Table 2-10 of MOE (2011)
Averaging period	Non-carcinogens	years	4.5	56	76	Table 2-11 of MOE (2011)
	Carcinogens	years	76	76	76	Table 2-12 of MOE (2011)

[a] Pregnant female characteristics required for assessment of developmental toxicants.
[b] Values for composite receptor calculated based on pro-rating all other life stages.

3.2.1.3. Outdoor Workers

Outdoor workers represent adults performing outdoor manual labour (e.g., lawn care and groundskeeping of the park) at the park. They are being assessed for potential risks due to soil contact (incidental ingestion and dermal contact) and soil inhalation (particulates and outdoor vapours). Outdoor worker characteristics required to quantitatively assess these pathways are summarized in Table 3-4. As shown, default values recommended by MECP for a long-term outdoor worker were used for the following:

- Body weight;
- Skin surface area;
- Soil adherence;
- Soil ingestion rate;
- Exposure frequency;
- Exposure duration; and
- Averaging periods.

MECP does not provide a recommended default inhalation rate for an outdoor worker. NovaTox assumed that this value would be the same as that recommended for a construction worker, as it is possible that an outdoor worker could be participating in physical activity that could increase his or her respiration rate (e.g., pushing a lawnmower, hauling bags of yard waste, etc.).

Table 3-4: Outdoor Worker Characteristics and Exposure Parameters

Characteristic		Units	Outdoor worker	
			Typical adult	Reference
Body weight		kg	70.7	Table 2-6 of MOE (2011)
Skin	Surface area	cm^2	3,400	Table 2-7 of MOE (2011)
	Soil adherence factor	mg/cm^2-day	0.2	Table 2-8 of MOE (2011)
Intake Rates	Soil ingestion	mg/day	100	Table 2-5 of MOE (2011)
	Inhalation	m^3/hour	1.5	NovaTox assumption, based on assumed equivalence to construction worker
Time outdoors		hours/day	9.8	Table 2-16 of MOE (2011)
		days/year	195	Table 2-14 and Table 2-15 of MOE (2011)
Exposure duration		years	56	Table 2-10 of MOE (2011)
Averaging period	Non-carcinogens	years	56	Table 2-11 of MOE (2011)
	Carcinogens	years	56	Table 2-12 of MOE (2011)

3.2.1.4. Construction Workers

Construction work is not anticipated at the site but typical HHRA practice is to assess construction workers as a receptor. They represent adults who could perform outdoor remediation work, construction work, and potentially subsurface work (e.g., installing infrastructure in a trench or excavation) at the site over a short-term timeframe (1.5 years). They are being assessed for potential risks due to soil contact (incidental ingestion and dermal contact) and soil inhalation (particulates and *trench* vapours). Construction worker characteristics required to quantitatively assess these pathways are summarized in Table 3-5. As shown, default values recommended by MECP for a construction/subsurface worker were used for the following:

- Body weight;
- Skin surface area;
- Soil adherence;
- Soil ingestion rate;
- Inhalation rate;
- Exposure frequency and duration at the construction site (195 days/year applied to incidental ingestion of soil, dermal contact with soil, and inhalation of soil particulates); and
- Averaging periods.

MECP does not provide recommended default exposure parameter values for a construction worker working in a trench or excavation. In general, it is expected that appropriate basic personal protective equipment (PPE) will be worn during construction activities by workers. Despite these assumptions, the RA considered that PPE would *not* be worn by these receptors (i.e., RA conducted in the absence of RM measures) and that exposure to soil may occur.

- The construction worker has been modelled as being in the trench for 50 days/year. This frequency is >25% of the overall exposure frequency of 195 days per year at the overall construction site. The time to install footings/ walls is typically 1/4 of the time (at maximum) it takes for installing the remainder of the buildings. Therefore, the 50 days/ year in a trench setting was considered to be appropriate/ reasonable. Note that once the footings and walls are installed, for safety reasons, trenches and sidewalls are backfilled with fill to level the area and allow work to proceed at the Site.

Table 3-5: Construction Worker Characteristics and Exposure Parameters

Characteristic		Units	Construction worker: Typical adult	Construction worker: Reference
Body weight		kg	70.7	Table 2-6 of MOE (2011)
Skin	Surface area	cm^2	3,400	Table 2-7 of MOE (2011)
	Soil adherence factor	mg/cm^2-day	0.2	Table 2-8 of MOE (2011)
Intake rates	Soil ingestion	mg/day	100	Table 2-5 of MOE (2011)
	Inhalation	m^3/hour	1.5	Table 2-18 of MOE (2011)
Time outdoors		hours/day	9.8	Table 2-16 of MOE (2011)
		days/year	195	Table 2-13 and Table 2-15 of MOE (2011)
Time in trench		days/year	50	NovaTox rationale (refer to text above)
Exposure duration		years	1.5	Table 2-10 of MOE (2011)
Averaging period	Non-carcinogens	years	1.5	Table 2-11 of MOE (2011)
	Carcinogens	years	56	Table 2-12 of MOE (2011)

3.2.1.5. Off-Site Receptors

Off-Site receptors do not require quantitative assessment, however O. Reg. 153/04 (as amended) Schedule C, Table 1, Section 4(b)(i) states describe in detail the characteristics of every human receptor, *both on and off the RA property*, identified in the human health conceptual site model. As such, off-Site human receptors are identified as follows:

- Construction workers: these represent adults participating in construction work at surrounding properties. They are assumed to have the same characteristics as identified above for on-Site construction workers (taken from Tables 2-5 through 2-18 of MOE 2011 Rationale Document).
- Outdoor workers: these represent adults participating in maintenance or groundskeeping work at surrounding properties. They are assumed to have the same characteristics as identified above for on-Site outdoor workers (taken from Tables 2-5 through 2-18 of MOE 2011 Rationale Document).
- Indoor workers: these represent adults working indoors at surrounding commercial properties. They are assumed to have the same characteristics as identified above for on-Site indoor workers (taken from Tables 2-5 through 2-16 of MOE 2011 Rationale Document).
- Community members: these represent people of all age groups who (i) may live at residential properties surrounding the Site, (ii) may live elsewhere but visit the surrounding commercial properties, or (iii) may be participating in outdoor recreational activities proximal to the site (e.g., running/biking along roadways). They are assumed to have the same characteristics as identified above for on-Site park visitors (taken from Tables 2-5 through 2-16 of MOE 2011 Rationale Document).

3.2.2. Pathway Analysis

Exposure pathways take into account the COC-containing *exposure* medium (i.e., soil, groundwater, vapour) and the biological *pathway* by which a medium contacts or enters the body of a receptor (i.e., dermal contact, ingestion, inhalation). All exposure pathways that were identified in the human health CSM are discussed and justified below, grouped according to soil pathways (Section 3.2.2.1) and other exposure pathways that were considered (Section 3.2.2.2). Exposure pathways for off-site receptors are discussed in Section 3.2.2.3.

3.2.2.1. Soil Ingestion, Dermal Contact, and Particulate Inhalation

Soil can adhere to the exposed skin of receptors after they touch the soil or as they otherwise work on or traverse a site. Receptors can also ingest small quantities of soil as a result of activities that place the hands of the receptor in close proximity to their face and mouth (e.g., eating food, scratching their face). Receptors can also inhale soil particulates entrained in outdoor air. These soil exposure pathways are typically most relevant to any receptor that spends a lot of time outdoors relative to indoors at the Site. A summary of the soil contact pathways is presented in Table 3-6. Soil exposure pathways requiring assessment are also shown in the CSMs (Figures 3 and 4).

The equations used to quantitatively estimate exposure to soil COCs via ingestion, dermal contact, and particulate inhalation are included in Appendices B2(a), B2(b), and B2(c), respectively. Relative absorption factors and COC physical-chemical properties that are required as inputs for these equations are provided in Appendix B1(e).

Table 3-6: Exposure Pathway Summary (Soil)

Source	Pathway	Receptor	Assessment	Rationale	Exposure frequency and duration
Soil	Incidental ingestion, dermal contact, and particulate inhalation	Residents	Quantitative	Receptor is expected to have extensive contact with soil	Toddler: 273 days/year, 4.5 years Full-life/composite: 273 days/year, 76 years
		Visitors	Qualitative	Receptor will have less exposure than residents	–
		Outdoor workers	Quantitative	Receptor is expected to have extensive contact with soil	195 days/year, 56 years
		Construction workers	Quantitative	Receptor is expected to have extensive contact with soil	195 days/year, 1.5 years

Notes:
1. Particulate inhalation pathway also requires application of an hours/day exposure frequency (refer to Appendix B1(d) for values).
2. Particulates that are inhaled have one of two fates (as described in Appendix B2(c)): (i) the fraction coughed and ingested is summed with COC intake from incidental ingestion and dermal contact; (ii) the fraction retained in the lungs is summed with COC intake from inhalation of soil vapours (not applicable at this site).

3.2.2.2. Vapour Inhalation Pathways

A summary of the vapour inhalation pathways is presented in Table 3-7 and also in the human health CSMs (Figures 3 and 4). Note that although mercury was reported on soil, it is likely that the form of mercury is not elemental, and therefore mercury vapours are unlikely to be present at the Site.

Table 3-7: Exposure Pathway Summary (Vapours)

Source	Pathway	Receptor	Assessment	Rationale	Exposure frequency and duration
Soil	Vapour inhalation	Residents	Quantitative (indoor air)	Pathway of concern and component values were exceeded (for Mercury).	Toddler: 1 hour/day, 350 days/year, 4.5 years. Full-life/composite: 1 hour/ day, 350 days/year, 76 years
		Visitors	Qualitative (indoor air)	Receptor will have less exposure than residents	–
		Outdoor workers	Quantitative (outdoor air)	Assessed to be conservative.	9.8 hours/day, 195 days/year, 56 years
		Construction workers	Quantitative (indoor air)	Assessed to be conservative.	9.8 hours/day, 250 days/year, 56 years

<u>Outdoor/Trench Vapours</u>

Outdoor and trench vapour concentrations were estimated using equations developed by the Atlantic Canada Partners in Risk-Based Corrective Action Implementation Group (Atlantic PIRI 2003); details of the equations are provided in Appendix B2(f). Results are provided in Appendix B3(f).

<u>Indoor Vapours</u>

Indoor vapour concentrations were estimated using a model developed by Johnson and Ettinger (1991), which is publicly available from the U.S. EPA (Version 3.1; US EPA 2004) and is described in Appendix B2(g). Indoor vapour modelling was performed for one building scenario:

1. **A generic residential building with a basement.** Generic dimensions as defined by MECP are 12.25 m x 12.25 m, with a mixing zone height of 3.66 m. Model inputs are provided in Appendix B1(c). Model output is provided in Appendix B3(g). Soil contamination was modelled at 188 cm below grade (basement extends to 150 cm, plus slab thickness of 8 cm, plus 29.9 cm of unsaturated gravel crush, plus 0.1 cm of clean fill under the gravel crush for functionality of the model).
2. **The site-specific building with a basement.** The existing building has an area of ~130 m^2. NovaTox set dimensions at 11.4 m x 11.4 m to approximate this area. All other parameters were set equal to a generic residential building with a basement. Model inputs are provided in Appendix B1(c). Model output is provided in Appendix B4(g). Soil contamination was modelled at 188 cm below grade (basement extends to 150 cm, plus slab thickness of 8 cm, plus 29.9 cm of unsaturated gravel crush, plus 0.1 cm of clean fill under the gravel crush for functionality of the model). We note that this structure will be removed from the Site, and hence RM measures only apply to generic buildings.

3.2.2.3. Negligible Exposure Pathways

The following exposure pathway is deemed to be negligible for on-Site receptors:

- Garden produce ingestion: This pathway is qualitatively identified, but not assessed quantitatively or discussed further in the RA as the uncertainties surrounding this pathway are deemed too significant to model receptor exposures with any validity (e.g., quantifying uptake of the COCs into produce; confirming the types and quantities of garden produce that may be grown in any given year; determining the amount of backyard garden produce that may be consumed).
- Vapour contact: This pathway is only assessed qualitatively, as there is a lack of data to determine uptake of vapours through the skin.

3.2.2.4. Exposure Pathways for Off-Site Receptors

Exposure pathways for off-site receptors are summarized in Table 3-8. They are not quantitatively assessed in this RA (as per O. Reg. 153/04). The discussion of off-Site health risks is provided in Section 3.4.5.

Table 3-8: Exposure Pathway Summary (Off-Site)

Source	Pathway	Receptor	Assessment	Rationale
Soil	Oral/dermal pathways	All off-Site receptors	Qualitative	Particulate inhalation is possible/feasible, should dust and soil particulates be re-entrained into ambient air (i.e., site related activities/construction, resulting in generation of particulates, migration in ambient air to off-site areas).
	Inhalation pathways	All off-Site receptors	Qualitative	Negligible (i.e., vapours sourced from soil, given the distance they would have to travel, etc.)

3.2.3. Exposure Estimates

The COC concentrations in soil are conservatively assumed to be steady state, constant concentrations to which any human receptor would be exposed as soon as they contact the soil. However, the *effective* exposure for any particular receptor can exhibit high variability depending on the biological/physiological characteristics of the receptor (e.g., body weight, intake rates of the various media, exposed skin surface area) and on his or her behavioural characteristics (i.e., time spent at the site, time spent completing activities that potentially expose the receptor to soil).

For risks from a COC to be assessed, exposure must be quantified on a basis that it can be integrated with relevant toxicological information. Exposure estimates suitable for this purpose are calculated by taking the COC concentrations to which a receptor is exposed (i.e., the REM concentrations summarized in

Section 3.1.2), then accounting for the fact that different receptors have different contact frequencies with the media containing those COCs (i.e., the intake rates and times spent on-Site summarized in Section 3.2.1), and finally normalizing the daily exposure data to a per-unit-body-mass basis, to arrive at a dose in units of milligram (mg) of COC per kilogram (kg) body weight of the receptor, per day (i.e., mg/kg-day, the typical units of a toxicological reference value). Inhalation risks can be assessed by integrating exposure estimates with toxicological reference values, with both in units of concentration (i.e., mg or µg of COC per m^3 of inhaled air). The exposure pathways requiring exposure estimates to be quantified were described in Section 3.2.2 (with the methods and equations used to integrate the above information described and referenced in detail in Appendices B2(a) through B2(g)). This section presents the exposure estimate results for each applicable COC-pathway-receptor combination.

Exposure estimates are presented as follows:

- Exposure to soil COCs is presented in Tables 3-9 through 3-12 (oral/dermal pathways) and Tables 3-13 through 3-18 (inhalation pathways).
- Note that all exposure estimate results are also provided in detail in Appendices B3 and B4.

Table 3-9: Exposure Estimates from Soil COC Oral/Dermal Contact (Toddler Resident)

COC	Soil incidental ingestion (mg/kg-day)	Soil dermal contact (mg/kg-day)	Soil particulate inhalation (followed by coughing/ ingestion) (mg/kg-day)	Total oral/ dermal from soil (mg/kg-day)
Antimony	4.54E-04	7.92E-05	7.91E-07	5.34E-04
Arsenic	2.96E-04	3.10E-05	1.03E-06	3.28E-04
Cadmium	4.24E-05	7.40E-07	7.40E-08	4.32E-05
Mercury	6.20E-06	2.16E-06	2.16E-08	8.39E-06
Benz[a]anthracene	9.66E-06	2.19E-06	1.68E-08	1.19E-05
Benzo[a]pyrene	1.17E-05	2.67E-06	2.05E-08	1.44E-05
Benzo[b]fluoranthene	1.49E-05	3.38E-06	2.60E-08	1.83E-05
Dibenz[a h]anthracene	1.85E-06	4.20E-07	3.23E-09	2.27E-06
Indeno[1 2 3-cd]pyrene	8.33E-06	1.89E-06	1.45E-08	1.02E-05
Total Carcinogenic PAHs	1.77E-05	4.02E-06	3.09E-08	2.18E-05

Results also presented in Appendix B3.

Table 3-10: Exposure Estimates from Soil COC Oral/Dermal Contact (Full-Life Resident)

COC	Soil incidental ingestion (mg/kg-day)	Soil dermal contact (mg/kg-day)	Soil particulate inhalation (followed by coughing/ ingestion) (mg/kg-day)	Total oral/ dermal from soil (mg/kg-day)
Antimony	3.52E-05	2.14E-05	3.71E-07	5.70E-05
Arsenic	2.30E-05	8.37E-06	4.84E-07	3.18E-05
Cadmium	3.29E-06	2.00E-07	3.47E-08	3.53E-06
Mercury	4.81E-07	5.84E-07	1.01E-08	1.08E-06
Benz[a]anthracene	7.50E-07	5.92E-07	7.90E-09	1.35E-06
Benzo[a]pyrene	9.12E-07	7.20E-07	9.61E-09	1.64E-06
Benzo[b]fluoranthene	1.16E-06	9.13E-07	1.22E-08	2.08E-06
Dibenz[a h]anthracene	1.44E-07	1.13E-07	1.51E-09	2.58E-07

COC	Soil incidental ingestion (mg/kg-day)	Soil dermal contact (mg/kg-day)	Soil particulate inhalation (followed by coughing/ ingestion) (mg/kg-day)	Total oral/ dermal from soil (mg/kg-day)
Indeno[1 2 3-cd]pyrene	6.47E-07	5.10E-07	6.82E-09	1.16E-06
Total Carcinogenic PAHs	1.38E-06	1.09E-06	1.45E-08	2.47E-06

Results also presented in Appendix B3.

Table 3-11: Exposure Estimates from Soil COC Oral/Dermal Contact (Outdoor Worker)

	Outdoor worker			
COC	Soil incidental ingestion (mg/kg-day)	Soil dermal contact (mg/kg-day)	Soil particulate inhalation (followed by coughing/ ingestion) (mg/kg-day)	Total oral/ dermal from soil (mg/kg-day)
Antimony	3.78E-05	2.57E-05	7.78E-07	6.43E-05
Arsenic	2.47E-05	1.01E-05	1.02E-06	3.57E-05
Cadmium	3.54E-06	2.40E-07	7.28E-08	3.85E-06
Mercury	5.17E-07	7.03E-07	2.13E-08	1.24E-06
Benz[a]anthracene	8.05E-07	7.12E-07	1.66E-08	1.53E-06
Benzo[a]pyrene	9.79E-07	8.66E-07	2.02E-08	1.87E-06
Benzo[b]fluoranthene	1.24E-06	1.10E-06	2.56E-08	2.37E-06
Dibenz[a h]anthracene	1.54E-07	1.36E-07	3.17E-09	2.94E-07
Indeno[1 2 3-cd]pyrene	6.95E-07	6.14E-07	1.43E-08	1.32E-06
Total Carcinogenic PAHs	1.48E-06	1.31E-06	3.04E-08	2.81E-06

Results also presented in Appendix B3.

Table 3-12: Exposure Estimates from Soil COC Oral/Dermal Contact (Construction Worker)

COC	Soil incidental ingestion (mg/kg-day)	Soil dermal contact (mg/kg-day)	Soil particulate inhalation (followed by coughing/ ingestion) (mg/kg-day)	Total oral/ dermal from soil (mg/kg-day)
Antimony	3.78E-05	2.57E-05	7.78E-07	6.43E-05
Arsenic	2.47E-05	1.01E-05	1.02E-06	3.57E-05
Cadmium	3.54E-06	2.40E-07	7.28E-08	3.85E-06
Mercury	5.17E-07	7.03E-07	2.13E-08	1.24E-06
Benz[a]anthracene	8.05E-07	7.12E-07	1.66E-08	1.53E-06
Benzo[a]pyrene	9.79E-07	8.66E-07	2.02E-08	1.87E-06
Benzo[b]fluoranthene	1.24E-06	1.10E-06	2.56E-08	2.37E-06
Dibenz[a h]anthracene	1.54E-07	1.36E-07	3.17E-09	2.94E-07
Indeno[1 2 3-cd]pyrene	6.95E-07	6.14E-07	1.43E-08	1.32E-06
Total Carcinogenic PAHs	1.48E-06	1.31E-06	3.04E-08	2.81E-06

Results also presented in Appendix B3.

Table 3-13: Exposure Estimates from Soil COC Inhalation (Toddler Resident; Generic Building)

COC	Soil particulate inhalation (fraction retained in lungs) (mg/m³)	Indoor soil vapour inhalation (mg/m³)	Total inhaled from soil (mg/m³)
Antimony	1.19E-06	–	1.19E-06
Arsenic	1.55E-06	–	1.55E-06
Cadmium	1.11E-07	–	1.11E-07
Mercury	3.24E-08	5.97E-03	5.97E-03
Benz[a]anthracene	2.53E-08	1.58E-07	1.83E-07
Benzo[a]pyrene	3.07E-08	–	3.07E-08
Benzo[b]fluoranthene	3.90E-08	–	3.90E-08
Dibenz[a h]anthracene	4.84E-09	–	4.84E-09
Indeno[1 2 3-cd]pyrene	2.18E-08	–	2.18E-08
Total Carcinogenic PAHs	4.63E-08	–	4.63E-08

Results also presented in Appendix B3.

Table 3-14: Exposure Estimates from Soil COC Inhalation (Toddler Resident; Site-Specific Building)

COC	Toddler resident		
	Soil particulate inhalation (fraction retained in lungs) (mg/m³)	Indoor soil vapour inhalation (mg/m³)	Total inhaled from soil (mg/m³)
Antimony	1.19E-06	–	1.19E-06
Arsenic	1.55E-06	–	1.55E-06
Cadmium	1.11E-07	–	1.11E-07
Mercury	3.24E-08	9.20E-03	9.20E-03
Benz[a]anthracene	2.53E-08	1.80E-07	2.05E-07
Benzo[a]pyrene	3.07E-08	–	3.07E-08
Benzo[b]fluoranthene	3.90E-08	–	3.90E-08
Dibenz[a h]anthracene	4.84E-09	–	4.84E-09
Indeno[1 2 3-cd]pyrene	2.18E-08	–	2.18E-08
Total Carcinogenic PAHs	4.63E-08	–	4.63E-08

Results also presented in Appendix B4.

Table 3-15: Exposure Estimates from Soil COC Inhalation (Full-Life Resident; Generic Building)

COC	Soil particulate inhalation (fraction retained in lungs) (mg/m³)	Indoor soil vapour inhalation (mg/m³)	Total inhaled from soil (mg/m³)
Antimony	5.57E-07	–	5.57E-07
Arsenic	7.26E-07	–	7.26E-07
Cadmium	5.21E-08	–	5.21E-08
Mercury	1.52E-08	5.60E-03	5.60E-03

COC	Soil particulate inhalation (fraction retained in lungs) (mg/m³)	Indoor soil vapour inhalation (mg/m³)	Total inhaled from soil (mg/m³)
Benz[a]anthracene	1.19E-08	1.48E-07	1.60E-07
Benzo[a]pyrene	1.44E-08	–	1.44E-08
Benzo[b]fluoranthene	1.83E-08	–	1.83E-08
Dibenz[a h]anthracene	2.27E-09	–	2.27E-09
Indeno[1 2 3-cd]pyrene	1.02E-08	–	1.02E-08
Total Carcinogenic PAHs	2.17E-08	2.99E-07	3.21E-07

Results also presented in Appendix B3.

Table 3-16: Exposure Estimates from Soil COC Inhalation (Full-Life Resident; Site-Specific Building)

COC	Full-life / composite resident		
	Soil particulate inhalation (fraction retained in lungs) (mg/m³)	Indoor soil vapour inhalation (mg/m³)	Total inhaled from soil (mg/m³)
Antimony	5.57E-07	–	5.57E-07
Arsenic	7.26E-07	–	7.26E-07
Cadmium	5.21E-08	–	5.21E-08
Mercury	1.52E-08	8.62E-03	8.62E-03
Benz[a]anthracene	1.19E-08	1.69E-07	1.81E-07
Benzo[a]pyrene	1.44E-08	–	1.44E-08
Benzo[b]fluoranthene	1.83E-08	–	1.83E-08
Dibenz[a h]anthracene	2.27E-09	–	2.27E-09
Indeno[1 2 3-cd]pyrene	1.02E-08	–	1.02E-08
Total Carcinogenic PAHs	2.17E-08	3.41E-07	3.63E-07

Results also presented in Appendix B4.

Table 3-17: Exposure Estimates from Soil COC Inhalation (Outdoor Worker)

COC	Soil particulate inhalation (fraction retained in lungs) (mg/m³)	Outdoor soil vapour inhalation (mg/m³)	Total inhaled from soil (mg/m³)
Antimony	1.17E-06	–	1.17E-06
Arsenic	1.52E-06	–	1.52E-06
Cadmium	1.09E-07	–	1.09E-07
Mercury	3.19E-08	5.60E-07	5.92E-07
Benz[a]anthracene	2.49E-08	3.08E-08	5.56E-08
Benzo[a]pyrene	3.02E-08	–	3.02E-08
Benzo[b]fluoranthene	3.83E-08	–	3.83E-08
Dibenz[a h]anthracene	4.76E-09	–	4.76E-09
Indeno[1 2 3-cd]pyrene	2.14E-08	–	2.14E-08

COC	Soil particulate inhalation (fraction retained in lungs) (mg/m^3)	Outdoor soil vapour inhalation (mg/m^3)	Total inhaled from soil (mg/m^3)
Total Carcinogenic PAHs	4.56E-08	5.20E-09	5.08E-08

Results also presented in Appendix B3.

Table 3-18: Exposure Estimates from Soil COC Inhalation (Construction Worker)

COC	Soil particulate inhalation (fraction retained in lungs) (mg/m^3)	Trench soil vapour inhalation (mg/m^3)	Total inhaled from soil (mg/m^3)
Antimony	1.17E-06	–	1.17E-06
Arsenic	1.52E-06	–	1.52E-06
Cadmium	1.09E-07	–	1.09E-07
Mercury	3.19E-08	3.91E-07	4.23E-07
Benz[a]anthracene	2.49E-08	2.15E-08	4.63E-08
Benzo[a]pyrene	3.02E-08	–	3.02E-08
Benzo[b]fluoranthene	3.83E-08	–	3.83E-08
Dibenz[a h]anthracene	4.76E-09	–	4.76E-09
Indeno[1 2 3-cd]pyrene	2.14E-08	–	2.14E-08
Total Carcinogenic PAHs	4.56E-08	3.63E-09	4.92E-08

Results also presented in Appendix B3.

3.2.3.1. Uncertainties in the Exposure Assessment

Each of the areas of the exposure assessment described above is associated with some level of uncertainty. To ensure that estimates of exposure to COCs were not underestimated, conservative assumptions were used throughout the exposure assessment. In combination, these conservative assumptions have the effect of almost certainly overestimating exposure to the COCs. Uncertainties and the ways in which they were dealt with include the following.

The soil concentrations of the COCs at the Site exhibit spatial variability. It was assumed in the risk assessment that the maximum detected concentration of each COC was representative of the entire Site. This is a highly conservative assumption when one considers the frequency of detection, the frequency of exceeding the SCS, and the measures of central tendency and variability at the Site. Nonetheless, this assumption ensures that health risks are not underestimated, and in fact means that the results of this risk assessment almost certainly overestimate potential health risks associated with the Site.

The maximum concentrations plus 20% of COCs detected in the soil were used for this assessment rather than estimates developed using the central tendency (CT) or upper bound estimates such as the 95% upper confidence limit (UCL) on the mean. Consequently, exposure estimates (ADDs), while taking into account sampling variability, are likely conservatively overestimated. Consequently, the actual exposure (and ultimately hazard and risk) associated with COCs at the site is likely to be lower.

A number of conservative assumptions have also been made regarding estimates of receptor characteristics (e.g., daily ingestion rates, skin surface areas, soil adherence factors, days per year on site, exposure durations). Combining the conservative point estimates of each of these parameters with the REM concentration will effectively overestimate the calculated exposures for receptors potentially exposed to COCs at the site.

Exposure estimates were conservatively assessed in the absence of risk management measures. For example, construction worker exposure was assessed assuming that appropriate basic personal protective equipment (PPE) will not be worn during construction activities.

3.3. Toxicity Assessment

The toxicity assessment provides the basis to interpret the exposure estimates from Section 3.2.3. The two main components of the toxicity assessment are hazard assessment (Section 3.3.1) and dose-response assessment (Section 3.3.2).

3.3.1. Nature of Toxicity (Hazard Assessment)

The hazard assessment categorizes the types of adverse health effects a COC may potentially cause. COCs are typically categorized with respect to the nature of their toxicity in three main ways:

- Chemicals that cause cancer;
- Chemicals that cause adverse health effects other than cancer; and
- Chemicals that act as developmental toxicants.

In this RA, nine COCs in soil were identified as requiring quantitative assessment. They all have the potential to cause adverse health effects unrelated to cancer. Seven of them are considered carcinogens: arsenic, cadmium, and 5 PAHs (note that additional PAHs are factored into the assessment of total/additive cancer risk). None of them is classified as a developmental toxicant.

3.3.2. Dose-Response Assessment

Dose-response assessment is the process of characterizing the relationship between the dose of an agent administered or received and the incidence of an adverse health effect in the exposed population. The intensity of exposure and potency of the agent play key roles in understanding the potential adverse health effects. The dose-response assessment characterizes how much chemical exposure may occur without unacceptable health effects occurring from lifetime (or a significant portion of a lifetime) exposure.

A dose-response assessment is conducted for each COC and considers the variable toxic effects that can occur as a result of different: (i) endpoints of concern (e.g., cancer or non-cancer); (ii) modes of action (e.g., threshold or non-threshold; (iii) receptors (e.g., child or adult); (iv) exposure pathways (e.g., oral or inhaled); and (v) exposure durations (e.g., chronic, sub-chronic, or acute).

The dose-response relationship for any chemical varies depending on all of the above factors, which can result in the development of numerous Toxicological Reference Values (TRVs) for any single chemical, depending on how extensively that chemical has been toxicologically characterized. For example, chemicals that cause cancer can typically also cause adverse health effects other than cancer, and the dose-response profiles will differ — not only for the endpoints, but also whether the dose-response profiles were characterized via the oral route or the inhalation route. Thus, a single COC can have up to four TRVs by considering just these variables (cancer vs. non-cancer, combined with oral vs. inhalation). Some other dose-response profiles are also regularly characterized (e.g., chronic vs. sub-chronic vs. acute exposure durations) and, in theory, even more dose-response profiles could be characterized (e.g., dermal route; child vs. adult; soil vs water). In practice, however, this is not typically feasible due to a lack of toxicological data (e.g., notably for the dermal exposure route). For receptors and pathways where toxicological information is lacking, it is possible to compensate in the exposure assessment phase of the RA. For example, this is the reason RAFs are applied in the calculation of exposure estimates. Another example is the calculation of risk from dermal exposures: due to a lack of toxicological data no TRVs exist for the dermal contact pathway, meaning that risk associated with this pathway cannot be assessed individually; therefore, dermal exposure estimates are summed with ingestion exposure estimates, and the total exposure estimate is compared to TRVs for oral exposure. It is also possible to compensate for a lack of toxicological information in the toxicity assessment phase of the RA; for example, U.S. EPA has some guidance on adjustment of TRVs to account for age-specific susceptibilities to cancer.

TRVs were obtained from MECP (mostly Canadian and U.S. EPA sources) or, if not available, other recognized regulatory jurisdictions. In the absence of a MECP TRV, risk assessment databases from other governmental jurisdictions (e.g., the U.S. Environmental Protection Agency's Integrated Risk Information System (IRIS)) were reviewed to determine if an applicable TRV has been adopted elsewhere. The TRVs used in the HHRA are summarized and referenced below. A summary of the TRV values used in the RA is also supplied in Appendix B1(f).

3.3.2.1. Non-Threshold-Acting Chemicals

For chemicals that cause cancer by interacting with DNA (i.e., genotoxic carcinogens), any level of exposure is assumed to pose a potential risk, because theoretically even a single interaction with DNA could initiate the future development of cancer. Such chemicals are referred to as non-threshold-acting chemicals, as there is no threshold dose below which the adverse effect (i.e., DNA damage leading to the future development of cancer) is not expected to occur.

Current regulatory guidance considers that any exposure to a genotoxic carcinogen is considered to be associated with some level of risk. At very low doses, the probability that an adverse effect (i.e., cancer) will occur is extremely small (e.g., 1-in-1 million lifetime cancer risk). The probability of developing cancer increases as the dose increases. Because it is possible for cancer to develop after exposure to a chemical has ceased (i.e., a latency period), the toxicity values are expressed as the probability of developing cancer over a lifetime. This is based on the assumption that the risk associated with an elevated exposure to a carcinogenic chemical for a short period of time is equivalent to the risk associated with a lower level of exposure over a longer period of time.

A TRV for a non-threshold-acting chemical is typically expressed as a cancer slope factor (CSF) or a unit risk factor (URF):

- The CSF can be defined as an upper bound, approximating a 95% confidence limit, on the increased cancer risk from a lifetime exposure to an agent. This estimate, usually expressed in units of proportion (of a population) affected per mg/kg-day, is generally reserved for use in the low-dose region of the dose-response relationship, that is, for exposures corresponding to risks less than 1 in 100. CSFs are generally derived using mathematical models that, in most cases, extrapolate results from animal studies conducted at high doses to low doses that may occur in human populations. This approach assumes that a threshold for the carcinogenic low dose response does not exist and that some risk is associated with any dose of the chemical. It should also be noted that for many compounds carcinogenicity has only been demonstrated in experimental animal models. Slope factors for each compound are derived for the most sensitive or affected organ or system (the target) in the studied species. In cases where only animal data are available, it is generally assumed that the target organ or system would be the same for a human subject. For strictly airborne concentrations where exposure occurs through inhalation, unit risk may be used to describe the risk associated with carcinogenicity.
- The URF is the upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 mg/m^3 in air (e.g., if the IUR was 2×10^{-3} per mg/m^3, then an individual continually exposed to 1 mg/m^3 would have a risk of developing cancer of 0.002 (0.2%); another way of interpreting it is if 1,000 people were continually exposed to 1 mg/m^3, then two excess cases of cancer would be expected).

The TRVs used to assess cancer risk in the HHRA are summarized and referenced in Table 3-19 (and Appendix B1(f)).

Table 3-19: Human Health TRVs to Assess Non-Threshold Health Risks

COC	TRV			Basis
	Type	Value	Units	
Arsenic	Non-threshold (oral)	9.5E+00	(mg/kg/day)$^{-1}$	MOE (2011) recommends a TRV of 1.5 (mg/kg-day)$^{-1}$ that was developed by CalEPA (2005) as part of the Air Toxics Hot Spots Program. A MOECC (2017) policy document contains preferred TRVs for selected COCs, including arsenic, with the recommended oral non-threshold TRV being revised to 9.5 (mg/kg-day)$^{-1}$, that was developed by CalEPA in setting its public health goal for arsenic in drinking water (CalEPA 2004). It is based on the incidence of lung and bladder cancer (CalEPA, 2004).
	Non-threshold (inhalation)	1.5E-01	(mg/m^3)$^{-1}$	MOE (2011) recommends a TRV of 1.5 (mg/m^3)$^{-1}$ that was developed by the WHO (2011). A MOECC (2017) policy document contains preferred TRVs for selected COCs, including arsenic, with the recommended inhalation non-threshold TRV being revised to 0.15 (mg/m^3)$^{-1}$, that was developed by the Texas Commission on Environmental Quality (TCEQ, 2012). TCEQ set its unit risk factor based on multiple epidemiological studies examining lung cancer mortality rates and survival probabilities (Enterline et al. 1995; Lubin et al. 2000, 2008; Järup et al. 1989 as cited in TCEQ 2012).
Cadmium	Non-threshold (oral)	nv	(mg/kg/day)$^{-1}$	MOE (2011) states none selected for oral slope factor.
	Non-threshold (inhalation)	9.8E+00	(mg/m^3)$^{-1}$	MOE (2011) recommends the TRV developed by Heath Canada (1996; Priority Substance List assessment). The IUR is based on the incidence of lung cancer in rats exposed to cadmium for 18 months (studies by Takenaka et al., 1983; Oldiges et al., 1984).

<table>
<tr><th rowspan="2">COC</th><th colspan="3">TRV</th><th rowspan="2">Basis</th></tr>
<tr><th>Type</th><th>Value</th><th>Units</th></tr>
<tr><td>General note on PAH carcino-genicity</td><td colspan="4">Non-threshold TRVs are not directly available for these 12 PAHs that require carcinogenic risk to be assessed (bold indicates the PAH is volatile according to MECP criteria):

- Acenaphthene
- Acenaphthylene
- Anthracene
- Benz[a]anthracene
- Benzo[b]fluoranthene
- Benzo[ghi]perylene
- Benzo[k]fluoranthene
- Chrysene
- Dibenzo[a,h]anthracene
- Fluoranthene
- Indeno[1,2,3-cd]pyrene
- Pyrene

Their carcinogenicity is expressed relative to benzo[a]pyrene and can be accounted for in the Exposure Assessment step or the Toxicity Assessment step of the HHRA. Notes:

- In the Exposure Assessment, a Toxic Equivalence Factor (TEF) was applied to every applicable carcinogenic PAH to calculate the level of Total Carcinogenic PAHs (measured in B(a)P equivalents). All TEFs and calculations were provided in the preamble of the Exposure Assessment (TEFs obtained from MOE 2011, which cites Kalberlah et al. 1995).

- If at least one carcinogenic PAH was identified as a COC requiring quantitative assessment via oral/ dermal contact, then all 13 carcinogenic PAHs were factored into the calculation of Total Carcinogenic PAHs (regardless of whether they were identified individually as COCs).

- If at least one volatile-carcinogenic PAH was identified as a COC requiring quantitative assessment via vapour inhalation, then all 5 volatile-carcinogenic PAHs were factored into the calculation of Total Carcinogenic PAHs (regardless of whether they were identified individually as COCs).

- The resulting exposure estimates are integrated with a single CSF or IUR (i.e., that for B(a)P)) in the Risk Characterization step of the HHRA.

- Each PAH identified individually as a COC requires human health effects-based values to be calculated. Cancer risk from individual PAHs can be assessed by instead applying the TEFs to the CSF/ IUR for B(a)P and integrating with the PAH-specific exposure estimate. TEF-adjusted TRVs are provided here.</td></tr>
<tr><td rowspan="2">Benz[a]-anthracene</td><td>Non-threshold (oral)</td><td>1.0E-01</td><td>$(mg/kg/day)^{-1}$</td><td>This is the TRV of benzo[a]pyrene with a TEF of 0.1 applied to it (MECP 2019 Policy Memorandum).</td></tr>
<tr><td>Non-threshold (inhalation)</td><td>6.0E-02</td><td>$(mg/m^3)^{-1}$</td><td>This is the TRV of benzo[a]pyrene with a TEF of 0.1 applied to it (MECP 2019 Policy Memorandum). This PAH meets MECP criteria for being volatile. This TRV can therefore be applied to exposure estimates for soil and groundwater vapours, and for soil particulates.</td></tr>
</table>

COC	TRV			Basis
	Type	Value	Units	
Benzo[a]-pyrene	Non-threshold (oral)	1.0E+00	(mg/kg/day)$^{-1}$	MOE (2011) recommends a TRV of 7.3 (mg/kg/day)$^{-1}$ developed by the U.S.EPA and listed on IRIS. MOE (2011) lists its reference as IRIS (1992). The U.S.EPA (1992) TRV was based on cancer of the gastrointestinal tract in male and female mice and rats after oral exposure (multiple toxicology studies). U.S.EPA calculated four slope factors using different models, and took the geometric mean as the CSF. The U.S.EPA completed a re-examination of the toxicity and carcinogenicity of benzo(a)pyrene in 2017 and currently lists a slope factor of 1.0 (mg/kg/day)$^{-1}$ on IRIS. A MECP 2019 Policy Memorandum recommends use of the U.S.EPA (2017) slope factor, which is based on the tumor response in the alimentary tract (forestomach, esophagus, tongue, and larynx) of female B6C3F1 mice in a study by Beland and Culp (1998). U.S.EPA states that this slope factor is the highest value (most sensitive) among a range of slope factors derived.
	Non-threshold (inhalation)	6.0E-01	(mg/m^3)$^{-1}$	MOE (2011) recommends the TRV of 1.1 (mg/m^3)$^{-1}$ developed by CalEPA (OEHHA, 1993; as cited in ATP, 2005). It is based on cancer of the respiratory tract in male hamsters after inhalation exposure (study by Thyssen et al., 1981). CalEPA calculated the IUR using the linearized multistage procedure. The U.S.EPA completed a re-examination of the toxicity and carcinogenicity of benzo(a)pyrene in 2017 and currently lists a unit risk factor of 0.6 (mg/m^3)$^{-1}$ on IRIS. A MECP 2019 Policy Memorandum recommends use of the U.S.EPA (2017) unit risk factor, which is based on squamous cell neoplasia in the larynx, pharynx, trachea, nasal cavity, esophagus, and forestomach (study by Thyssen et al., 1981). This PAH does not meet MECP criteria for being volatile. This TRV can therefore only be applied to exposure estimates for soil particulates.
Benzo[b/j]-fluoranthene	Non-threshold (oral)	1.0E-01	(mg/kg/day)$^{-1}$	This is the TRV of benzo[a]pyrene with a TEF of 0.1 applied to it (MECP 2019 Policy Memorandum).
	Non-threshold (inhalation)	6.0E-02	(mg/m^3)$^{-1}$	This is the TRV of benzo[a]pyrene with a TEF of 0.1 applied to it. This PAH does not meet MECP criteria for being volatile. This TRV can therefore only be applied to exposure estimates for soil particulates.
Dibenzo[a,h]-anthracene	Non-threshold (oral)	1.0E+00	(mg/kg/day)$^{-1}$	This is the TRV of benzo[a]pyrene with a TEF of 1 applied to it (MECP 2019 Policy Memorandum).
	Non-threshold (inhalation)	6.0E-01	(mg/m^3)$^{-1}$	This is the TRV of benzo[a]pyrene with a TEF of 1 applied to it. This PAH does not meet MECP criteria for being volatile. This TRV can therefore only be applied to exposure estimates for soil particulates.
Indeno[1,2,3-cd]pyrene	Non-threshold (oral)	1.0E-01	(mg/kg/day)$^{-1}$	This is the TRV of benzo[a]pyrene with a TEF of 0.1 applied to it (MECP 2019 Policy Memorandum).
	Non-threshold (inhalation)	6.0E-02	(mg/m^3)$^{-1}$	This is the TRV of benzo[a]pyrene with a TEF of 0.1 applied to it. This PAH does not meet MECP criteria for being volatile. This TRV can therefore only be applied to exposure estimates for soil particulates.

nv = no value

3.3.2.2. Threshold-Acting Chemicals

Some chemicals (i.e., non-carcinogenic chemicals, and non-genotoxic carcinogens) have a threshold at or below which no adverse effects are anticipated. Such chemicals are referred to as threshold-acting chemicals. Such a threshold can exist for any number of reasons (e.g., insufficient levels of the chemical absorbed into the body; the levels absorbed by the body were metabolized or eliminated very efficiently; the damage done at the cellular and tissue levels was repaired very efficiently).

A TRV for a threshold-acting chemical is typically expressed as a tolerable daily intake (TDI), a reference dose (RfD), a tolerable concentration (TC), or a reference concentration (RfC):

- The TDI is often used to describe a daily intake of a substance over a lifetime that is considered to be without appreciable health risk.
- The RfD is often used as an analog to the TDI, but is specific to direct contact (ingestion and dermal). The RfD is as an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. It can be derived from a NOAEL (No-Observed Adverse Effect Level), LOAEL (Lowest-Observed Adverse Effect Level), or benchmark dose, with uncertainty factors generally applied to reflect limitations of the data used.
- The TC is often used to describe the airborne concentration of a substance that is considered to be without appreciable health risk.
- The RfC is 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 effects during a lifetime. It can be derived from a NOAEL, LOAEL, or benchmark concentration, with uncertainty factors generally applied to reflect limitations of the data used.

The TRVs used to assess non-cancer hazard in the HHRA are summarized and referenced in Table 3-20 (and Appendix B1(f)).

Table 3-20: Human Health TRVs to Assess Threshold Health Effects

COC	TRV			Basis
	Type	**Value**	**Units**	
Antimony	Threshold (oral)	4.0E-04	mg/kg/day	MOE (2011) recommends the TRV developed by the U.S.EPA and listed on IRIS. MOE (2011) lists its reference as IRIS (1991). NovaTox notes that U.S.EPA states their assessment for antimony on IRIS was last revised in 1987. The U.S.EPA (1987) Reference Dose is based on a study by Schroeder et al. (1970), in which rats were exposed to soluble antimony in drinking water. The critical endpoint was hematological (effects on blood glucose and cholesterol). U.S.EPA took the LOAEL of 0.35 mg/kg-day and applied a total UF of 1000 to arrive at the RfD.
	Threshold (inhalation)	2.0E-04	mg/m^3	MOE (2011) recommends the TRV developed by the U.S.EPA and listed on IRIS (1995). The U.S.EPA (1995) Reference Concentration is based on a study by Newton et al. (1994), in which rats were exposed to antimony trioxide in air. The critical endpoint was pulmonary toxicity and chronic interstitial inflammation. U.S.EPA took a benchmark concentration (BMC10-HEC) of 0.074 mg/m^3 and applied a total UF of 300 to arrive at the RfC.

COC	TRV			Basis
	Type	Value	Units	
Arsenic	Threshold (oral)	3.0E-04	mg/kg/day	MOE (2011) recommends a TRV of 3 x 10^{-4} mg/kg-day that was developed by the U.S.EPA and referenced to IRIS (1993). A MOECC (2017) policy document contains preferred TRVs for selected COCs, including arsenic, with the recommended oral chronic non-cancer TRV remaining the same as MOE (2011) but referencing U.S.EPA IRIS (1991). The U.S.EPA (1991) Reference Dose is based on studies by Tseng et al. (1968) and Tseng (1977), in which effects from chronic oral exposure in humans were examined. The critical endpoints were dermal (hyperpigmentation and keratosis) and vascular (complications). U.S.EPA took the NOAEL of 0.009 mg/L in drinking water, converted it to a dose of 0.0008 mg/kg-day, and applied a total UF of 3 to arrive at the RfD.
	Threshold (inhalation)	1.5E-05	mg/m^3	MOE (2011) recommends a TRV of 3.0 x 10^{-5} mg/m^3 developed by CalEPA (2000; Chronic Reference Exposure Level). CalEPA regularly examines and periodically revises its RELs. The REL for arsenic was revised to 1.5 x 10^{-5} mg/m^3 in 2014. NovaTox has defaulted to this value, which is more conservative than the TRV it is replacing. It is based on neurological effects in people exposed to arsenic in drinking water. An oral LOAEL of 2.27 µg/day was converted to an inhalation value of 0.46 µg/m^3 by assuming an inhalation rate of 9.9 m^3/day and an absorption rate of 50% (i.e., 2.3 ÷ 9.9 ÷ 0.5 = 0.46). CalEPA applied a total uncertainty factor of 30 (3 for use of a LOAEL, 10 for inter-individual variation) to arrive at its REL (LOAEL obtained from examining Tsai et al. 2003 and Wasserman et al. 2004). A MOECC (2017) policy document contains preferred TRVs for selected COCs, including arsenic, with the recommended inhalation chronic non-cancer TRV being revised to a statement of none selected. To be conservative, NovaTox is using CalEPA's updated recommended TRV so that inhalation hazards can be calculated for this compound.
Cadmium	Threshold (oral)	3.2E-05	mg/kg/day	MOE (2011) states that its recommended TRV is modified from the TRV developed by CalEPA in setting its Public Health Goal for drinking water (CalEPA 2006). CalEPA (2006) states that its TRV is based on various studies in humans indicating the critical endpoint is kidney toxicity (e.g., Ellis et al., 1979; Fox, 1983; Friberg, 1950; Vahter et al., 2002). CalEPA took a NOAEL of 19 µg/day from Ellis et al. (1979) (daily oral intake estimated to limit cadmium levels to 1 µg Cd/g creatinine after 50 years of exposure), divided it by an adult female body weight of 60 kg to obtain a dose-based NOAEL of 0.317 µg/kg-day, then divided this by a total UF of 50 to obtain a TRV of 6.3E-03 µg/kg-day. MOE (2011) does not state how or why the CalEPA (2006) TRV was modified (the modified TRV is 5X higher than the original).
	Threshold (inhalation)	3.0E-05	mg/m^3	MOE (2011) states that its recommended TRV is modified from the Ontario 24-hour ambient air quality criterion (MOE 2007; AAQC guidance) for cadmium. Ontario's 24-hour AAQC for cadmium is listed as 2.5E-05 mg/m^3. Its basis could not be found online. MOE (2011) does not state how or why the AAQC was modified (appears to be just rounding artifact, from 2.5 to 3).

COC	TRV Type	Value	Units	Basis
Mercury	Threshold (oral)	3.0E-04	mg/kg/day	MOE (2011) recommends the TRV developed by the U.S.EPA and listed on IRIS (1995). The U.S.EPA (1995) Reference Dose for mercuric chloride is based on a U.S.EPA (1987) peer review workshop which examined the entire inorganic mercury database, including experimental studies in rats by Druet et al. (1978), Bernaudin et al. (1981), and Andres (1984). Based on an intensive review, workshop discussions, and a weight of evidence approach, the workshop determined that the critical effect of mercury was immunological toxicity (e.g., autoimmune effects). The workshop developed a 'drinking water equivalent level' (DWEL) of 0.010 mg/L. U.S. EPA (1995) derived an RfD by back-calculating from the DWEL, assuming a 70 kg body weight and a drinking water ingestion of 2 L/day.
	Threshold (inhalation)	9.0E-05	mg/m^3	MOE (2011) recommends a TRV of 9.0 x 10^{-5} mg/m3 developed by CalEPA as a chronic reference exposure level (ChREL) in 2000 (CalEPA 2000). The basis of the value could not be found, as CalEPA updated its ChREL for mercury in 2008, to a value of 3.0 x 10^{-5}. The 2008 ChREL is based on studies by Piikivi and Hanninen (1989), Fawer et al. (1983), Piikivi and Tolonen (1989), Piikivi (1989), and Ngim et al. (1992) that examined occupational exposure to mercury vapour in humans. The critical effect was neurotoxicity (e.g., intention tremor; memory and sleep disturbances; decreased performance on neurobehavioral tests (finger tapping, visual scan, visuomotor coordination, visual memory); decreased EEG activity). CalEPA took a LOAEL of 0.025 mg/m^3, converted it for continuous exposure to a LOAEL of 0.009 mg/m^3, then divided it by a total UF of 300 to arrive at their ChREL. NovaTox is defaulting to the recommendation of MOE (2011).
Benz[a]-anthracene	Threshold (oral)	nv	mg/kg/day	MOE (2011) states none selected for oral chronic non-cancer TRV.
	Threshold (inhalation)	nv	mg/m^3	MOE (2011) states none selected for inhalation chronic non-cancer TRV.
Benzo[a]-pyrene	Threshold (oral)	3.0E-04	mg/kg/day	MOE (2011) states none selected for oral chronic non-cancer TRV. A MECP 2019 Policy Memorandum recommends use of the U.S.EPA (2017) Reference Dose of 0.0003 mg/kg/day, which is based on developmental neurobehavioural changes in rats (study by Chen et al. 2012). MECP (2019) states that although the critical effect is developmental in nature, the TRV does not require restrictions on pro-rating.
	Threshold (inhalation)	2.0E-06	mg/m^3	MOE (2011) states none selected for inhalation chronic non-cancer TRV. A MECP 2019 Policy Memorandum recommends use of the U.S.EPA (2017) Reference Concentration of 0.000002 mg/kg/day, which is based on decreased embryo/fetal survival in rats (study by Archibong et al. 2002). MECP (2019) states that although the critical effect is developmental in nature, the TRV does not require restrictions on pro-rating. This PAH does not meet MECP criteria for being volatile. NovaTox calculated an inhalation TRV using route-to-route extrapolation from the oral TRV (body weight of 70.7kg and inhalation rate of 20 m^3/day), *applicable only to when the soil particulate inhalation pathway is assessed for this PAH.*
Benzo[ghi]-perylene	Threshold (oral)	nv	mg/kg/day	MOE (2011) states none selected for oral chronic non-cancer TRV.
	Threshold (inhalation)	nv	mg/m^3	MOE (2011) states none selected for inhalation chronic non-cancer TRV.

COC	TRV			Basis
	Type	Value	Units	
Fluoranthene	Threshold (oral)	4.0E-02	mg/kg/day	MOE (2011) recommends the TRV developed by the U.S.EPA and listed on IRIS. MOE (2011) lists its reference as IRIS (1993). NovaTox notes that U.S.EPA states their assessment for fluoranthene on IRIS was last revised in 1990. The U.S.EPA (1990) Reference Dose is based on a study by U.S.EPA (1988) in which mice were exposed to fluoranthene sub-chronically via gavage. The critical endpoints were liver toxicity (increased liver weights), kidney toxicity (nephropathy), hematological alterations and clinical effects. U.S.EPA took the NOAEL of 125 mg/kg-day and applied a total UF of 3000 to arrive at the RfD.
	Threshold (inhalation)	1.41E-01	mg/m^3	MOE (2011) states none selected for inhalation chronic non-cancer TRV. This PAH does not meet MECP criteria for being volatile. NovaTox calculated an inhalation TRV using route-to-route extrapolation from the oral TRV (body weight of 70.7kg and inhalation rate of 20 m^3/day), *applicable only to when the soil particulate inhalation pathway is assessed for this PAH*.
Indeno[1,2,3-cd]pyrene	Threshold (oral)	nv	mg/kg/day	MOE (2011) states none selected for oral chronic non-cancer TRV.
	Threshold (inhalation)	nv	mg/m^3	MOE (2011) states none selected for inhalation chronic non-cancer TRV.

nv = no value

3.3.2.3. Developmental Toxicants

Chemicals that act as prenatal developmental toxicants (i.e., those that interfere with proper growth or health any time between conception and birth) are of particularly high concern. If the toxicity assessment identifies a COC with a TRV that was derived based on developmental effects, then this dose-response profile is accounted for not in the toxicity assessment but instead in the exposure assessment. That is, most receptor exposure estimates take into account some fractional exposure frequency (i.e., exposure is 'pro-rated' for a typical adult receptor). However, in the case of a developmental toxicant, exposure cannot be pro-rated because it must take into account the possibility that the exposed receptor is a pregnant female, with the ultimate target/receptor being still *in utero*. In this case, the relevant exposure duration is assumed to be short-term because in theory even a single exposure to a developmental toxicant may be sufficient to elicit an adverse developmental effect (MOE 2011 Rationale document).

As previously stated, none of the COCs is classified as a developmental toxicant.

3.3.2.4. Uncertainties in the Toxicity Assessment

In the dose-response assessment, the major sources of uncertainty concerning the toxicity assessment include the extrapolation from high doses in animals to low doses in humans, and conservative assumptions built into the derivation of TRVs. Each of the toxicologically based exposure limits used to estimate potential health risks have uncertainty factors associated with them. These factors largely account for the strength of the toxicological data and incorporate uncertainty factors to account for intra-species and interspecies extrapolations of toxicological data as well as extrapolations from acute and sub-chronic exposure studies to chronic exposures.

TRVs incorporate uncertainty factors to address the following sources of uncertainty:

- The expected differences in responsiveness between humans and animals; for example, chemicals may be assumed to be human carcinogens based on animal studies even when there is limited or no available evidence that the chemical is a human carcinogen. Such chemicals may not actually be carcinogenic in humans, and therefore overestimate the potential risk levels. Candidates for long-term carcinogenicity studies in laboratory animals are typically selected based on preliminary evidence that indicates a potential concern. Included are results of short-term mutagenicity studies, chemical class considerations, or presence of structural elements that are similar to those present on known carcinogens. While many high priority chemicals have been studied, not all chemicals have undergone testing for carcinogenesis and as a result, some chemicals that have not been tested may actually be carcinogenic and therefore could pose a cancer risk. However, the toxicity data applied herein are based on the current state of the science regarding potential health effects caused by chemical exposure and therefore are appropriate.

- CSFs and URFs are derived from study data on animals dosed with high concentrations, and therefore may not be applicable to the evaluation of low concentration exposures. High doses of chemicals may overwhelm the detoxification or excretion capabilities of an organism and allow the chemical to impact the target cells, and therefore result in an overestimation of the risk and provide lower, more conservative effects-based values. In cases where chemicals are activated to carcinogens by metabolism, tumor incidence may not increase at higher dose levels because the responsible metabolic pathway becomes saturated. The impact of this response on derived CSFs and URFs is unclear because derivation of CSFs and URFs involves fitting experimental data to a dose-response model and linearly extrapolating the curve through the origin. The slope of this linear portion of the curve is used to derive CSFs and URFs. As such, the impact of saturation at high doses on the extrapolated linear low-dose portion of the dose-response curve is uncertain;
- Variability among individuals within the human population;
- Extrapolation from a LOAEL to a NOAEL;
- Extrapolation from a sub-chronic to chronic exposure; and
- An inadequate toxicity database.

These uncertainty factors reflect the adequacy (or inadequacy) of the toxicological data available for each compound. Where toxicological data is poor or limited to one or two studies, large uncertainty factors are applied to ensure adequate protection of sensitive members of the population.

The assumed cancer slope factors and unit risks provided by the regulatory jurisdictions were assumed to be reliable and accurate in characterizing the relationship between chemical concentrations, doses and adverse health effects. Most regulatory agencies typically derive cancer slope factors by evaluating the 95% upper confidence limit of the slope of the dose response curve (U.S. EPA, etc.). The use of this upper limit is highly conservative, and is intended to account for uncertainties that are brought upon, for example, by the use of experimental animals. This linear relationship assumption implies that any concentration of a carcinogen other than zero increases the risk of developing cancer by some extent, which could lead to a significant overestimation of the total risk.

3.4. Risk Characterization

3.4.1. Interpretation of Health Risks

3.4.1.1. Risk Results

All of the methods and equations used to integrate exposure estimates (from Section 3.2) with TRVs (from Section 3.3) to quantitatively characterize risk are described in detail in Appendices B2(h) (hazard quotients) and B2(i) (incremental lifetime cancer risk). Briefly:

- Non-carcinogenic risks were assessed for each relevant COC/exposure pathway/receptor by comparing an exposure estimate (units of dose or concentration) with the appropriate toxicological reference value to yield a hazard quotient (HQ). The acceptable HQ for most COCs is set at 0.2; this is based on the Ministry's assumption that 80% of allowable exposure occurs via other exposure pathways (i.e., exposure to the COCs from food, consumer products, environmental sources off-Site, etc.).

- Carcinogenic risks were assessed for each relevant COC/exposure pathway/receptor by integrating an exposure estimate (units of dose or concentration) with the appropriate toxicological reference value to yield an incremental lifetime cancer risk (ILCR). The ILCR is a unitless value that expresses the probability of developing cancer for a specified level of exposure averaged over a lifetime. As recommended by the Ministry, an incremental lifetime cancer risk of less than one-in-one-million (10^{-6}) is considered *de minimis* for human health and the associated risk is considered negligible.

3.4.1.2. Human Health Effects-Based Values

A human heath effects-based value represents the concentration of a COC in soil that has been calculated as the 'boundary' between acceptable and unacceptable risk. That is, if the COC concentration was equal to the effects-based value, then the HQ/ILCR would be equal to their acceptable limit; any COC concentration lower than the effects-based value would result in an acceptable HQ/ILCR; any COC concentration higher than the effects-based value would result in an unacceptable HQ/ILCR. It is important to note that the calculation is not a 'hard boundary', in that if the acceptable limit is exceeded, it means that there is an erosion in the margin of safety.

An effects-based value is calculated as follows:

$$\text{Human Health Effects-Based Value} = \frac{HQ_{acceptable} \text{ or } ILCR_{acceptable}}{\text{Calculated HQ or ILCR}} \times REM_{soil\ or\ groundwater}$$

This is because the relationship between the concentration of a COC in soil and the final calculated HQ/ ILCR is assumed to be essentially linear (e.g., if the concentration of a given COC in soil increased 10-fold, then any final calculated HQ/ILCR will also increase 10-fold).

An effects-based value was calculated for each COC, for each relevant receptor, and each complete exposure pathway. They are presented in each table of Section 3.4.2.1.

The *minimum* effects-based value for any COC can be used as an indication as to whether risk management measures are required for that COC. That is, if the minimum effects-based value is less than the REM, then this indicates a potentially unacceptable health risk for at least one receptor/pathway, and risk management measures must be implemented at the site to ensure human health is protected. The ratio of the REM to the minimum effects-based value represents the required hazard or risk reduction' deemed necessary to mitigate the most-at-risk receptor/pathway. By managing risks for the most-at-risk receptor/pathway, then by extension, other receptors/pathways with less risk will also be managed. Minimum effects-based values for all COCs assessed quantitatively are presented in Section 3.4.2.2.

3.4.2. Quantitative Interpretation of Health Risks

3.4.2.1. Soil COCs

Risk results and calculated effects-based values for soil COCs are summarized in Tables 3-21 through 3-23 (oral/dermal results), and Tables 3-24 through 3-27 (particulate inhalation results). Note that all risk characterization results are also provided in detail in Appendices B3 and B4. Note that a more detailed discussion of the uncertainty surrounding these conclusions about human health risks is presented in Section 3.4.6.

Key points about risk from soil COCs include:

- **Oral/dermal contact**: Residents (Table 3-21) have been calculated to have unacceptable HQ values (antimony, arsenic, cadmium) and unacceptable ILCR values (arsenic, PAHs). Outdoor workers (Table 3-22) have been calculated to have unacceptable ILCR values (arsenic, PAHs). Construction workers (Table 3-23) have been calculated to have an unacceptable ILCR value (arsenic). Risk management measures on the form of addition of fill cap (i.e., soil capping layers) or hard cap barriers (e.g., asphalt, concrete, the building footings/ walls and floors) should be installed at the Site over areas that are impacted with levels of the these COCs above health based limits. Additional details concerning the necessary Risk Management (RM) measures are provided in Section 4.1 below.

- **Inhalation**: Residents (Table 3-24; generic buildings and Table 3-25; existing building) have been calculated to have a potential unacceptable HQ value due to potential exposure to mercury through vapour and particulate inhalation).
    - Mercury was identified as posing a potential (theoretical, calculated) risk via indoor vapour intrusion, however additional discussion is warranted to put this into context. The maximal mercury impacted soil is primarily found at BH-2, at between 0.3-1.35 m below grade, and slightly lower levels are found at BH-4 (1.01 µg/g). The other boreholes had levels of mercury about the effects-based concentration but below the applicable SCS.
    - Mercury is a chemical element, and can exist in two oxidation states (Mercury (I) and Mercury (II)). Mercury (I) can form stable derivatives such as chloride and nitrate derivatives. These derivative are not common in nature, rather Mercury (II) derivatives are more frequently encountered. For example, mercury(II)oxide (HgO) and mercury(II)sulphide (HgS) which occurs in the ore cinnabar. There is a high probability that the mercury reported on the site is not found in its elemental form, but rather as a complex. As such, mercury on the site would not be found in a vapour form. The risk estimates that were derived assumed that mercury is found in the elemental form, and available to form a vapour. As this is not likely to occur, the risk estimates related to elemental forms of mercury (which can form a vapour) can be discounted at the Site.
- **Inhalation:** Outdoor workers (Table 3-26) have been calculated to have an unacceptable ILCR value as a result of potential exposure to cadmium in particulates. Risk Management (RM) measures in the form of fill or har cap barriers are required to mitigate risks as a result of this pathway. The locations where RM measures are required are depicted in Figure 1. Additional details are provided in Section 4.1 below.
- **Inhalation:** Construction workers (Table 3-27) have been calculated to have no unacceptable risk.

Table 3-21: Risk Results from Soil COC Oral/Dermal Contact (Resident)

		Non-cancer hazard				Cancer risk			
COC	Soil REM (µg/g)	Toddler oral/ dermal dose (mg/kg-day)	Oral TRV (mg/kg-day)	HQ	Effects-based value (µg/g)	Full-life oral/ dermal dose (mg/kg-day)	Oral TRV (mg/kg-day)$^{-1}$	ILCR	Effects-based value (µg/g)
Antimony	50.0	5.34E-04	4.0E-04	***1.33E+00***	7.50E+00	–	–	–	–
Arsenic	65.3	3.28E-04	3.0E-04	***1.09E+00***	1.19E+01	3.18E-05	9.5E+00	***3.02E-04***	2.16E-01
Cadmium	4.68	4.32E-05	3.2E-05	***1.35E+00***	6.93E-01	–	–	–	–
Mercury	1.37	8.39E-06	3.0E-04	2.80E-02	9.79E+00	–	–	–	–
Benz[a]anthracene	1.07	–	–	–	–	1.35E-06	1.0E-01	1.35E-07	7.90E+00
Benzo[a]pyrene	1.30	1.44E-05	3.0E-04	4.81E-02	5.39E+00	1.64E-06	1.0E+00	***1.64E-06***	7.90E-01
Benzo[b]fluoranthene	1.64	–	–	–	–	2.08E-06	1.0E-01	2.08E-07	7.90E+00
Dibenz[a h]anthracene	0.20	–	–	–	–	2.58E-07	1.0E+00	2.58E-07	7.90E-01
Indeno[1 2 3-cd]pyrene	0.92	–	–	–	–	1.16E-06	1.0E-01	1.16E-07	7.90E+00
Total Carcinogenic PAHs	1.95	–	–	–	–	2.47E-06	1.0E+00	***2.47E-06***	7.90E-01

Results also presented in Appendix B3.
Bold/italic indicates exceedance of acceptable limit.

Table 3-22: Risk Results from Soil COC Oral/Dermal Contact (Outdoor Worker)

COC	Soil REM (µg/g)	Non-cancer hazard				Cancer risk			
		Total oral/ dermal dose (mg/kg-day)	Oral TRV (mg/kg-day)	HQ	Effects-based value (µg/g)	Amortized oral/ dermal dose (mg/kg-day)	Oral TRV (mg/kg-day)$^{-1}$	ILCR	Effects-based value (µg/g)
Antimony	50.0	6.43E-05	4.0E-04	1.61E-01	6.23E+01	–	–	–	–
Arsenic	65.3	3.57E-05	3.0E-04	1.19E-01	1.10E+02	3.57E-05	9.5E+00	***3.40E-04***	1.92E-01
Cadmium	4.68	3.85E-06	3.2E-05	1.20E-01	7.78E+00	–	–	–	–
Mercury	1.37	1.24E-06	3.0E-04	4.14E-03	6.61E+01	–	–	–	–
Benz[a]anthracene	1.07	–	–	–	–	1.53E-06	1.0E-01	1.53E-07	6.95E+00
Benzo[a]pyrene	1.30	1.87E-06	3.0E-04	6.22E-03	4.17E+01	1.87E-06	1.0E+00	***1.87E-06***	6.95E-01
Benzo[b]fluoranthene	1.64	–	–	–	–	2.37E-06	1.0E-01	2.37E-07	6.95E+00
Dibenz[a h]anthracene	0.20	–	–	–	–	2.94E-07	1.0E+00	2.94E-07	6.95E-01
Indeno[1 2 3-cd]pyrene	0.92	–	–	–	–	1.32E-06	1.0E-01	1.32E-07	6.95E+00
Total Carcinogenic PAHs	1.95	–	–	–	–	2.81E-06	1.0E+00	***2.81E-06***	6.95E-01

Results also presented in Appendix B3.
Bold/italic indicates exceedance of acceptable limit.

Table 3-23: Risk Results from Soil COC Oral/Dermal Contact (Construction Worker)

COC	Soil REM (µg/g)	Non-cancer hazard				Cancer risk			
		Total oral/ dermal dose (mg/kg-day)	Oral TRV (mg/kg-day)	HQ	Effects-based value (µg/g)	Amortized oral/ dermal dose (mg/kg-day)	Oral TRV (mg/kg-day)$^{-1}$	ILCR	Effects-based value (µg/g)
Antimony	50.0	6.43E-05	4.0E-04	1.61E-01	6.23E+01	–	–	–	–
Arsenic	65.3	3.57E-05	3.0E-04	1.19E-01	1.10E+02	9.57E-07	9.5E+00	***9.10E-06***	7.18E+00
Cadmium	4.68	3.85E-06	3.2E-05	1.20E-01	7.78E+00	–	–	–	–
Mercury	1.37	1.24E-06	3.0E-04	4.14E-03	6.61E+01	–	–	–	–
Benz[a]anthracene	1.07	–	–	–	–	4.11E-08	1.0E-01	4.11E-09	2.59E+02
Benzo[a]pyrene	1.30	1.87E-06	3.0E-04	6.22E-03	4.17E+01	5.00E-08	1.0E+00	5.00E-08	2.59E+01
Benzo[b]fluoranthene	1.64	–	–	–	–	6.34E-08	1.0E-01	6.34E-09	2.59E+02
Dibenz[a h]anthracene	0.20	–	–	–	–	7.86E-09	1.0E+00	7.86E-09	2.59E+01
Indeno[1 2 3-cd]pyrene	0.92	–	–	–	–	3.54E-08	1.0E-01	3.54E-09	2.59E+02
Total Carcinogenic PAHs	1.95	–	–	–	–	7.53E-08	1.0E+00	7.53E-08	2.59E+01

Results also presented in Appendix B3.
Bold/italic indicates exceedance of acceptable limit.

Table 3-24: Risk Results from Soil COC Inhalation (Resident; Generic Building)

COC	Soil REM (µg/g)	Non-cancer hazard				Cancer risk			
		Toddler inhaled conc. (mg/m^3)	Inhal. TRV (mg/m^3)	HQ	Effects-based value (µg/g)	Full-life inhaled conc. (mg/m^3)	Inhal. TRV (mg/m^3)$^{-1}$	ILCR	Effects-based value (µg/g)
Antimony	50.0	1.19E-06	2.0E-04	5.93E-03	1.69E+03	–	–	–	–

COC	Soil REM (µg/g)	Non-cancer hazard				Cancer risk			
		Toddler inhaled conc. (mg/m³)	Inhal. TRV (mg/m³)	HQ	Effects-based value (µg/g)	Full-life inhaled conc. (mg/m³)	Inhal. TRV (mg/m³)-1	ILCR	Effects-based value (µg/g)
Arsenic	65.3	1.55E-06	1.5E-05	1.03E-01	1.27E+02	7.26E-07	1.5E-01	1.09E-07	5.99E+02
Cadmium	4.68	1.11E-07	3.0E-05	3.70E-03	2.53E+02	5.21E-08	9.8E+00	5.10E-07	9.17E+00
Mercury	1.37	5.97E-03	9.0E-05	***6.63E+01***	4.12E-03	–	–	–	–
Benz[a]anthracene	1.07	–	–	–	–	1.60E-07	6.0E-02	9.61E-09	1.11E+02
Benzo[a]pyrene	1.30	3.07E-08	2.0E-06	1.54E-02	1.69E+01	1.44E-08	6.0E-01	8.65E-09	1.50E+02
Benzo[b]fluoranthene	1.64	–	–	–	–	1.83E-08	6.0E-02	1.10E-09	1.50E+03
Dibenz[a h]anthracene	0.20	–	–	–	–	2.27E-09	6.0E-01	1.36E-09	1.50E+02
Indeno[1 2 3-cd]pyrene	0.92	–	–	–	–	1.02E-08	6.0E-02	6.14E-10	1.50E+03
Total Carcinogenic PAHs	1.95	–	–	–	–	3.21E-07	6.0E-01	1.93E-07	1.01E+01

Results also presented in Appendix B3.
Bold/italic indicates exceedance of acceptable limit.

Table 3-25: Risk Results from Soil COC Inhalation (Resident; Site-Specific Building)

COC	Soil REM (µg/g)	Non-cancer hazard				Cancer risk			
		Toddler inhaled conc. (mg/m³)	Inhal. TRV (mg/m³)	HQ	Effects-based value (µg/g)	Full-life inhaled conc. (mg/m³)	Inhal. TRV (mg/m³)-1	ILCR	Effects-based value (µg/g)
Antimony	50.0	1.19E-06	2.0E-04	5.93E-03	1.69E+03	–	–	–	–
Arsenic	65.3	1.55E-06	1.5E-05	1.03E-01	1.27E+02	7.26E-07	1.5E-01	1.09E-07	5.99E+02
Cadmium	4.68	1.11E-07	3.0E-05	3.70E-03	2.53E+02	5.21E-08	9.8E+00	5.10E-07	9.17E+00
Mercury	1.37	9.20E-03	9.00E-05	***1.02E+02***	2.68E-03	–	–	–	–
Benz[a]anthracene	1.07	–	–	–	–	1.81E-07	6.0E-02	1.08E-08	9.83E+01
Benzo[a]pyrene	1.30	3.07E-08	2.0E-06	1.54E-02	1.69E+01	1.44E-08	6.0E-01	8.65E-09	1.50E+02
Benzo[b]fluoranthene	1.64	–	–	–	–	1.83E-08	6.0E-02	1.10E-09	1.50E+03
Dibenz[a h]anthracene	0.20	–	–	–	–	2.27E-09	6.0E-01	1.36E-09	1.50E+02
Indeno[1 2 3-cd]pyrene	0.92	–	–	–	–	1.02E-08	6.0E-02	6.14E-10	1.50E+03
Total Carcinogenic PAHs	1.95	–	–	–	–	3.63E-07	6.0E-01	2.18E-07	8.98E+00

Results also presented in Appendix B4.
Bold/italic indicates exceedance of acceptable limit.

Table 3-26: Risk Results from Soil COC Inhalation (Outdoor Worker)

COC	Soil REM (µg/g)	Non-cancer hazard				Cancer risk			
		Total inhaled conc. (mg/m³)	Inhal. TRV (mg/m³)	HQ	Effects-based value (µg/g)	Amortized inhaled conc. (mg/m³)	Inhal. TRV (mg/m³)-1	ILCR	Effects-based value (µg/g)
Antimony	50.0	1.17E-06	2.0E-04	5.84E-03	1.71E+03	–	–	–	–
Arsenic	65.3	1.52E-06	1.5E-05	1.02E-01	1.29E+02	1.52E-06	1.5E-01	2.28E-07	2.86E+02
Cadmium	4.68	1.09E-07	3.0E-05	3.64E-03	2.57E+02	1.09E-07	9.8E+00	***1.07E-06***	4.37E+00
Mercury	1.37	5.92E-07	9.0E-05	6.58E-03	4.16E+01	–	–	–	–
Benz[a]anthracene	1.07	–	–	–	–	5.56E-08	6.0E-02	3.34E-09	3.19E+02
Benzo[a]pyrene	1.30	3.02E-08	2.0E-06	1.51E-02	1.71E+01	3.02E-08	6.0E-01	1.81E-08	7.14E+01
Benzo[b]fluoranthene	1.64	–	–	–	–	3.83E-08	6.0E-02	2.30E-09	7.14E+02

COC	Soil REM (µg/g)	Non-cancer hazard: Total inhaled conc. (mg/m^3)	Non-cancer hazard: Inhal. TRV (mg/m^3)	Non-cancer hazard: HQ	Non-cancer hazard: Effects-based value (µg/g)	Cancer risk: Amortized inhaled conc. (mg/m^3)	Cancer risk: Inhal. TRV (mg/m^3)$^{-1}$	Cancer risk: ILCR	Cancer risk: Effects-based value (µg/g)
Dibenz[a h]anthracene	0.20	–	–	–	–	4.76E-09	6.0E-01	2.86E-09	7.14E+01
Indeno[1 2 3-cd]pyrene	0.92	–	–	–	–	2.14E-08	6.0E-02	1.29E-09	7.14E+02
Total Carcinogenic PAHs	1.95	–	–	–	–	5.08E-08	6.0E-01	3.05E-08	6.41E+01

Results also presented in Appendix B3.
Bold/italic indicates exceedance of acceptable limit.

Table 3-27: Risk Results from Soil COC Inhalation (Construction Worker)

COC	Soil REM (µg/g)	Non-cancer hazard: Total inhaled conc. (mg/m^3)	Non-cancer hazard: Inhal. TRV (mg/m^3)	Non-cancer hazard: HQ	Non-cancer hazard: Effects-based value (µg/g)	Cancer risk: Amortized inhaled conc. (mg/m^3)	Cancer risk: Inhal. TRV (mg/m^3)$^{-1}$	Cancer risk: ILCR	Cancer risk: Effects-based value (µg/g)
Antimony	50.0	1.17E-06	2.0E-04	5.84E-03	1.71E+03	–	–	–	–
Arsenic	65.3	1.52E-06	1.5E-05	1.02E-01	1.29E+02	4.08E-08	1.5E-01	6.12E-09	1.07E+04
Cadmium	4.68	1.09E-07	3.0E-05	3.64E-03	2.57E+02	2.92E-09	9.8E+00	2.87E-08	1.63E+02
Mercury	1.37	4.23E-07	9.0E-05	4.70E-03	5.83E+01	–	–	–	–
Benz[a]anthracene	1.07	–	–	–	–	1.24E-09	6.0E-02	7.44E-11	1.43E+04
Benzo[a]pyrene	1.30	3.02E-08	2.0E-06	1.51E-02	1.71E+01	8.10E-10	6.0E-01	4.86E-10	2.67E+03
Benzo[b]fluoranthene	1.64	–	–	–	–	1.03E-09	6.0E-02	6.16E-11	2.67E+04
Dibenz[a h]anthracene	0.20	–	–	–	–	1.27E-10	6.0E-01	7.65E-11	2.67E+03
Indeno[1 2 3-cd]pyrene	0.92	–	–	–	–	5.74E-10	6.0E-02	3.45E-11	2.67E+04
Total Carcinogenic PAHs	1.95	–	–	–	–	1.32E-09	6.0E-01	7.91E-10	2.47E+03

Results also presented in Appendix B3.

3.4.2.2. Summary of Risk Results and Final Human Health-Based Values

A tabular summary of all HHRA results, for all complete and incomplete exposure pathways, and all receptors, is presented in Table 3-28. Note that a more detailed discussion of the uncertainty surrounding these conclusions about human health risks is presented in Section 3.4.6.

Final calculated human health-based values for soil are summarized in Table 3-29 and Table 3-30.

Table 3-28: Summary of Risk Results

Source	Pathway	Receptor	Endpoint	Calculated Risk	Risk management Deemed Necessary
Soil	Direct Contact Pathways	Residents	C	Arsenic, PAHs	Yes; fill or hard cap cover
			Non-C	Antimony, arsenic, cadmium, lead	Yes; fill or hard cap cover
		Outdoor Workers	C	Arsenic, PAHs	Yes; fill or hard cap cover
			Non-C	No risk	No
		Construction Workers	C	Arsenic	Yes; fill or hard cap cover
			Non-C	No risk	No
			C	No risk	No

Source	Pathway	Receptor	Endpoint	Calculated Risk	Risk management Deemed Necessary
Soil	Inhalation (Particulate and Vapour)	Residents	Non-C	Mercury (Vapour and Particulate)	No; mercury unlikely to be found as a vapour; RM in the form of fill/ hard cap required.
		Outdoor Workers	C	Cadmium (Particulate)	Yes; fill or hard cap cover
			Non-C	No risk	No
		Construction Workers	C	No risk	No
			Non-C	No risk	No

Endpoints: C indicates cancer; Non-C indicates non-cancer.
- Risk: No risk for cancer endpoint indicates all calculated ILCR values below acceptable limits; for non-cancer endpoints indicates all calculated HQ values below acceptable limits.

Table 3-29: Summary of Human Health-Based Values for Soil (Outdoor Pathways)

COC	Soil REM (µg/g)	Oral/Dermal		Particulate Inhalation	
		Calculated effects-based value (µg/g)	X-fold risk reduction required	Calculated effects-based value (µg/g)	X-fold risk reduction required
Antimony	50.0	7.50	6.7	>REM	NA
Arsenic	65.3	0.19	340	>REM	NA
Cadmium	4.68	0.69	6.8	4.37	1.07
Mercury	1.37	>REM	NA	>REM	NA
Benz[a]anthracene	1.07	>REM	NA	>REM	NA
Benzo[a]pyrene	1.30	0.69	1.87	>REM	NA
Benzo[b]fluoranthene	1.64	>REM	NA	>REM	NA
Dibenz[a h]anthracene	0.20	>REM	NA	>REM	NA
Indeno[1 2 3-cd]pyrene	0.92	>REM	NA	>REM	NA

Results also presented in Appendix B3.

The human health-based standards related to indoor air pathways are presented in Table 3-30. We note that the existing building (assessed for completeness) is being demolished at the Site, therefore, the effects-based standards can be discounted/ disregarded. Mercury is not likely present at the site in an elemental form. As a result, the effects-based standards for mercury can be discounted.

Table 3-30: Summary of Human Health-Based Values for Soil (Indoor Pathways)

COC	Soil REM (µg/g)	Indoor Vapour (Generic Building)		Indoor Vapour (Existing Building)	
		Calculated effects-based value (µg/g)	X-fold risk reduction required	Calculated effects-based value (µg/g)	X-fold risk reduction required
Antimony	50.0	>REM	NA	>REM	NA
Arsenic	65.3	>REM	NA	>REM	NA
Cadmium	4.68	>REM	NA	>REM	NA
Mercury	1.37	0.0041	331	0.0027	510
Benz[a]anthracene	1.07	>REM	NA	>REM	NA
Benzo[a]pyrene	1.30	>REM	NA	>REM	NA
Benzo[b]fluoranthene	1.64	>REM	NA	>REM	NA
Dibenz[a h]anthracene	0.20	>REM	NA	>REM	NA

COC	Soil REM (µg/g)	Indoor Vapour (Generic Building) Calculated effects-based value (µg/g)	Indoor Vapour (Generic Building) X-fold risk reduction required	Indoor Vapour (Existing Building) Calculated effects-based value (µg/g)	Indoor Vapour (Existing Building) X-fold risk reduction required
Indeno[1 2 3-cd]pyrene	0.92	>REM	NA	>REM	NA

Results also presented in Appendix B3 and Appendix B4.

3.4.3. Qualitative Interpretation of Health Risks

3.4.3.1. COCs Assessed Qualitatively

Contaminants in soil at the Site that could potentially pose a risk to human or ecological health were identified in Section 3 by screening the maximum-detected concentration of each parameter against its respective SCS. Each parameter that was detected at least once at a concentration exceeding its SCS was identified as a COC and required evaluation. This section discusses the COCs that were assessed *qualitatively* with regard to their potential to pose a human health risk. COCs that were assessed qualitatively are summarized in Table 3-1. Each of these COCs was assessed qualitatively because their REM values were less than their respective human health component values (with the exception of lead, discussed below). The fact that the maximum/REM concentrations were less than applicable human health component values indicates the SCSs that served as the basis for identifying the other COCs were set based on *ecological effects*. On this basis, the qualitatively assessed COCs are considered to pose no risk to human health.

Lead was identified as a COC in soil because its maximum concentration exceeds its SCS (required to use 120 µg/g; set based on Ontario background). The potential risks from lead could not be assessed quantitatively, however, due to the lack of reliable up to date TRVs for lead. Lead is therefore assessed qualitatively as follows. Lead has the potential to adversely affect human health in a variety of ways but it is typically most well known for its association with developmental neurotoxicity in children (including effects on behaviour and intelligence, as well as other sensory, motor, and cognitive deficits). The current state of the science on the toxicological mechanism of action of lead is that although the critical health effect is a non-cancer-related endpoint, it is of sufficient toxic potency to be categorized as essentially having no threshold. Health and environment regulatory agencies in Canada and internationally that serve as the source of MECP TRVs therefore do not currently provide a threshold-based TRV for lead as they continue to review toxicity and risk information. The state of the science of lead toxicology precludes the development of a non-threshold-based TRV (i.e., analogous to that which is used to assess risk from carcinogens). Based on the above, the MECP's position is that any exposure to lead increases the risk of an adverse health effect and therefore exposure to soil containing lead should be limited, to the extent possible (guidance document dated April 28th, 2014). Any level of lead above Ontario background is therefore deemed to be unacceptable and as a result, RM measures are needed to be implemented at the Site for areas where soil concentrations exceed 120 µg/g.

3.4.3.2. Pathways Assessed Qualitatively

<u>Garden Produce Ingestion</u>

- This pathway is qualitatively identified, but not assessed quantitatively as the uncertainties surrounding this pathway are deemed too significant to model receptor exposures with any validity (e.g., quantifying uptake of the COCs into produce; confirming the types and quantities of garden produce that may be grown in any given year; determining the amount of backyard garden produce that may be consumed). If there are concerns about this pathway then risk could be managed through the use of administrative controls from MECP (e.g., require that gardens used for growing produce be restricted to gardens within raised planters). Additional details are provided in the RM section of the report.

Odours

- Soil component values for direct odour (S-Nose) and indoor air odour were not exceeded by any COC.

Free-Phase Product

- Soil component values for the expected development of free-phase product (free phase threshold) were not exceeded by any COC.

3.4.3.3. Receptors Assessed Qualitatively

As discussed in Section 3.2.1, some on-Site receptors were assessed qualitatively in this HHRA:

- Residential visitors represent people who may visit residents living at the Site. Risks to these receptors are assumed to be conservatively represented by potential risks to residents living at the Site (i.e., it is unlikely a visitor would be at the site longer than the person living there). Health effects-based values protective of residents are considered to provide adequate protection for visitors.

3.4.4. Special Considerations

The RA property is not located in an environmentally sensitive area. For example, Section 41 of O.Reg 153/04 (as amended) does not apply to the property. The RA property is not located in an area of natural significance, and does not include or is adjacent to an area of natural significance or part of such an area. Furthermore, the RA property does not include land that is within 30 m of an area of natural significance, and lastly, the soil pH is found in the standard range (i.e., pH is >5 and < 9 for surficial soil, etc.).

3.4.5. Interpretation of Off-Site Health Risks

Soil from the Site can potentially undergo fate-and-transport processes that would result in off-Site receptors being exposed to COCs from this Site. Given that risks were identified on-Site it is conceivable that off-Site receptors might also be at risk (should exposure actually be occurring). Off-Site health risks from on-Site soil are discussed qualitatively.

COCs are not reasonably expected to migrate to such an extent that concentrations would exceed soil SCS at surrounding off-Site properties. The only manner in which on-Site soil could migrate or otherwise undergo fate-and-transport to an off-Site property is via particulates blowing in the wind. Quantitative assessment of on-Site risks from soil indicate that soil particulate inhalation only contributes ~1.5% of the total exposure doses from soil for any given receptor. Given further dilution by the time particulates reach an off-Site property, and that wind blows in a variety of directions (limiting the amount of Site-derived particulates any individual off-Site receptor may inhale), risks to off-Site receptors from soil from this Site are expected to be minimal.

3.4.6. Discussion of Uncertainty

At each stage of a risk assessment, assumptions must be made due to a lack of scientific certainty. The use of assumptions introduces some degree of uncertainty into the risk assessment process. As such, to the extent possible, conservative assumptions are made throughout the risk assessment to ensure that estimates of risks to human receptors are exaggerated rather than underestimated. The predominant uncertainties of each of the main steps of the risk assessment were discussed in their respective sections (Problem Formulation, Exposure Assessment, Toxicity Assessment). This section will provide a more in-depth discussion of the potential risks and uncertainties.

3.4.6.1. Uncertainty of Risk Assessment Results

The main risk from soil COCs was preliminarily identified for residents:

- Antimony, arsenic, cadmium, and lead were each identified as posing a potential risk via direct contact. Based on the information provided by Bluewater, these impacts are primarily found in the west corner of the site (BH-2), at a depth of 0.3 to 1.35 m below grade. No soil samples were collected from shallower depths therefore it is unclear if impacts extend to the surface. On this basis, there is some uncertainty regarding the potential for any residential receptors to contact metal-impacted soil. In general, typical digging activities at a residential site by residents include gardening activities, and these are generally completed at shallower depths (e.g., maximum of 1 foot, or ~30 cm).
- Mercury was initially identified as posing a potential risk via indoor vapour intrusion, however the RA calculations and method had *assumed* that mercury is present in an elemental form. It is not feasible for mercury to be in a elemental form at the site, rather it would be present as a mercury(II) complex (mercury(II)oxide or mercury(II)sulphide complexes). These forms are not volatile, and as a result no risk management measures are deemed necessary to address mercury at the Site.
- Numerous polycyclic aromatic hydrocarbons (PAHs) were identified as posing a potential risk via direct contact. Based on the information provided by Bluewater, these impacts are primarily found in the south corner of the site (BH-6), at a depth of 0 to 1.35 m below grade.

Additional risks were preliminarily identified for outdoor workers, via soil contact (arsenic, lead, and PAHs) and soil particulate inhalation (cadmium). Outdoor workers were modelled as being at the site 9.8 hours/day, 195 days/year, 56 years, which is not considered realistic for a residential site. Even with this conservatism, the calculated risks are marginal for PAHs (2-3X fold risk reduction required) and cadmium (1.1X fold risk reduction required). The calculated risk for arsenic required a 340X-fold risk reduction, which may require RM measures to be implemented.

Finally, a potential risk was preliminarily identified for construction workers, via soil contact (arsenic, requiring a 9.1X-fold risk reduction, as well as lead). Construction workers may access soils at deeper depths, during trenching or excavation activities. It is recommended that a health and safety plan be developed by a Competent person as defined under the Occupational Health and Safety Act (Ontario, 2018) prior to construction, excavation or trenching activities being completed at the Site.

4. Conclusions and Recommendations

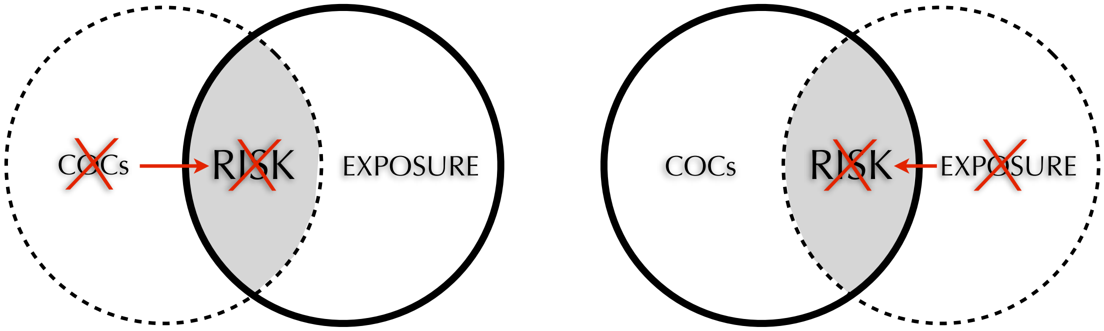
The Site will be developed as residential. Based on the results of the RA, the main findings of the HHRA were as follows:

Residential Receptors: Residents have ben calculated to have unacceptable risk as a result of potential exposure to metals and PAHs at the Site, through direct contact pathways.

Outdoor workers and construction workers: These receptors have also been calculated to have unacceptable risks as a result of oral and dermal contact with soil at the Site.

4.1. Recommendations

The fundamental concept behind risk management involves eliminating the exposure pathways between contaminated media and human receptors (see figure below). In cases where elimination of an exposure pathway is not feasible (e.g., for construction workers), then a Health and Safety Plan (H&SP) is required.



Risk is managed by managing one of the key contributing elements of risk. That is, either by (i) eliminating COCs by remediating contaminated soil or groundwater, or (ii) (more commonly) eliminating exposure pathways between contaminants and receptors (e.g., natural barriers such as a layer or 'cap' of clean soil; artificial barriers such as asphalt and geotextile vapour membranes; 'personal barriers' such as personal protective equipment for construction workers; administrative measures such as restrictions on potable wells).

Based on the information provided by Bluewater, metal COCs in soil are predominantly found at a depth of 0.3 to 1.35 m below grade. It is not known whether the surficial soil profile from 0 (surface) to 0.3 m below grade is also impacted, however we must assume that it is. Therefore, effectively, soil impacts across the north portion of the Site extend from 0 to 1.35 m bgs.

The development plan is to install a row of new residential houses that front Emslie St. There will be a need to build up the grade in the front area of the houses, to backfill the foundations/ and walls of the new structures. In addition, fill will need to be added to raise the grade prior to installing the driveways (which will connect to Emslie St., the front of the houses).

There is only a single area located around BH-6 that is potentially impacted with lead greater than 120 µg/g at BH-6 (extending to a depth of 1.35 mbgs). This area should be excavated, and the soils that are excavated (i.e., brought to the surface) should be moved and deposited towards/ or adjacent to Emslie Street up to the limits of the "Red Highlighted Line" and then covered by a minimum of 1m of clean fill. The excavation should be completed to a depth of 1.0 m bgs at and around BH-6 and extend outward 1-2 m maximum until a clean-line (i.e., delineated lead is found to be < 120 µg/g). If any soils are scrapped they can also be deposited towards and adjacent to Emslie street.

Once the impacts at BH-6 are dealt with and addressed, additional loads of backfill (meeting Table 1 or Table 6 site condition standards (T1 SCS or T6 SCS) should be brought to the site and deposited over the impacts that extend from BH-2 towards BH-4. The areas are depicted in Figure 1. These areas are approximate, and should be confirmed with the QPESA that prepared the Phase Two ESA at the Site.

If any additional excavation activities are to occur on the Site (i.e., for the purpose of installing a piping or infrastructure), the soils that are excavated can and should be deposited within the "Red Highlighted Area" depicted on Figure 1, and then covered with a minimum 1m of soil meeting T1 or T6 SCS (T6 are the same as T2 SCS for soil). We also recommend that following the installation of piping or other infrastructure work activities, clean un-impacted soil (fill cap barriers) meeting the applicable SCS (i.e., Table 1 or Table 6/T2 SCS), and subject to requirements under the On-Site and Excess Soils Management Regulations (O.Reg. 406./19) be installed over buried infrastructure. A warning tape, as appropriate for the type of service should also be installed over the infrastructure prior to back-filling.

The recommended RM measures are outlined as follows:

Recommended Risk Management Measures

<u>RM Measure # 1. Implement a Health and Safety Plan (HASP):</u>

To mitigate risks to construction or utility workers, the following measures are recommended:

A health and safety plan (HASP) should be prepared by a Competent individual as defined under the *Ontario Health and Safety Act* and must be implemented prior to any excavation which may extend to depths intersecting impacted soil at the site (e.g., around BH-6). The HSP should be designed to protect construction workers from potential exposure to arsenic and lead in soil. The HSP shall be specific to the planned excavation and must consider the COCs at the site and make provision for occupational hygiene, personal protective equipment, contingency measures and documentation.

At a minimum, the health and safety plan shall include the following:

1. The procedures and timing for implementing the plan, including the supervision of persons implementing the plan;
2. All relevant information concerning the presence of, human exposure to, and risk posed by, the Contaminants of Concern (i.e., lead, cadmium, PAHs) through dermal contact, soil ingestion and inhalation of soil particles that may be present at the Property including information in the Risk Assessment,
3. All relevant information, measures and procedures concerning protection of the persons from exposure to the Property Specific Contaminants of Concern and the precautions to be taken when undertaking Intrusive Activities, including the supervision of workers, occupational hygiene requirements, use of personal protective equipment, provision of air flow augmentation in excavations or other areas or situations of minimal air ventilation, and other protective measures and procedures as appropriate;
4. All relevant information concerning the presence and significance of the risk management measures and requirements which are being, or have been, implemented at the Property,
5. The procedures and timing for implementing emergency response and contingency measures and procedures, including contact information, in the event of a health and safety incident; and
6. The recording, in writing, of the implementation of the plan and any health and safety incidents that occur, to be retained by the Owner;

and which is,

7. Delivered to the Owner before any Intrusive Activities are undertaken at the Property; and
8. Updated and delivered to the Owner within 30 days following making any alteration to the plan.

Note that there is a requirement under O. Reg. 231/91, Section 230 to de-water trenches prior to entry. Dewatering of trenches will minimize co-exposure to COCs sourced from groundwater for construction/ utility workers (through direct contact pathways).

Within the HASP, we recommend the following:

- All persons conducting subsurface activities or other earthworks at the site should wear long sleeves and long pants which provide full coverage to arms and legs. Dirty work gear should be sealed in isolated container(s) when leaving the work area, and either properly disposed or thoroughly washed prior to reuse.
- Safety glasses should also be worn.
- Cloth, leather, rubber (or similar material) work gloves should be worn. Work gloves should be left at the site and disposed of with municipal waste upon completion of their use at the site.
- CSA-approved construction or rubber boots should be worn by all persons working at the site. The boots should be thoroughly cleaned so as to remove all loose dirt prior to leaving the site.
- No smoking, drinking or eating shall be permitted in active trench or excavation work areas on the site.

- The contractor shall provide hand washing stations on site, which shall be used by all workers prior to smoking, drinking or eating.
- The HSP should be maintained at the Site, and a hard copy shall be made available to all workers. The HSP is required in all areas across the Property where trenches or other excavation activities will be completed within the "Red Highlighted Areas" listed on Figure 1.

RM Measure # 2. Fill and Hard Cap Barriers

A fill (i.e., soil) cap or hard cap (i.e., building(s), asphalt driveways, concrete patios) barrier (as defined under the Ministry's Approved Model (MECP, 2016) is needed in areas of the Site where the levels of COCs exceed the effects based standards. These areas are depicted on Figure 1 as the "*Red Highlighted Area*" and areas around BH-6. The fill cap or hard cap RM measures must consider the following:

a. Covering of specific areas of the Site (refer to Figure 1, consisting of the "Red Highlighted Areas") where Contaminants of Concern are present at or within 1.0 m below ground surface to ensure that the necessary hard cap barrier or fill cap barrier thickness (as defined under the MGRA Approved model) is in place in these areas, so as to prevent exposure to the Contaminants of Concern at the Site, in conjunction with any existing barriers in any other areas of the Site where the Contaminants of Concern are present below the soil surface;

b. Before commencing development of all or any part of the Site, installing fencing and implementing dust control measures for any part of the Site requiring covering (e.g., all "Red Highlighted Areas" depicted on Figure 1, but which has not been covered, so as to restrict access to the part fenced and prevent exposure to the Contaminants of Concern at the Site, with the fencing and dust control measures to be maintained until covering of the part fenced is complete, or until the impacts at BH-6 delineated laterally are moved adjacent to Emslie Street;

c. Ensuring the impacts are covered sufficiently with 1 m of clean (T1 or T2 SCS) soils or hard capping to ensure the continuing integrity of each barrier at the Property so long as the Contaminants of Concern are present at the Site, including, at a minimum:
   i. inspections by a Qualified Person (QPESA, in conjunction with a QPRA) after the fill or hard cap barrier(s) have been put into place and prior to transferring ownership of the property on-title;
   ii. noting any deficiencies in the Barrier observed during the inspections, and correcting those deficiencies;
   iii. obtaining written confirmation by a Qualified Person that the Barrier has been properly installed, to be retained by the builder;
   iV. recording, in writing, the inspections, deficiencies, and implementation notes, to be retained by the builder;

   and which is,

   vii. maintained on file, before use of all or any part of the Site begins by a new property owner, or within 90 days following completion of covering of all or any part of the Site, whichever is earlier; and
   viii. updated and maintained on file, following making any alteration to the fill or hard cap barriers as development is completed and prior to transferring ownership of the properties to a new land owner;

d. Preparing a site plan of the (entire) individual property(ies) (located on the Site), prepared by a qualified person (QPESA) and to be retained by the developer, showing the Property, any fencing, and the location, type and design of each Barrier at the Property, including cross-sectional drawings of the Barrier showing its design and vertical and lateral extent;

   and which is,

   i. prepared before use of all or any part of the Property begins by a new purchaser, or within 90 days following completion of covering of all or any part of the Property, whichever is earlier; and

ii. updated and maintained on file, following making any alteration to the location, design or extent of the Barrier, or other relevant feature shown on the site plan; and

e. Preparing and implementing written procedures, prepared by Qualified Person and to be retained by the developer and builder, for written and oral communication to all persons who may be involved in Intrusive Activities at the Property that may disturb a Barrier at the Property, so as to ensure the persons are made aware of the presence and significance of the Barrier and the Property Specific Contaminants of Concern at the Property and the precautions to be taken to ensure the continued integrity of the Barrier when undertaking the Intrusive Activities, and if damaged, to ensure that the Barrier is repaired promptly to the original design specifications, or, if it cannot be repaired promptly, to ensure that the contingency measures are implemented, and records kept, as specified in the inspection and maintenance program;

   and which are,

   i. maintained on file, before any Intrusive Activities are undertaken at the Property; and
   ii. updated and maintained on file, following making any alteration to the procedures.

5. Closure

This report has been prepared and the work referred to in this report has been undertaken by NovaTox for Mezcon Construction Limited. It is intended for the sole and exclusive use of Mezcon Construction Limited, and any contractors that he hires for use at the Site. Any use, reliance on, or decision made by any person other than Mezcon Construction Limited based on this report is the sole responsibility of such other person. NovaTox makes no representation or warranty to any such other person with regard to this report and the work referred to in this report and accepts no duty of care to any person and any liability or responsibility whatsoever for any losses, expenses, damages, fines, penalties, or other harm that may be suffered or incurred by any other person as a result of the use of or reliance on any decision made or any action taken based on this report or the report of the work referred to in this report. Any conclusions or recommendations made in this report reflect NovaTox's best judgment based on information available at the time of the report's preparation based, in part, on monitoring at various locations of the site, and specific analysis of specific chemical parameters and materials during a specific time interval, all as described in this report and other reports referenced herein.

Other than by Mezcon Construction Limited, copying or distribution of this report or use of or reliance on the information contained herein, in whole or in part, is not permitted without the express written permission of NovaTox, or Mezcon Construction Limited. Nothing in this report is intended to constitute or provide a legal opinion.

We trust the enclosed report satisfies your requirements at this time. If you have any questions or concerns, please contact the undersigned.

NovaTox Inc.
per,

Mark J Chappel, M.Sc., DABT, QP_{RA}
Principal Toxicologist, Vice President

Kevin Haines, MSc., DABT, QP_{RA}
Senior Toxicologist

6. References

MOE (2005) Procedures of Use of Risk Assessment under Part XV.1 of the Environmental Protection Act. Ontario Ministry of the Environment, Standards Development Branch, Toronto. PIBs 5404e. October 2005.

MOE (2011a) Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario. Standards Development Branch, Ontario Ministry of the Environment, Toronto, Ontario. PIBS 7386e01. April 15, 2011.

MOE (2011b) Soil, Ground Water and Sediment Standards for Use Under Part XV.1 of the *Environmental Protection Act*. Ontario Ministry of the Environment, Toronto, Ontario. PIBS #7382e01. April 15, 2011.

Figures

NovaTox
10 Crane Avenue, Guelph, Ontario
1-877-680-7256 • http://novatox.ca

Project: 151 Bristol Street, Guelph, Ontario	Project No.: 20-538	**Figure 1: Site/Sampling Locations, Risk Management Location Plan**
Client: Bluewater Geoscience Consultants Inc.	Date: Apr. 2021	

Contaminant Source	Fate and Transport Pathway (or Site Activity)	Exposure Medium	Biological Pathway	On-Site Receptors CW	On-Site Receptors OW	On-Site Receptors IW	On-Site Receptors Vis	On-Site Receptors Res			Off-Site Receptors CW	Off-Site Receptors OW	Off-Site Receptors IW	Off-Site Receptors CM
Soil	Traversing the Site	Soil	Ingestion											
			Dermal Contact											
	Entrainment	Particulates in Outdoor Air	Inhalation											
	Volatilization	Vapours in Outdoor Air	Inhalation											
			Vapour Contact	N	N			N						
			Odours											
		Vapours in Trench Air	Inhalation											
			Vapour Contact	N										
			Odours											
		Vapours in Indoor Air	Inhalation											
			Vapour Contact					N						
			Odours											
	Bioaccumulation	Garden Produce	Ingestion											
Groundwater	Potable Well Installation	Potable Water	Ingestion											
			Dermal Contact											
	Pooling at Bottom of Trench	Trench Water	Ingestion											
			Dermal Contact											
	Volatilization	Vapours in Outdoor Air	Inhalation											
			Vapour Contact											
			Odours											
		Vapours in Trench Air	Inhalation											
			Vapour Contact											
			Odours											
		Vapours in Indoor Air	Inhalation											
			Vapour Contact											
			Odours											

Legend

→		On-Site exposure pathway is complete, and QUANTITATIVELY assessed.
→		On-Site exposure pathway is complete, and QUALITATIVELY assessed. N refers to negligible pathway
→	–	On-Site exposure pathway is potentially complete, but is NEGLIGIBLE and NOT ASSESSED.
→		Off-Site exposure pathway is potentially complete, but off-site risks are NOT ASSESSED in HHRA.
→		Exposure pathway is INCOMPLETE (NOT ASSESSED in the HHRA).

Receptors: CW = construction worker; OW = outdoor worker; IW = indoor worker; Pat. = commercial patron; Res. = resident; Vis. = residential visitor; Tres. = trespasser; CM = off-site community members, including residents, recreators, commercial patrons, etc

NovaTox
10 Crane Avenue, Guelph, Ontario
1-877-680-7256 • http://novatox.ca

Project: 151 Bristol Street, Guelph, Ontario

Client: Mezcon Construction Ltd.

Project No.: 20-538

Date: April 2021

Figure 2: Human Health Conceptual Site Model - No RM Applied

Contaminant Source	Fate and Transport Pathway (or Site Activity)	Exposure Medium	Biological Pathway	On-Site Receptors CW	OW	IW	Vis	Res			Off-Site Receptors CW	OW	IW	CM
Soil	Traversing the Site	Soil	Ingestion											
			Dermal Contact											
	Entrainment	Particulates in Outdoor Air	Inhalation											
	Volatilization	Vapours in Outdoor Air	Inhalation											
			Vapour Contact	N	N			N						
			Odours											
		Vapours in Trench Air	Inhalation											
			Vapour Contact	N										
			Odours											
		Vapours in Indoor Air	Inhalation											
			Vapour Contact					N						
			Odours											
	Bioaccumulation	Garden Produce	Ingestion											
Groundwater	Potable Well Installation	Potable Water	Ingestion											
			Dermal Contact											
	Pooling at Bottom of Trench	Trench Water	Ingestion											
			Dermal Contact											
	Volatilization	Vapours in Outdoor Air	Inhalation											
			Vapour Contact											
			Odours											
		Vapours in Trench Air	Inhalation											
			Vapour Contact											
			Odours											
		Vapours in Indoor Air	Inhalation											
			Vapour Contact											
			Odours											

Legend

→		Blocked exposure pathway (potential risk was identified based on quantitative assessment; risk management measures will block exposure and will also be protective of receptors assessed qualitatively).
→		Exposure pathway with no risk (based on QUANTITATIVE assessment).
→		Exposure pathway with no risk (based on QUALITATIVE assessment). (e.g., mercury not found in vapour form)
→	–	Exposure pathway with no risk (negligible exposure).
→		Off-site risks are not assessed in HHRA (RM measures not applicable).
→		Exposure pathway is INCOMPLETE (RM measures not applicable).

Receptors: CW = construction worker; OW = outdoor worker; IW = indoor worker; Pat. = commercial patron; Res. = resident; Vis. = residential visitor; Tres. = trespasser; CM = off-site community members, including residents, recreators, commercial patrons, etc

NovaTox
10 Crane Avenue, Guelph, Ontario
1-877-680-7256 • http://novatox.ca

Project: 151 Bristol Street, Guelph, Ontario

Client: Mezcon Construction Ltd.

Project No.: 20-538

Date: April 2021

Figure 3:
Human Health Conceptual Site Model with Risk Management Applied

Appendix A

Analytical Data Tables (Soil; reproduced from Bluewater Geoscience)

Table 1: Laboratory VOC Soil Analysis
151 Bristol Street, Guelph
BG-770

Parameter	Ont. Reg. 153/04 Table 6 RPI SCS coarse-texture (ug/g)	BH-2, CS-1 0.3 - 1.35 m (ug/g)	BH-4, CS-1 0.0 - 1.05 m (ug/g)
Acetone	16	<0.5	<0.5
Benzene	0.21	<0.0068	<0.0068
Bromodichloromethane	1.5	<0.05	<0.05
Bromoform	0.27	<0.05	<0.05
Bromomethane	0.05	<0.05	<0.05
Carbon tetrachloride	0.05	<0.05	<0.05
Chlorobenzene	2.4	<0.05	<0.05
Dibromochloromethane	2.3	<0.05	<0.05
Chloroform	0.05	<0.05	<0.05
1,2-Dibromomethane	0.05	<0.05	<0.05
1,2-Dichlorobenzene	1.2	<0.05	<0.05
1.3-Dichlorobenzene	4.8	<0.05	<0.05
1,4-dichlorobenzene	0.083	<0.05	<0.05
Dichlorodifluoromethane	16	<0.05	<0.05
1,1-Dichloroethane	0.47	<0.05	<0.05
1,2-Dichloroethane	0.05	<0.05	<0.05
1,1-Dichloroethylene	0.05	<0.05	<0.05
cis-1,2Dichloroethylene	1.9	<0.05	<0.05
trans-1,2Dichloroethylene	0.084	<0.05	<0.05
1,3-Dichloropropene	0.05	<0.042	<0.042
Methylene Chloride	0.1	<0.05	<0.05
1,2-Dichloropropane	0.05	<0.05	<0.05
cis-1,3-Dichloropropene	0.05	<0.03	<0.03
trans-1,3-Dichloropropene	0.05	<0.03	<0.03
Ethyl benzene	1.1	<0.018	<0.018
Hexane	2.8	<0.05	<0.05
Methyl ethyl ketone	16	<0.5	<0.5
Methyl isobutyl Ketone	1.7	<0.5	<0.5
MTBE	0.75	<0.05	<0.05
Styrene	0.7	<0.05	<0.05
1,1,1,2-tetrachloroethane	0.058	<0.05	<0.05
1,1,2,2-tetrachloroethane	0.05	<0.05	<0.05
Tetrachloroethylene	0.28	<0.05	<0.05
Toluene	2.3	<0.08	<0.08
1,1,1-trichloroethane	0.38	<0.05	<0.05
1,1,2-trichloroethane	0.05	<0.05	<0.05
Trichloroethylene	0.061	<0.01	<0.01
Trichlorofluoromethane	4	<0.05	<0.05
Vinyl Chloride	0.02	<0.02	<0.02
Xylenes)Total)	3.1	<0.05	<0.05

Table 2: Laboratory Soil PHC Analysis
151 Bristol Street, Guelph
BG-770

Parameter	Ont. Reg. 153/04 Table 6 RPI SCS Coarse soil (ug/g)	BH-2, CS-1 0.3 - 1.35 m (ug/g)	BH-4, CS-1 0.0 - 1.05 m (ug/g)
PHC-F1 (C6-C10)	55	<5	<5
PHC F1-BTEX	55	<5	<5
PHC-F2	98	<10	<10
PHC-F3	300	152	59
PHC-F4	2800	78	<50

Values shown in **BOLD** exceed Table 6 RPI SCS
RPI = residential/parkland/institutional land use

Table 3: Laboratory PAH Soil Analysis
151 Bristol Street, Guelph
BG-770

Parameter	Ont. Reg. 153/04 Table 6 SCS Coarse Soil RPI Land Use	BH-1, CS-1 0.0 - 1.05 m (ug/g)	BH-3, CS-1 0.3 - 1.2 m (ug/g)	BH-5, CS-1 0.0 - 0.6 m (ug/g)	BH-6, CS-1 0.0 - 1.35 m (ug/g)
Acenaphthene	7.9	<0.05	<0.05	<0.05	<0.05
Acenaphthylene	0.15	<0.05	<0.05	0.072	**0.274**
Anthracene	0.67	<0.05	<0.05	<0.05	0.138
Benzo(a)anthracene	0.5	<0.05	<0.05	0.228	**0.888**
Benzo(a)pyrene	0.3	<0.05	<0.05	0.249	**1.08**
Benzo(b)fluoranthene	0.78	<0.05	<0.05	0.355	**1.37**
Benzo(ghi)perylene	6.6	<0.05	<0.05	0.192	0.929
Benzo(k)fluoranthene	0.78	<0.05	<0.05	0.116	0.386
Chrysene	7	<0.05	<0.05	0.226	0.839
Dibenzo(ah)anthracene	0.1	<0.05	<0.05	<0.05	**0.17**
Fluoranthene	0.69	<0.05	<0.05	0.388	**1.41**
Fluorene	62	<0.05	<0.05	<0.05	<0.05
Indeno(123,cd)pyrene	0.38	<0.05	<0.05	0.172	**0.766**
1+2 Methylnaphthalene	0.99	<0.042	<0.042	<0.042	<0.042
1-Methylnaphthalene	0.99	<0.03	<0.03	<0.03	<0.03
2-Methylnaphthalene	0.99	<0.03	<0.03	<0.03	0.037
Naphthalene	0.6	<0.013	<0.013	<0.013	0.049
Phenanthrene	6.2	<0.046	<0.046	0.133	0.447
Pyrene	78	<0.05	<0.05	0.358	1.43

Values shown in **BOLD** exceed Table 6 RPI SCS
RPI = residential/parkland/institutional land use

Table 4: Laboratory Metals & Inorganics Soil Analysis
151 Bristol Street, Guelph
BG-770

Parameter	Ont. Reg. 153/04 Table 6 SCS Coarse Soil RPI Land Use	BH-1, CS-1 0.0 - 1.05 m (ug/g)	BH-2, CS-1 0.3 - 1.35 m (ug/g)	BH-3, CS-1 0.3 - 1.2 m (ug/g)	BH-4, CS-1 0.0 - 1.05 m (ug/g)	BH-5, CS-1 0.0 - 0.6 m (ug/g)	BH-6, CS-1 0.0 - 1.35 m (ug/g)
Conductivity	0.7	0.315	0.397	0.274	0.287	0.484	0.202
pH		8.4	7.2	8.29	7.45	7.63	7.67
SAR	5	0.54	0.48	0.42	<0.1	0.73	0.11
Cyanide	0.051	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Antimony	7.5	<1	**41.7**	<1	7.1	<1	<1
Arsenic	18	1.8	**54.4**	3.7	**19.4**	2.4	5.9
Barium	390	2.8	**733**	6.1	236	24.7	107
Beryllium	4	<0.5	<2	<0.5	0.63	<0.5	<0.5
Boron	120	<5	<100	<5	10.7	<5	<5
Boron HWE	1.5	<0.1	0.74	<0.1	0.92	0.28	0.26
Cadmium	1.2	<0.5	**3.9**	<0.5	0.81	<0.5	1.02
Chromium	160	2.3	28	2.6	22.7	4.9	13
Cobalt	22	<1	6.4	<1	8.5	<1	4.9
Copper	140	1.1	**251**	2	49.1	8.8	27.2
Lead	120	4.1	**871**	6.2	**406**	52.3	**190**
Mercury	0.27	0.0055	**1.14**	0.0143	**1.01**	0.095	0.245
Molybdenum	6.9	<1	<2	<1	3.2	<1	1.2
Nickel	100	1.2	17	1.1	19.5	2.8	10.7
Selenium	2.4	<1	<4	<1	1.4	<1	<1
Silver	20	<0.2	<2	<0.2	0.29	<0.2	<0.2
Thallium	1	<0.5	<1	<0.5	<0.5	<0.5	<0.5
Uranium	23	<1	1.2	<1	<1	<1	<1
Vanadium	86	7.6	30.8	6.8	35.6	8.8	23.1
Zinc	340	19.9	**2610**	23.6	**435**	70.4	158
Chromium 6	8	<0.2	<0.2	<0.2	<0.2	<0.2	0.29

Appendix B

Appendix B: Human Health Equations and Results

				Coarse/ Med/Fine	Coarse/ Med/Fine	Coarse/ Med/Fine *sub-surface*	Coarse/ Med/Fine	Coarse	Coarse	Coarse	Coarse	Coarse
				Res.	Comm./Ind.	Comm./Ind.		Res.	Res.			
Soil COC	**Maximum soil conc. (µg/g)**	**REM (µg/g)**	**Ontario Generic SCS (Table 6)**	**Contact S1**	**Contact S2**	**Contact S3**	**Outdoor Air Inhalation S-OA**	**Indoor Air Inhalation S-IA**	**Indoor Air Odour S-O**	**Direct Odour Nose**	**Leaching S-GW-1**	**Free phase threshold**
Antimony	41.7	50.0	7.5	*7.5*	63	63	–	–	–	–	–	8,000
Arsenic	54.4	65.3	18	*0.95*	*1.3*	*47*	–	–	–	–	–	12,000
Barium	733	880	390	3,800	32,000	8,600	–	–	–	–	–	7,700
Cadmium	3.9	4.68	1.2	*0.69*	7.9	7.9	–	–	–	–	–	18,000
Copper	251	301	140	600	5,600	5,600	–	–	–	–	–	–
Lead	871	1,045	120	*120*	*120*	*120*	–	–	–	–	–	24,000
Mercury	1.14	1.37	0.27	9.8	67	670	36	*0.25*	–	–	550	34,000
Zinc	2,610	3,132	340	5,600	47,000	47,000	–	–	–	–	–	15,000
Acenaphthylene	0.274	0.33	0.15	7.8	9.6	360	96	0.45	–	–	2.3	2,900
Benz[a]anthracene	0.888	1.07	0.5	*0.78*	*0.96*	36	330	65	–	–	190	7,700
Benzo[a]pyrene	1.08	1.30	0.3	*0.078*	*0.096*	3.6	170	820	–	–	6.6	7,700
Benzo[b]fluoranthene	1.37	1.64	0.78	*0.78*	*0.96*	36	2,000	5,500	–	–	67	7,700
Dibenz[a h]anthracene	0.17	0.20	0.1	*0.078*	*0.096*	3.6	430	33,000	–	–	22	7,700
Fluoranthene	1.41	1.69	0.69	7.8	9.6	360	2,500	250	–	–	24	7,700
Indeno[1 2 3-cd]pyrene	0.766	0.92	0.38	*0.78*	0.96	36	4,000	46,000	–	–	220	7,700
TOTAL CARC. PAHs (13 carcinogenic PAHs were adjusted for B(a)P equivalence and then summed. See table (i) on the Appendix B1(a) sheet for calculation of max.)	1.63	1.95	–	–	–	–	–	–	–	–	–	–

Notes:

- Reasonable estimate of the maximum (REM) used for exposure and risk calculations and is the indicated maximum plus 20%.
- Ontario MECP Generic SCS are Table 6 Residential/Parkland/Institutional, for coarse soils.
- Other values are human health component values that factored into the derivation of the SCS (where the REM exceeds a component value, the component value is highlighted yellow).
- If a COC was identified as only requiring assessment via one pathway (e.g., contact or inhalation) it was nonetheless conservatively also assessed via the other pathway if possible (i.e., it was assessed via both contact and inhalation). This was for comprehensiveness and ease of RA preparation and review (i.e., the same soil COC list is maintained throughout each table of the exposure assessment and risk characterization sections). In this regard, all COCs identified as requiring quantitative assessment were conservatively assessed via pathways for which no component values are available (e.g., construction worker exposure to vapours while in a trench or excavation).

Lookup Table (i)

		Soil (ug/g)	
Carcinogenic PAH	**TEF**	**Max**	**BaP Equiv.**
Acenaphthene	0.001	0.05	0.00005
Acenaphthylene	0.01	0.274	0.00274
Anthracene	0.01	0.138	0.00138
Benz(a)anthracene	0.1	0.888	0.0888
Benzo(a)pyrene	1	1.08	1.08
Benzo(b/j)fluoranthene	0.1	1.37	0.137
Benzo(g,h,i)perylene	0.01	0.929	0.00929
Benzo(k)fluoranthene	0.1	0.386	0.0386
Chrysene	0.01	0.839	0.00839
Dibenzo[a,h]anthracene	1	0.17	0.17
Fluoranthene	0.01	1.41	0.0141
Indeno(1,2,3-cd)pyrene	0.1	0.766	0.0766
Pyrene	0.001	1.43	0.00143
TOTAL Carcinogenic PAHs			1.62838

Notes:
- TEFs obtained from MOE (2011) Rationale Document (citing Kalberlah et al., 1995)
- Max concentration of 'Total Carcinogenic PAHs' in soil is converted to a REM concentration for exposure calculations.

Site Characteristics				
Category	**Site Characteristic**	**Symbol**	**Units**	**Value**
Water Potability	Potability of groundwater		–	Potable
J&E Building Inputs	Type of Building		–	Residential Building-with-Basement
	Length		cm	1,225
	Width		cm	1,225
	Height (of mixing zone)		cm	366
	Slab Thickness	Lcrack	cm	8
	Depth below grade to bottom of floor	L_F	cm	158
	Crack depth below grade	X_{crack} or Z_{crack}	cm	158
	Crack Width	w	cm	0.1
	Pressure Differential, Building - Soil	Δp	g/cm-sec2	40
	Air Exchange Rate	ER	1/hour	0.3
	Flow rate of soil vapour into building (or leave blank)	Q_{SOIL}	L/min	8.45
	Floor-wall seam perimeter	X_{crack}	cm	4,900
	Building ventilation rate	$Q_{building}$	cm^3/s	4.58E+04
	Area of enclosed space below grade	A_B	cm^2	2.27E+06
	Crack-to-total area ratio	η	–	2.15E-04
J&E Soil Inputs	Depth below grade to top of contaminated soil	zsoil or L_t	cm	0
	Depth to contaminated soil used in indoor model	zsoil or L_t	cm	188
	Soil Source-bldg. separation	L_T	cm	30.00
	Soil Stratum A - Thickness	h_A	cm	158
	Soil Stratum B - Thickness (Soil model)	h_B	cm	29.90
	Soil Stratum C - Thickness (Soil model)	h_C	cm	0.10
	MECP Source Depletion Multiplier (SDM) Applied	SDM	unitless	Yes
	Depth below grade to bottom of contaminated soil	L_b	cm	0

Building characteristics listed here obtained from Lookup Table (i) on the G1(c) sheet.

This is the shallowest depth at which any volatile soil COC exceeds its Site Condition Standard. The next cell automatically calculates the depth used in the J&E soil model. At minimum, must account for depth to bottom of floor (stratum A), plus full 29.9 cm layer of crushed gravel (stratum B). For functionality of the model NovaTox assumes that at least 0.1 cm of soil / clean fill remains as stratum C.

Source depletion model (if used) uses initial source volume of 13m X 13m X 2m (minus volume of soil that must be excavated to allow placement of building).

Parameter native to the J&E model that determines whether the source is finite (value >0) or is conservatively assumed to be infinite (value of 0). Cannot be used simultaneously with MECP SDM.

Site Characteristics Category	Site Characteristic	Symbol	Units	Value
J&E Soil Stratum A Parameters	Stratum A SCS soil type			Sand
	Stratum A soil total porosity	n^A	–	0.375
	Stratum A water filled porosity	θ_W^A	cm^3/cm^3	0.054
	Stratum A soil air-filled porosity	θ_a^A	cm^3/cm^3	0.321
	Stratum A soil dry bulk density	ρ_b^A	g/cm^3	1.66
	Stratum A soil organic carbon fraction	f_{OC}^A	–	0.005
	User defined stratum A soil vapour permeability	k_V	cm^2	
	Stratum A effective total fluid saturation	S_{te}	cm^3/cm^3	0.003
	Stratum A soil intrinsic permeability	k_i	cm^2	1.00E-07
	Stratum A soil relative air permeability	k_{rg}	cm^2	0.998
	Stratum A soil effective vapour permeability	k_v	cm^2	9.99E-08
J&E Soil Stratum B Parameters	Stratum B SCS soil type			Gravel Crush
	Stratum B soil total porosity	n^B	–	0.400
	Stratum B water filled porosity	θ_W^B	cm^3/cm^3	0.010
	Stratum B soil air-filled porosity	θ_a^B	cm^3/cm^3	0.390
	Stratum B soil dry bulk density	ρ_b^B	g/cm^3	1.60
	Stratum B soil organic carbon fraction	f_{OC}^B	–	0.000
J&E Soil Stratum C Parameters	Stratum C SCS soil type			Sand
	Stratum C soil total porosity	n^C	–	0.375
	Stratum C water filled porosity	θ_W^C	cm^3/cm^3	0.054
	Stratum C soil air-filled porosity	θ_a^C	cm^3/cm^3	0.321
	Stratum C soil dry bulk density	ρ_b^C	g/cm^3	1.66
	Stratum C soil organic carbon fraction	f_{OC}^C		0.005
J&E Miscellaneous Parameters	Soil/Groundwater temperature		°C	15
	Exposure duration		y	56
	Exposure duration	τ	s	1.77E+09
	Conversion factor	C	cm^3-kg/m^3-g	1,000

Stratum A soil characteristics listed here obtained from (or calculated from) the values listed in Lookup Table (ii) on the G1(c) sheet.

Stratum B soil characteristics listed here obtained from (or calculated from) the values listed in Lookup Table (ii) on the G1(c) sheet.

Stratum C soil characteristics listed here obtained from (or calculated from) the values listed in Lookup Table (ii) on the G1(c) sheet.

NovaTox

Site Characteristics Category	Site Characteristic	Symbol	Units	Value
Outdoor Vapour Modelling Inputs	Depth below grade to contaminated soil		cm	0 (assumes surface contamination)
	Depth below grade to contaminated GW	L_{gw}	cm	5
	Soil type for the outdoor model			Sand
	Outdoor Model: Capillary zone thickness	h_c	cm	1.250
	Outdoor Model: Capillary zone total porosity	n_{CZ}	cm^3/cm^3	0.375
	Outdoor Model: Capillary zone water-filled porosity	$\theta_{w,cz}$	cm^3/cm^3	0.253
	Outdoor Model: Capillary zone air-filled porosity	$\theta_{a,cz}$	cm^3/cm^3	0.122
	Outdoor Model: Vadose zone thickness	h_v	cm	3.750
	Outdoor Model: Vadose zone total porosity	E_t	cm^3/cm^3	0.375
	Outdoor Model: Vadose zone water-filled porosity	Θ_{ws}	cm^3/cm^3	0.054
	Outdoor Model: Vadose zone air-filled porosity	Θ_{as}	cm^3/cm^3	0.321
	Soil fraction organic carbon	ƒoc	–	0.005
	Soil bulk density	B	g/cm^3	1.66
	Mean annual wind speed	U	cm/s	410
	Width of contaminant source (max = “breathing zone”)	W_c	cm	1,000
	Mixing zone height = Height of “breathing zone”	δ_{AIR}	cm	200
	Depth (thickness) of contaminated soil (default value)	D_c	cm	200
	Averaging time for flux	t	s	31,536,000
Trench Vapour Modelling Inputs	Depth below trench to contaminated soil		cm	0 (assumes surface contamination)
	Depth below trench to contaminated GW	$L_{tr\text{-}gw}$	cm	1
	Soil type for the trench model			Sand
	Trench Model: Capillary zone thickness	h_c	cm	0.250
	Trench Model: Capillary zone total porosity	n_{CZ}	cm^3/cm^3	0.375
	Trench Model: Capillary zone water-filled porosity	$\theta_{w,cz}$	cm^3/cm^3	0.253
	Trench Model: Capillary zone air-filled porosity	$\theta_{a,cz}$	cm^3/cm^3	0.122
	Trench Model: Vadose zone thickness	h_v	cm	0.750
	Trench Model: Vadose zone total porosity	E_t	cm^3/cm^3	0.375
	Trench Model: Vadose zone water-filled porosity	Θ_{ws}	cm^3/cm^3	0.054
	Trench Model: Vadose zone air-filled porosity	Θ_{as}	cm^3/cm^3	0.321
	Soil fraction organic carbon	ƒoc	–	0.005
	Soil bulk density	B	g/cm^3	1.66
	Mean annual wind speed	U	cm/s	410
	Fraction of total wind speed that occurs in trench	F_t	–	0.25
	Air exchange rate in trench = $(UxFxLxD)/V_{trench}$	AXR	s^{-1}	0.51250
	Width of contaminant source (max = “breathing zone”)	W_c	cm	1,000
	Trench length	L_{tr}	cm	1,000
	Trench width	W_{tr}	cm	200
	Trench depth (= mixing zone height / “breathing zone”)	$D_{tr} = \delta_{AIR}$	cm	200
	Trench volume	V_{tr}	cm^3	40,000,000
	Averaging time for flux	t	s	31,536,000

Shallowest depth at which groundwater has been observed at the site.

For outdoor vapour modelling, Atlantic PIRI (2003) (the source of the modelling equations) provides a default capillary zone thickness of 0.05, but for logical consistency with the indoor vapour intrusion model, NovaTox has calculated it according to the equation used by J&E. Diffusion through the capillary zone (higher water content) is generally lower than diffusion through the vadose zone (higher air content). Therefore to ensure conservatism, NovaTox has set the thickness of the capillary zone as no more than ¼ the total depth below grade to GW (with 17.045 cm set as the maximum possible value for sand). E.g., if the depth to GW was 20 cm, the capillary zone would be 5 cm; any depth to GW greater than 68.18 cm gives a maximum capillary zone thickness of 17.045 cm for sand.

Long-term average annual wind speed at Lester B. Pearson International Airport, between 1961 and 1990 (Section 7.2.7 of MOE 2011).

As with the outdoor model, to ensure conservatism, NovaTox has set the thickness of the capillary zone as no more than ¼ the total depth to GW. Depth below trench to GW is always set at 1 cm, therefore capillary zone thickness is always set at 0.25 cm.

Lookup Table (i)				
Building Characteristics	**Residential Building-with-Basement**	**Residential Slab-on-Grade**	**Commercial Building-with-Basement**	**Commercial Slab-on-Grade**
Depth below grade to bottom of floor (a)	158	8	161.25	11.25
Length (a)	1,225	1,225	2,000	2,000
Width (a)	1,225	1,225	1,500	1,500
Height (a)	366	366	300	300
Slab Thickness (a)	8	8	11.25	11.25
Crack Width (a)	0.1	0.1	0.1	0.1
Pressure Differential, Building - Soil (a)	40	40	20	20
Air Exchange Rate (a)	0.3	0.3	1.0	1.0
Crack depth below grade (a)	158	8	161.25	11.25
Flow rate of soil vapour into building (a)	8.45	8.45	9.80	9.80
Floor-wall seam perimeter (b)	4,900	4,900	7,000	7,000
Building ventilation rate (b)	4.58E+04	4.58E+04	2.50E+05	2.50E+05
Area of enclosed space below grade (b)	2.27E+06	1.50E+06	4.13E+06	3.00E+06
Crack-to-total area ratio (b)	2.15E-04	3.27E-04	1.70E-04	2.33E-04

Notes:
- Residential building-with-basement and commercial slab-on-grade buildings are MECP default building types.
- Commercial building-with-basement assumed to be same dimensions and characteristics as commercial slab-on-grade building, but with a basement that extends to 150 cm (i.e., same as residential building-with-basement), and a default commercial slab thickness of 11.25 cm, for a total depth to bottom of floor of 161.25 cm.
- Residential slab-on-grade building assumed to be same dimensions and characteristics as residential building-with-basement, but no basement means that the total depth below grade to bottom of floor is 8 cm.
(a) MECP default values.
(b) Calculated per J&E model equation.

Lookup Table (ii)												
Soil Properties												
SCS Soil Type	**K_s (cm/h)**	**α_1 (1/cm)**	**N (unitless)**	**M (unitless)**	**n (cm^3/cm^3)**	**θ_r (cm^3/cm^3)**	**Mean Grain Diameter (cm)**	**Bulk density (g/cm^3)**	**θ_w (cm^3/cm^3)**	**f_{OC}**	**SCS Soil Name**	**Texture**
C	0.61	0.01496	1.253	0.2019	0.459	0.098	0.0092	1.43	0.215	0.005	Clay	fine
CL	0.34	0.01581	1.416	0.2938	0.442	0.079	0.016	1.48	0.168	0.005	Clay Loam	fine
L	0.50	0.01112	1.472	0.3207	0.399	0.061	0.020	1.59	0.148	0.005	Loam	medium
LS	4.38	0.03475	1.746	0.4273	0.390	0.049	0.040	1.62	0.076	0.005	Loamy Sand	coarse
Gravel Crush	36,000		5.000	0.8000	0.400	0.010	1.000	1.60	0.010	0.000	Gravel Crush	
Sand	26.78	0.03524	3.177	0.6852	0.375	0.053	0.044	1.66	0.054	0.005	Sand	coarse
SC	0.47	0.03342	1.208	0.1722	0.385	0.117	0.025	1.63	0.197	0.005	Sandy Clay	medium
SCL	0.55	0.02109	1.330	0.2481	0.384	0.063	0.029	1.63	0.146	0.005	Sandy Clay Loam	medium
SI	1.82	0.00658	1.679	0.4044	0.489	0.050	0.0046	1.35	0.167	0.005	Silt	medium
SIC	0.40	0.01622	1.321	0.2430	0.481	0.111	0.0039	1.38	0.216	0.005	Silty Clay	fine
SICL	0.46	0.00839	1.521	0.3425	0.482	0.090	0.0056	1.37	0.198	0.005	Silty Clay Loam	fine
SIL	0.76	0.00506	1.663	0.3987	0.439	0.065	0.011	1.49	0.180	0.005	Silt Loam	medium
SL	1.60	0.02667	1.449	0.3099	0.387	0.039	0.030	1.62	0.103	0.005	Sandy Loam	coarse

Notes:
- Ks = hydraulic conductivity (does not actually factor into model calculations)
- α1 = van Genuchten point of inflection in the water retention curve (does not actually factor into model calculations)
- N = van Genuchten curve shape parameter (essentially the ability of soil to retain water; higher value = less retention)
- M = van Genuchten parameter = 1 - (1/N)
- n = total porosity
- θr = residual water content (factors into the calculation of θw)
- θw = water-filled porosity
- fOC = fraction organic carbon
- Values for the 12 SCS soil types obtained from J&E model
- Values for gravel crush obtained from MECP guidance memorandum: Ks, n, θw, bulk density
- Value for gravel crush assumed by NovaTox: N (higher value than soil = less retention of water than soil)
- Value for gravel crush assumed by NovaTox: mean grain diameter (assumed 1 cm diameter of typical piece of gravel)
- Value for gravel crush assumed by NovaTox: fOC

Site Characteristics				
Category	**Site Characteristic**	**Symbol**	**Units**	**Value**
Water Potability	Potability of groundwater		–	Potable
J&E Building Inputs	Type of Building		–	Residential Building-with-Basement
	Length		cm	1,140
	Width		cm	1,140
	Height (of mixing zone)		cm	366
	Slab Thickness	Lcrack	cm	8
	Depth below grade to bottom of floor	L_F	cm	158
	Crack depth below grade	X_{crack} or Z_{crack}	cm	158
	Crack Width	w	cm	0.1
	Pressure Differential, Building - Soil	Δp	g/cm-sec2	40
	Air Exchange Rate	ER	1/hour	0.3
	Flow rate of soil vapour into building (or leave blank)	Q_{SOIL}	L/min	8.45
	Floor-wall seam perimeter	X_{crack}	cm	4,560
	Building ventilation rate	$Q_{building}$	cm^3/s	3.96E+04
	Area of enclosed space below grade	A_B	cm^2	2.02E+06
	Crack-to-total area ratio	η	–	2.26E-04
J&E Soil Inputs	Depth below grade to top of contaminated soil	zsoil or L_t	cm	0
	Depth to contaminated soil used in indoor model	zsoil or L_t	cm	188
	Soil Source-bldg. separation	L_T	cm	30.00
	Soil Stratum A - Thickness	h_A	cm	158
	Soil Stratum B - Thickness (Soil model)	h_B	cm	29.90
	Soil Stratum C - Thickness (Soil model)	h_C	cm	0.10
	MECP Source Depletion Multiplier (SDM) Applied	SDM	unitless	Yes
	Depth below grade to bottom of contaminated soil	L_b	cm	0

Building characteristics listed here obtained from Lookup Table (i) on the G1(c) sheet.

This is the shallowest depth at which any volatile soil COC exceeds its Site Condition Standard. The next cell automatically calculates the depth used in the J&E soil model. At minimum, must account for depth to bottom of floor (stratum A), plus full 29.9 cm layer of crushed gravel (stratum B). For functionality of the model NovaTox assumes that at least 0.1 cm of soil / clean fill remains as stratum C.

Source depletion model (if used) uses initial source volume of 13m X 13m X 2m (minus volume of soil that must be excavated to allow placement of building).

Parameter native to the J&E model that determines whether the source is finite (value >0) or is conservatively assumed to be infinite (value of 0). Cannot be used simultaneously with MECP SDM.

Site Characteristics Category	Site Characteristic	Symbol	Units	Value
J&E Soil Stratum A Parameters	Stratum A SCS soil type			Sand
	Stratum A soil total porosity	n^A	–	0.375
	Stratum A water filled porosity	θ_W^A	cm^3/cm^3	0.054
	Stratum A soil air-filled porosity	θ_a^A	cm^3/cm^3	0.321
	Stratum A soil dry bulk density	ρ_b^A	g/cm^3	1.66
	Stratum A soil organic carbon fraction	f_{OC}^A	–	0.005
	User defined stratum A soil vapour permeability	k_V	cm^2	
	Stratum A effective total fluid saturation	S_{te}	cm^3/cm^3	0.003
	Stratum A soil intrinsic permeability	k_i	cm^2	1.00E-07
	Stratum A soil relative air permeability	k_{rg}	cm^2	0.998
	Stratum A soil effective vapour permeability	k_v	cm^2	9.99E-08
J&E Soil Stratum B Parameters	Stratum B SCS soil type			Gravel Crush
	Stratum B soil total porosity	n^B	–	0.400
	Stratum B water filled porosity	θ_W^B	cm^3/cm^3	0.010
	Stratum B soil air-filled porosity	θ_a^B	cm^3/cm^3	0.390
	Stratum B soil dry bulk density	ρ_b^B	g/cm^3	1.60
	Stratum B soil organic carbon fraction	f_{OC}^B	–	0.000
J&E Soil Stratum C Parameters	Stratum C SCS soil type			Sand
	Stratum C soil total porosity	n^C	–	0.375
	Stratum C water filled porosity	θ_W^C	cm^3/cm^3	0.054
	Stratum C soil air-filled porosity	θ_a^C	cm^3/cm^3	0.321
	Stratum C soil dry bulk density	ρ_b^C	g/cm^3	1.66
	Stratum C soil organic carbon fraction	f_{OC}^C		0.005
J&E Miscellaneous Parameters	Soil/Groundwater temperature		^oC	15
	Exposure duration		y	56
	Exposure duration	τ	s	1.77E+09
	Conversion factor	C	cm^3-kg/m^3-g	1,000

Stratum A soil characteristics listed here obtained from (or calculated from) the values listed in Lookup Table (ii) on the G1(c) sheet.

Stratum B soil characteristics listed here obtained from (or calculated from) the values listed in Lookup Table (ii) on the G1(c) sheet.

Stratum C soil characteristics listed here obtained from (or calculated from) the values listed in Lookup Table (ii) on the G1(c) sheet.

Appendix B1: HHRA Inputs (B1(c): Site Characteristics - Site-Specific Building)

NovaTox

Site Characteristics Category	Site Characteristic	Symbol	Units	Value
Outdoor Vapour Modelling Inputs	Depth below grade to contaminated soil		cm	0 (assumes surface contamination)
	Depth below grade to contaminated GW	L_{gw}	cm	5
	Soil type for the outdoor model			Sand
	Outdoor Model: Capillary zone thickness	h_c	cm	1.250
	Outdoor Model: Capillary zone total porosity	n_{CZ}	cm^3/cm^3	0.375
	Outdoor Model: Capillary zone water-filled porosity	$\theta_{w,cz}$	cm^3/cm^3	0.253
	Outdoor Model: Capillary zone air-filled porosity	$\theta_{a,cz}$	cm^3/cm^3	0.122
	Outdoor Model: Vadose zone thickness	h_v	cm	3.750
	Outdoor Model: Vadose zone total porosity	E_t	cm^3/cm^3	0.375
	Outdoor Model: Vadose zone water-filled porosity	Θ_{ws}	cm^3/cm^3	0.054
	Outdoor Model: Vadose zone air-filled porosity	Θ_{as}	cm^3/cm^3	0.321
	Soil fraction organic carbon	f_{oc}	–	0.005
	Soil bulk density	B	g/cm^3	1.66
	Mean annual wind speed	U	cm/s	410
	Width of contaminant source (max = “breathing zone”)	W_c	cm	1,000
	Mixing zone height = Height of “breathing zone”	δ_{AIR}	cm	200
	Depth (thickness) of contaminated soil (default value)	D_c	cm	200
	Averaging time for flux	t	s	31,536,000
Trench Vapour Modelling Inputs	Depth below trench to contaminated soil		cm	0 (assumes surface contamination)
	Depth below trench to contaminated GW	$L_{tr\text{-}gw}$	cm	1
	Soil type for the trench model			Sand
	Trench Model: Capillary zone thickness	h_c	cm	0.250
	Trench Model: Capillary zone total porosity	n_{CZ}	cm^3/cm^3	0.375
	Trench Model: Capillary zone water-filled porosity	$\theta_{w,cz}$	cm^3/cm^3	0.253
	Trench Model: Capillary zone air-filled porosity	$\theta_{a,cz}$	cm^3/cm^3	0.122
	Trench Model: Vadose zone thickness	h_v	cm	0.750
	Trench Model: Vadose zone total porosity	E_t	cm^3/cm^3	0.375
	Trench Model: Vadose zone water-filled porosity	Θ_{ws}	cm^3/cm^3	0.054
	Trench Model: Vadose zone air-filled porosity	Θ_{as}	cm^3/cm^3	0.321
	Soil fraction organic carbon	f_{oc}	–	0.005
	Soil bulk density	B	g/cm^3	1.66
	Mean annual wind speed	U	cm/s	410
	Fraction of total wind speed that occurs in trench	F_t	–	0.25
	Air exchange rate in trench = $(UxFxLxD)/V_{trench}$	AXR	s^{-1}	0.51250
	Width of contaminant source (max = “breathing zone”)	W_c	cm	1,000
	Trench length	L_{tr}	cm	1,000
	Trench width	W_{tr}	cm	200
	Trench depth (= mixing zone height / “breathing zone”)	$D_{tr} = \delta_{AIR}$	cm	200
	Trench volume	V_{tr}	cm^3	40,000,000
	Averaging time for flux	t	s	31,536,000

Shallowest depth at which groundwater has been observed at the site.

For outdoor vapour modelling, Atlantic PIRI (2003) (the source of the modelling equations) provides a default capillary zone thickness of 0.05, but for logical consistency with the indoor vapour intrusion model, NovaTox has calculated it according to the equation used by J&E. Diffusion through the capillary zone (higher water content) is generally lower than diffusion through the vadose zone (higher air content). Therefore to ensure conservatism, NovaTox has set the thickness of the capillary zone as no more than ¼ the total depth below grade to GW (with 17.045 cm set as the maximum possible value for sand). E.g., if the depth to GW was 20 cm, the capillary zone would be 5 cm; any depth to GW greater than 68.18 cm gives a maximum capillary zone thickness of 17.045 cm for sand.

Long-term average annual wind speed at Lester B. Pearson International Airport, between 1961 and 1990 (Section 7.2.7 of MOE 2011).

As with the outdoor model, to ensure conservatism, NovaTox has set the thickness of the capillary zone as no more than ¼ the total depth to GW. Depth below trench to GW is always set at 1 cm, therefore capillary zone thickness is always set at 0.25 cm.

Lookup Table (i)

Building Characteristics	Residential Building-with-Basement	Residential Slab-on-Grade	Commercial Building-with-Basement	Commercial Slab-on-Grade
Depth below grade to bottom of floor (a)	158	8	161.25	11.25
Length (a)	1,140	1,225	2,000	2,000
Width (a)	1,140	1,225	1,500	1,500
Height (a)	366	366	300	300
Slab Thickness (a)	8	8	11.25	11.25
Crack Width (a)	0.1	0.1	0.1	0.1
Pressure Differential, Building - Soil (a)	40	40	20	20
Air Exchange Rate (a)	0.3	0.3	1.0	1.0
Crack depth below grade (a)	158	8	161.25	11.25
Flow rate of soil vapour into building (a)	8.45	8.45	9.80	9.80
Floor-wall seam perimeter (b)	4,560	4,900	7,000	7,000
Building ventilation rate (b)	3.96E+04	4.58E+04	2.50E+05	2.50E+05
Area of enclosed space below grade (b)	2.02E+06	1.50E+06	4.13E+06	3.00E+06
Crack-to-total area ratio (b)	2.26E-04	3.27E-04	1.70E-04	2.33E-04

Notes:
- Residential building-with-basement and commercial slab-on-grade buildings are MECP default building types.
- Commercial building-with-basement assumed to be same dimensions and characteristics as commercial slab-on-grade building, but with a basement that extends to 150 cm (i.e., same as residential building-with-basement), and a default commercial slab thickness of 11.25 cm, for a total depth to bottom of floor of 161.25 cm.
- Residential slab-on-grade building assumed to be same dimensions and characteristics as residential building-with-basement, but no basement means that the total depth below grade to bottom of floor is 8 cm.
(a) MECP default values.
(b) Calculated per J&E model equation.

Lookup Table (ii)

Soil Properties

SCS Soil Type	K_s (cm/h)	α_1 (1/cm)	N (unitless)	M (unitless)	n (cm^3/cm^3)	θ_r (cm^3/cm^3)	Mean Grain Diameter (cm)	Bulk density (g/cm^3)	θ_w (cm^3/cm^3)	f_{OC}	SCS Soil Name	Texture
C	0.61	0.01496	1.253	0.2019	0.459	0.098	0.0092	1.43	0.215	0.005	Clay	fine
CL	0.34	0.01581	1.416	0.2938	0.442	0.079	0.016	1.48	0.168	0.005	Clay Loam	fine
L	0.50	0.01112	1.472	0.3207	0.399	0.061	0.020	1.59	0.148	0.005	Loam	medium
LS	4.38	0.03475	1.746	0.4273	0.390	0.049	0.040	1.62	0.076	0.005	Loamy Sand	coarse
Gravel Crush	36,000		5.000	0.8000	0.400	0.010	1.000	1.60	0.010	0.000	Gravel Crush	
Sand	26.78	0.03524	3.177	0.6852	0.375	0.053	0.044	1.66	0.054	0.005	Sand	coarse
SC	0.47	0.03342	1.208	0.1722	0.385	0.117	0.025	1.63	0.197	0.005	Sandy Clay	medium
SCL	0.55	0.02109	1.330	0.2481	0.384	0.063	0.029	1.63	0.146	0.005	Sandy Clay Loam	medium
SI	1.82	0.00658	1.679	0.4044	0.489	0.050	0.0046	1.35	0.167	0.005	Silt	medium
SIC	0.40	0.01622	1.321	0.2430	0.481	0.111	0.0039	1.38	0.216	0.005	Silty Clay	fine
SICL	0.46	0.00839	1.521	0.3425	0.482	0.090	0.0056	1.37	0.198	0.005	Silty Clay Loam	fine
SIL	0.76	0.00506	1.663	0.3987	0.439	0.065	0.011	1.49	0.180	0.005	Silt Loam	medium
SL	1.60	0.02667	1.449	0.3099	0.387	0.039	0.030	1.62	0.103	0.005	Sandy Loam	coarse

Notes:
- Ks = hydraulic conductivity (does not actually factor into model calculations)
- α1 = van Genuchten point of inflection in the water retention curve (does not actually factor into model calculations)
- N = van Genuchten curve shape parameter (essentially the ability of soil to retain water; higher value = less retention)
- M = van Genuchten parameter = 1 - (1/N)
- n = total porosity
- θr = residual water content (factors into the calculation of θw)
- θw = water-filled porosity
- fOC = fraction organic carbon
- Values for the 12 SCS soil types obtained from J&E model
- Values for gravel crush obtained from MECP guidance memorandum: Ks, n, θw, bulk density
- Value for gravel crush assumed by NovaTox: N (higher value than soil = less retention of water than soil)
- Value for gravel crush assumed by NovaTox: mean grain diameter (assumed 1 cm diameter of typical piece of gravel)
- Value for gravel crush assumed by NovaTox: fOC

Receptor Characteristic	Units	Community Members (Residents/Recreators)							Workers					
		Infant	Toddler	Child	Teen	Adult	Adult Female	Full-Life Composite	Indoor worker	Pregnant Indoor worker	Outdoor worker	Pregnant Outdoor worker	Construc. worker	Pregnant Construc. worker
Body weight	**kg**	8.2	16.5	32.9	59.7	70.7	63.1	62.44	70.7	63.1	70.7	63.1	70.7	63.1
Skin surface area	**cm^2**	1,105	1,745	2,822	3,858	4,343	3988	3,977	4,343	3988	3,400	3090	3,400	3090
Soil adherence rate	**$mg/cm^2/d$**	0.07	0.2	0.2	0.07	0.07	0.07	0.09	0.07	0.07	0.2	0.2	0.2	0.2
Soil ingestion rate	**mg/d**	30	200	50	50	50	50	58.75	50	50	100	100	100	100
	kg/d	3.0E-05	2.0E-04	5.0E-05	5.0E-05	5.0E-05	5.0E-05	5.9E-05	5.0E-05	5.0E-05	1.0E-04	1.0E-04	1.0E-04	1.0E-04
Drinking water intake rate	**L/d**	0.6	1.2	1.3	1.7	2.3	2.1	2.1	2.3	2.1	–	–	–	–
Incidental GW ingestion rate	**L/d**	–	–	–	–	–	–	–	–	–	–	–	0.15	0.15
Inhalation rate	**m^3/h**	0.092	0.346	0.604	0.65	0.692	0.692	0.655	–	–	1.5	1.5	1.5	1.5
PM_{10} concentration	**$\mu g/m^3$**	30	30	30	30	30	30	30	–	–	100	100	100	100
Time Indoors	**h/d**	24	24	22.23	21.83	22.5	24	22.5	9.8	24	–	–	–	–
	d/wk	7	7	7	7	7	7	7	5	7	–	–	–	–
	wks/y	50	50	50	50	50	52	50	50	52	–	–	–	–
	d/y	350	350	350	350	350	365	350	250	365	–	–	–	–
Time Outdoors	**h/d**	24	24	22.23	21.83	22.5	24	22.5	–	–	9.8	24	9.8	24
	d/wk	7	7	7	7	7	7	7	–	–	5	7	5	7
	wks/y	39	39	39	39	39	52	39	–	–	39	52	39	52
	d/y	273	273	273	273	273	365	273	–	–	195	365	195	365
Time in Trench	**hr/event**	–	–	–	–	–	–	–	–	–	–	–	0.006	0.006
	events/day	–	–	–	–	–	–	–	–	–	–	–	10	10
	d/y	–	–	–	–	–	–	–	–	–	–	–	50	365
Exposure Duration	**y**	0.5	4.5	7	8	56	56	76	56	56	56	56	1.5	1.5
Averaging period (non-canc)	**y**	0.5	4.5	7	8	56	56	76	56	56	56	56	1.5	1.5
Averaging period (canc)	**y**	76	76	76	76	76	76	76	56	56	56	56	56	56

Notes:
- Body weights obtained from Table 2.6 of MOE (2011) Rationale Document
- Skin surface areas obtained from Table 2.7 of MOE (2011) Rationale Document
- Soil adherence factors obtained from Table 2.8 of MOE (2011) Rationale Document
- Soil ingestion rates obtained from Table 2.5 of MOE (2011) Rationale Document
- Drinking water ingestion rates obtained from Table 2.9 of MOE (2011) Rationale Document
- Groundwater incidental ingestion rate assumed based on USEPA (2013)
- Inhalation rate for construction worker obtained from Table 2.18 of MOE (2011) Rationale Document
- Inhalation rate for outdoor worker assumed equal to construction worker
- Inhalation rates for community members obtained from Health Canada 2012 (PQRA Guidance)
- Time spent indoor and outdoors at Site obtained from Tables 2.13, 2.14, 2.15, 2.16 of MOE (2011) Rationale Document
- Time spent in trench is assumed
- Exposure durations obtained from Table 2.10 of MOE (2011) Rationale Document
- Averaging periods obtained from Tables 2.11, 2.12 of MOE (2011) Rationale Document
- Composite receptor characteristics calculated by pro-rating values from all other life stages
- Adult female / pregnant receptor characteristics used for exposure assessment calculations for developmental toxicants
- "–" indicates not applicable (e.g., incomplete exposure pathway)

COC Physical & Chemical Properties																
COC	Mol wt. (g/mol)	Log K_{OW}	Vapour pressure (mm Hg)	Max theoretical vapour conc. in a headspace (ppm)	Max theoretical vapour conc. in a headspace (mg/m3)	Henry's Law constant at ref. temp, H (atm-m³/mol)	Henry's Law constant, H (unitless)	K_{OC} (cm³/g)	Diffusivity in air, D_a (cm²/s)	Diffusivity in water, D_w (cm²/s)	Aqueous solubility (mg/L)	Boiling point, T_B (°K)	Critical temp., T_C (°K)	Enthalpy of vaporization, DH_{vb} (cal/mol)	Density (g/cm³)
Antimony	1.25E+02		0.00E+00	0.00E+00	0.00E+00			0.00E+00			2.30E+04				3.78E+00
Arsenic	7.80E+01		1.01E+04	1.33E+07	4.24E+07			0.00E+00			3.47E+04				5.75E+00
Cadmium	1.12E+02		8.98E-18	1.18E-14	5.41E-14			0.00E+00			1.23E+05				8.69E+00
Mercury	2.01E+02	6.20E-01	1.96E-03	2.58E+00	2.12E+01	1.15E-02	4.70E-01	1.32E+06	3.07E-02	6.30E-06	6.00E-02	6.30E+02	1.75E+03	1.41E+04	1.35E+01
Benz[a]anthracene	2.28E+02	5.76E+00	1.90E-06	2.50E-03	2.33E-02	1.20E-05	4.91E-04	4.62E+05	5.10E-02	9.00E-06	9.40E-03	7.08E+02	1.00E+03	1.60E+04	1.25E+00
Benzo[a]pyrene	2.52E+02	6.13E+00	5.49E-09	7.22E-06	7.45E-05	4.58E-07	1.87E-05	1.57E+06	4.30E-02	9.00E-06	1.62E-03	7.16E+02	9.69E+02	1.90E+04	1.25E+00
Benzo[b]fluoranthene	2.52E+02	5.78E+00	5.00E-07	6.58E-04	6.78E-03	6.58E-07	2.69E-05	1.61E+06	2.26E-02	5.56E-06	1.50E-03	7.16E+02	9.69E+02	1.70E+04	1.25E+00
Dibenz[a h]anthracene	2.78E+02	6.54E+00	1.39E-11	1.83E-08	2.08E-07	1.23E-07	5.03E-06	5.24E+06	2.02E-02	5.18E-06	1.03E-03	7.43E+02	9.90E+02	3.00E+04	1.25E+00
Indeno[1 2 3-cd]pyrene	2.76E+02	6.70E+00	1.25E-10	1.64E-07	1.86E-06	3.47E-07	1.42E-05	5.36E+06	1.90E-02	5.66E-06	1.90E-04	8.09E+02	1.08E+03	1.90E+04	1.25E+00
TOTAL CARC. PAHs				7.22E-06	7.45E-05										

Notes:
- Non-highlighted cells from MGRA model (MOE 2011).

Relative Absorption Factors						
COC	MOE RAF Soil Oral	MOE RAF Soil Dermal	MOE RAF Water Oral	MOE RAF Water Dermal	RAGS FA Water Dermal	MOE RAF Inhalation
Antimony	1.00	0.10	1.00	1.00		1
Arsenic	0.50	0.03	1.00	1.00		1
Cadmium	1.00	0.01	1.00	1.00		1
Mercury	0.50	0.10	1.00	1.00		1
Benz[a]anthracene	1.00	0.13	1.00	1.00	1.0	1
Benzo[a]pyrene	1.00	0.13	1.00	1.00	1.0	1
Benzo[b]fluoranthene	1.00	0.13	1.00	1.00	1.0	1
Dibenz[a h]anthracene	1.00	0.13	1.00	1.00	0.6	1
Indeno[1 2 3-cd]pyrene	1.00	0.13	1.00	1.00	0.6	1
TOTAL CARC. PAHs (benzo[a]pyrene values used as surrogates)	1.00	0.13	1.00	1.00	1.0	1

Notes:
- Soil dermal RAF for n-hexane not available from MOE (2011); value set to most conservative value of 1.00.

Toxicity Reference Values	Non-Cancer								Cancer							
COC	Oral chronic TRV (mg/kg/d)	Flag	Ref.	Note	Inhalation chronic TRV (mg/m^3)	Flag	Ref.	Note	Oral slope factor $(mg/kg/d)^{-1}$	Flag	Ref.	Note	Inhalation Unit Risk $(mg/m^3)^{-1}$	Flag	Ref.	Note
Antimony	4.0E-04		1a		2.0E-04		1a									
Arsenic	3.0E-04		1a	Up.by MECP	1.5E-05	As	3c	Up.by MECP	9.5E+00		3d	Up.by MECP	1.5E-01		12	Up.by MECP
Cadmium	3.2E-05		3d		3.0E-05		6						9.8E+00		4b	
Mercury	3.0E-04		1a		9.0E-05		3c									
Benz[a]anthracene									1.0E-01		1a, 10	Up.by MECP	6.0E-02		1a, 10	Up.by MECP
Benzo[a]pyrene	3.0E-04		1a	Up.by MECP	2.0E-06		1a	Up.by MECP	1.0E+00		1a, 10	Up.by MECP	6.0E-01		1a, 10	Up.by MECP
Benzo[b]fluoranthene									1.0E-01		1a, 10	Up.by MECP	6.0E-02		1a, 10	Up.by MECP
Dibenz[a h]anthracene									1.0E+00		1a, 10	Up.by MECP	6.0E-01		1a, 10	Up.by MECP
Indeno[1 2 3-cd]pyrene									1.0E-01		1a, 10	Up.by MECP	6.0E-02		1a, 10	Up.by MECP
TOTAL CARC. PAHs (i.e., benzo[a]pyrene values)									1.0E+00		1a, 10	Up.by MECP	6.0E-01		1a, 10	Up.by MECP

Flags:

- **As**: A MECP update removed this TRV and now states "none selected". NovaTox is retaining a TRV for conservatism; MOE (2011) references CalEPA (2000), but CalEPA updated the TRV in 2014. NovaTox is using the updated value.

References:

1. U.S. EPA (Environmental Protection Agency)
   a. IRIS (Integrated Risk Information System)
   b. HEAST (Health Effects Assessment Summary Tables)
   c. PPRTV (Provisional Peer-Reviewed Toxicity Value)
   d. Region III
   e. HESD
2. ATSDR (Agency for Toxic Substances and Disease Registry, of the U.S. Department of Health and Human Services)
3. CalEPA (California Environmental Protection Agency)
   a. ATH (Air Toxics Hotspots)
   b. chRD (child-specific Reference Dose)
   c. ChREL (Chronic Reference Exposure Level)
   d. DW (Drinking Water)
   e. P65 (No Significant Risk Level for Proposition 65)
4. Health Canada
   a. DWQG (Drinking Water Quality Guideline documentation)
   b. PSL1 (first Priority Substances List documentation)
   c. PSL2 (second Priority Substances List documentation)
   d. CSD (Contaminated Sites Division documentation)
5. CCME (Canadian Council of Ministers of the Environment)
6. Ontario MOE/MECP Air
7. RIVM (Netherlands National Institute for Public Health and the Environment)
8. WHO (World Health Organization)
   a. CICAD (Concise International Chemical Assessment Document)
   b. EHC (Environmental Health Criteria)
   c. JECFA (Joint FAO/WHO Expert Committee on Food Additives)
   d. DW (Drinking Water)
   e. Air (Air Quality Guidelines)
9. TPHCWG (Total Petroleum Hydrocarbons Working Group)
10. Kalberlah et al., 1995
11. TERA (Toxicology Excellence for Risk Assessment)
12. TCEQ (Texas Commission on Environmental Quality)

Notes:

All TRV references are as recommended by MOE (2011) unless otherwise noted as follows:

- **Up.by MECP**: TRV differs from MOE (2011) because MECP updated their recommended TRV in a policy document or technical memorandum (e.g., August 2019 Summary of Human Health TRVs).
- **Up.by Source**: TRV differs from MOE (2011), because the source recommended by MOE (2011) has updated their TRV (but has not yet been adopted as a formal recommendation by MECP).

Incidental ingestion of soil can be an important source of exposure to COCs for receptors that spend significant amounts of time outdoors, such as construction workers, outdoor workers, and residents.

The extent to which this pathway contributes to overall COC exposure depends on (i) the amount of time spent outdoors by the receptor, (ii) receptor-specific behaviour that determines the extent to which soil is incidentally ingested (e.g., frequent hand-to-mouth activity by the toddler resident, especially), (iii) soil-specific, COC-specific, and receptor-specific characteristics that combined will influence the extent to which COCs are released from the soil to be absorbed by the gastrointestinal tract (although this is usually held constant for all receptors for any particular COC, as determined by the COC's RAF).

Exposure estimates for the soil ingestion pathway are calculated using the following equation, which is the standard equation used by MECP and other regulatory agencies for this pathway. Soil concentrations are provided in the Problem Formulation of the HHRA and Appendix B1(a). Receptor characteristics are provided in the Exposure Assessment of the HHRA and Appendix B1(d). COC characteristics are provided in Appendix B1(e). Final exposure doses for this pathway are presented in the Exposure Assessment of the HHRA, with example calculations being provided in Appendix B3(a).

Equation for calculating exposure dose to a COC via soil ingestion

$$ADD_{soil\text{-}ing} = \left(\frac{C_{soil} \times IR_{soil} \times RAF_{soil\text{-}oral}}{BW}\right) \times \frac{days}{365}$$

Where:

Where:	$ADD_{soil\text{-}ing}$	=	Average daily *non-carcinogenic* dose due to soil ingestion (mg/kg-day);
	C_{soil}	=	COC concentration in the soil (mg/kg);
	IR_{soil}	=	Soil intake rate (kg/day);
	$RAF_{soil\text{-}oral}$	=	Relative Absorption Factor for oral exposure to soil;
	BW	=	Body weight (kg);
	$days$	=	Days per year exposed.

Note: for assessment of carcinogenic risks, an additional exposure adjustment factor is applied: $\left(\frac{\text{years exposed}}{\text{amortization period}}\right)$

Dermal contact with soil can be an important source of exposure to COCs for receptors that spend significant amounts of time outdoors, such as construction workers, outdoor workers, and residents.

The extent to which this pathway contributes to overall COC exposure depends on (i) the amount of time spent outdoors by the receptor, (ii) the amount of the receptor's skin that is uncovered and is thus available for soil to adhere to it, (iii) soil-specific characteristics and receptor-specific skin characteristics that together can influence the extent to which soil adheres to the skin, and (iv) soil-specific, COC-specific, and receptor-specific skin characteristics that combined will influence the extent to which COCs are released from the soil to be absorbed by the skin (although this is usually held constant for all receptors for any particular COC, as determined by the COC's RAF).

Exposure estimates for the soil dermal contact pathway are calculated using the following equation, which is the standard equation used by MECP and other regulatory agencies for this pathway. Soil concentrations are provided in the Problem Formulation of the HHRA and Appendix B1(a). Receptor characteristics are provided in the Exposure Assessment of the HHRA and Appendix B1(d). COC characteristics are provided in Appendix B1(e). Final exposure doses for this pathway are presented in the Exposure Assessment of the HHRA, with example calculations being provided in Appendix B3(b).

Equation for calculating exposure dose to a COC via soil dermal contact

$$ADD_{soil\text{-}derm} = \left(\frac{C_{soil} \times SA \times R_{adher} \times RAF_{soil\text{-}derm}}{BW}\right) \times \frac{days}{365}$$

Where:

$ADD_{soil\text{-}derm}$	=	Average daily *non-carcinogenic* dose due to dermal contact with soil (mg/kg-day);
C_{soil}	=	COC concentration in the soil (mg/kg);
SA	=	Surface area of skin for the exposed body parts (cm^2);
R_{adher}	=	Rate of soil adherence to skin (kg/cm^2-d);
$RAF_{soil\text{-}derm}$	=	Relative Absorption Factor for dermal exposure to soil (COC-specific; unitless);
BW	=	Body weight (kg);
days	=	Days per year exposed.

Note: for assessment of carcinogenic risks, an additional exposure adjustment factor is applied: $\left(\frac{\text{years exposed}}{\text{amortization period}}\right)$

Inhalation of soil particulates entrained in the outdoor air can be an important source of exposure to COCs for receptors that spend significant amounts of time outdoors, such as construction workers, outdoor workers, and residents.

The extent to which particulate inhalation contributes to overall COC exposure depends on (i) the amount of time spent outdoors by the receptor, (ii) site-specific characteristics that determine the extent to which particulates are entrained and then dispersed in outdoor air, (iii) site-specific characteristics that determine the size distribution of particulates at a site (assumed to be a wide ranges of sizes, including but not limited to PM_{10}, as described below), and (iv) soil-specific, COC-specific, and receptor-specific characteristics that combined will influence the extent to which COCs are released from the soil to be absorbed by the body (although this is usually held constant for all receptors for any particular COC).

Exposure estimates for soil particulate inhalation are calculated using the following equations, used by the Massachusetts Department of Environmental Protection (MassDEP 2008). Soil concentrations are provided in the Problem Formulation of the HHRA and Appendix B1(a). Receptor characteristics are provided in the Exposure Assessment of the HHRA and Appendix B1(d). COC characteristics are provided in Appendix B1(e). Final exposure doses and concentrations for this pathway are presented in the Exposure Assessment of the HHRA, with example calculations being provided in Appendix B3(c).

Equation for calculating exposure dose to a COC via soil particulate inhalation (with particulates being retained in the lungs)

$$ADD_{part\text{-}lungs} = \left(\frac{(C_{part} \times 0.6 \times C_{soil}) \times IR_{air} \times RAF_{soil\text{-}inh}}{BW}\right) \times \frac{hours}{24} \times \frac{days}{365}$$

Equation for calculating exposure dose to a COC via soil particulate inhalation (followed by coughing & ingestion)

$$ADD_{part\text{-}ing} = \left(\frac{(C_{part} \times 1.4 \times C_{soil}) \times IR_{air} \times RAF_{soil\text{-}oral}}{BW}\right) \times \frac{hours}{24} \times \frac{days}{365}$$

Where:

Where:	$ADD_{part\text{-}lungs}$	=	Average daily *non-carcinogenic* dose due to particulate inhalation (fraction retained in lungs) (mg/kg-day);
	$ADD_{part\text{-}ing}$	=	Average daily *non-carcinogenic* dose due to particulate inhalation (fraction coughed/ingested) (mg/kg-day);
	C_{part}	=	Particulate (PM_{10}) concentration in air (100 μg/m^3 = 1 x 10^{-7} kg/m^3);
	0.6	=	Fraction of inhaled particulate matter that is retained in lungs (unitless);
	1.4	=	Fraction of inhaled particulate matter that is coughed/ingested (unitless);
	C_{soil}	=	COC concentration in soil (mg/kg);
	IR_{air}	=	Inhalation rate (m^3/day);
	$RAF_{soil\text{-}oral}$	=	Relative Absorption Factor for soil ingestion exposure (COC-specific; unitless);
	$RAF_{soil\text{-}inh}$	=	Relative Absorption Factor for inhalation exposure (COC-specific; unitless);
	BW	=	Body weight (kg);
	hours	=	Hours per day exposed;
	days	=	Days per year exposed.

Note: for assessment of carcinogenic risks, an additional exposure adjustment factor is applied: $\left(\frac{\text{years exposed}}{\text{amortization period}}\right)$

The two equations represent the two possible fates of particulates after they are inhaled:

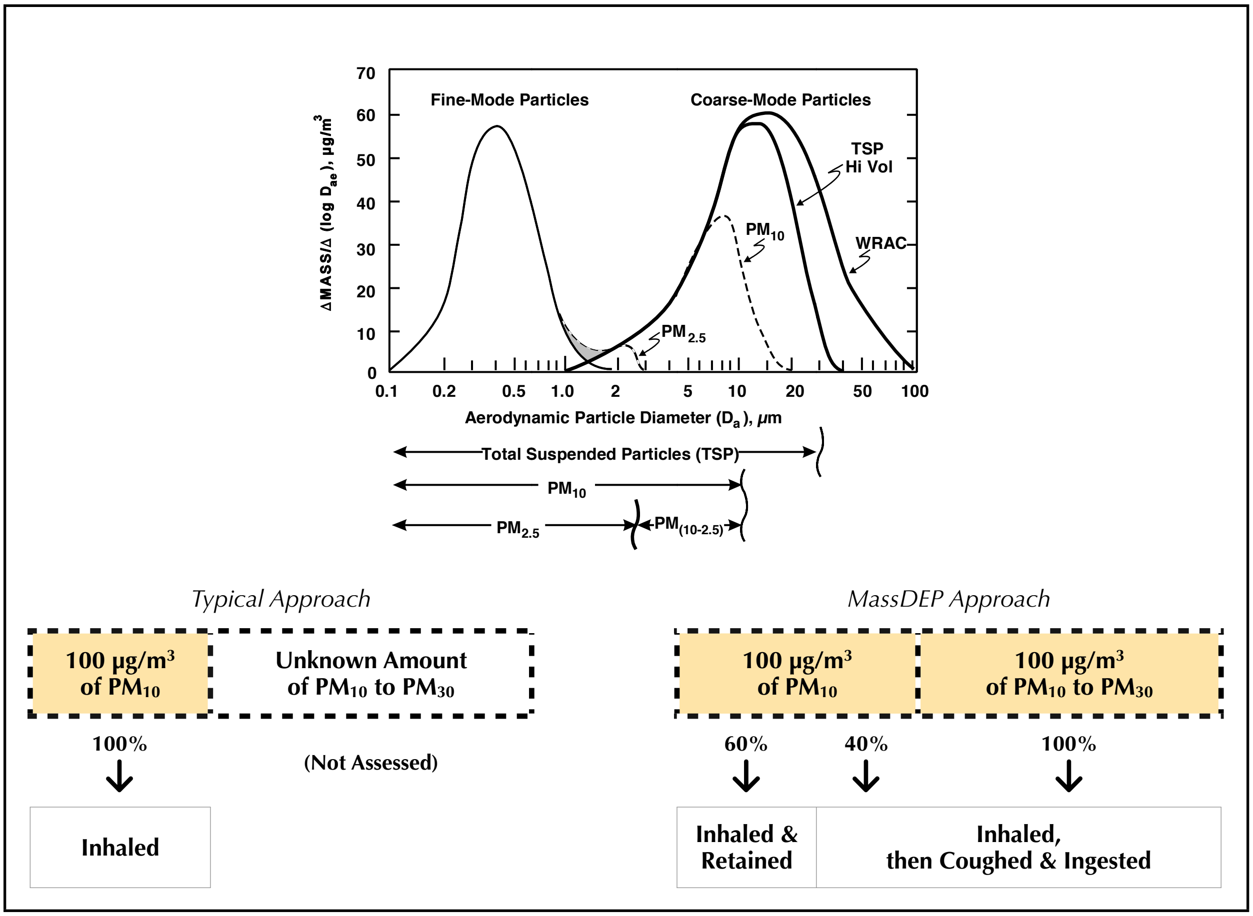
1. Some particulates are retained in the lungs and are deposited within alveolar regions. This is typically a greater concern for smaller particulates, less than or equal to 10 µm in diameter (referred to as PM_{10}). However, not all PM_{10} inhaled is actually deposited. MassDEP (2008) recommends an assumption of 50%. NovaTox has increased the proportion deposited to 60% to be consistent with MOE (2011), Table 2.18. This is represented by the fraction of 0.6 that is included as a term in the first equation. The concentration of PM_{10} in the air is set at 100 µg/m^3, per MOE (2011), Table 2.17. Note that the equation as provided by MassDEP (2008) results in an exposure estimate in dose units of mg/kg-day. Given that this fraction of particulates is retained in the lungs, an inhalation TRV is considered appropriate for risk characterization calculations. The dose in units of mg/kg-day is converted to a concentration in units of mg/m^3 by route-to-route extrapolation (70 kg body weight and 20 m^3/day inhalation rate used by convention). For volatile contaminants in *soil*, the particulate exposure concentration in units of mg/m^3 is summed with the soil vapour concentration (also in units of mg/m^3) to be used in risk characterization calculations.

2. Some particulates are removed from the respiratory tract via muco-ciliary clearance and/or coughing and, when they reach the pharyngeal region, are ingested into the gastrointestinal tract. As stated above, 60% of inhaled PM_{10} is assumed to be deposited in the alveolar region of the lungs. The remaining 40% (fraction of 0.4) of PM_{10} is assumed to undergo muco-ciliary clearance and be ingested. Dust in the air, however, does not *only* contain PM_{10}, and larger particulates (e.g., those ranging from 10 to 30 µm in diameter, referred to as PM_{10} - PM_{30}) are also entrained in the air and can be inhaled. These larger particulates are assumed to either not enter the lower respiratory tract at all (e.g., caught in the nose or mouth), or, if any do enter, they are coughed up or otherwise very efficiently cleared. It is assumed that they are all eventually ingested (i.e., 100%, or a fraction of 1.0). Thus, the *effective* fraction of particulates in the air that is ingested is 1.4, and this accounts for its inclusion as a term in the second of the two equations. Again, the concentration of PM_{10} in the air is set at 100 µg/m^3, per MOE (2011), Table 2.17. Multiplying this by the fraction of 1.4 effectively means that the concentration of PM_{10} - PM_{30} in the air is also 100 µg/m^3. The resulting exposure estimate is in dose units of mg/kg-day. This dose is summed with dose estimates from the incidental ingestion and dermal contact pathways, for a *total oral/dermal dose from soil* that is then used in risk characterization calculations.

A diagrammatic conceptualization of the approach is provided below to more clearly demonstrate its validity and conservatism. As shown, the full 100 µg/m^3 amount of PM_{10} that is typically assessed in other approaches is also assessed in the MassDEP approach that was used in this RA. The difference is that instead of 100% being assessed via the inhalation pathway, the MassDEP approach apportions 60% to inhalation and 40% to ingestion. The MassDEP approach provides added conservatism because it accounts for larger particulates in the air with 100% of these larger particulates being ingested. As an assumption of convenience, the concentration of these larger particulates (PM_{10} to PM_{30}) is set equal to the concentration of PM_{10} (i.e., 100 µg/m^3).

Overall therefore, the MassDEP approach is considered scientifically robust as well as very conservative. It reflects (i) "real-world" exposure (particulates in air are a wide range of sizes, with only some of them being PM_{10}), as well as (ii) "real-world" physiological responses to inhalation of particulates (of the PM_{10} respired, only some is actually retained in the alveolar region of the lungs).

Note that the approach furthermore reflects the U.S.EPA position (U.S.EPA being a major source of chronic inhalation TRVs for risk assessment) on assessment of particulates, that "a more appropriate dose metric for particle exposures may be to take into account clearance of the deposited dose and thereby calculate the retained dose and the dose rate to extra-respiratory tissues" (U.S.EPA 1994).



Size Distribution of Ambient Particulate Matter (Adapted from U.S. EPA, 1996) and Conceptualization of Exposure Pathways (Adapted from Weidner et al, 1997)

References

MassDEP. 2008. Technical Update: Characterization of Risks Due to Inhalation of Particulates by Construction Workers. Update to: Section 7.3 and Appendix B of the MA DEP Guidance for Disposal Site Risk Characterization – In Support of the Massachusetts Contingency Plan (1995). Revised July 2008. Massachusetts Department of Environmental Protection.

MOE. 2011. Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario. Toronto, Ontario. Standards Development Branch, Ontario Ministry of the Environment.

U.S. EPA. 1994. Methods for Derivation of Inhalation Reference Concentrations and Application of Inhalation Dosimetry. October 1994. United States Environmental Protection Agency, Office of Research and Development. EPA/600/8-90/066F.

U.S. EPA. 1996. Air Quality Criteria for Particulate Matter. April 1996. United States Environmental Protection Agency, Office of Research and Development. EPA/600/P-95/001aF.

Weidner C, Fitzgerald J, and Vallatini M. 1997. Real-Time Air Monitoring at Construction and Remediation Sites to Estimate Risks of Contaminated Dust Migration. Paper presented at the *12th Annual Conference on Contaminated Soils*, University of Massachusetts at Amherst, October 1997.

Inhalation of vapours arising from soil and/or groundwater COCs and migrating to outdoor air and trench/excavation air are considered complete exposure pathways for receptors who spend the majority of their time outdoors (e.g., outdoor workers, construction workers). Outdoor and trench vapour concentrations can be estimated by applying a volatilization factor to the COC concentration in soil or groundwater as follows.

Equation for Calculating COC Exposure Concentration in Outdoor/Trench Air

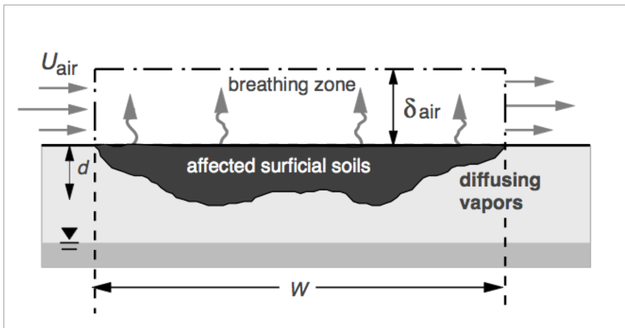
$$C_{\text{outdoor or trench air}} = C_{\text{soil or groundwater}} \times VF \times \frac{\text{hours}}{24} \times \frac{\text{days}}{365}$$

Where:

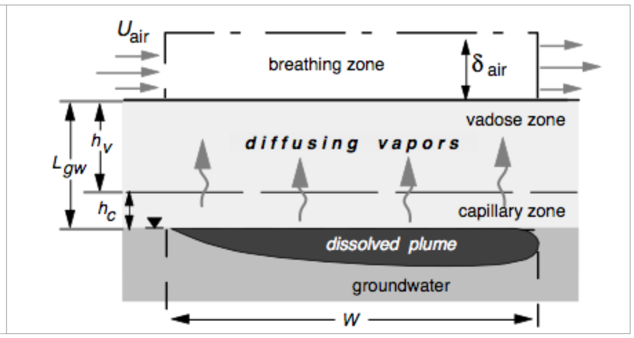
$C_{\text{outdoor or trench}}$	=	COC concentration in outdoor/trench air (µg/m³)
$C_{\text{soil or groundwater}}$	=	COC concentration in soil or groundwater (µg/g or µg/L)
VF	=	Volatilization factor (g/m³ or L/m³)
hours	=	Hours per day exposed to the vapours
days	=	Days per year exposed to the vapours

Note: for assessment of carcinogenic risks, an additional exposure adjustment factor is applied: $\left(\frac{\text{years exposed}}{\text{amortization period}}\right)$

Volatilization factors are calculated differently depending on whether the source of contamination is in soil or groundwater, and on whether the vapours are migrating to outdoor air or trench air. Conceptual diagrams showing volatilization from soil and groundwater sources to *outdoor air* are shown in the figures below. Equations used for calculating the various volatilization factors are provided on the following page. The conceptual diagrams and equations were obtained from the *Atlantic Canada Partners in Risk-Based Corrective Action Implementation Group* (Atlantic PIRI 2003).



Soil Vapour-to-Outdoor Air Conceptualization



Groundwater Vapour-to-Outdoor Air Conceptualization

Equations for Calculating Volatilization Factors

$$VF_{S\text{-}OA} = \left(\frac{2 \cdot W \cdot B}{U_{air} \cdot \delta_{air}}\right)\left(\sqrt{\frac{D_{soil}^{eff} \cdot H}{\pi \cdot t \cdot \left(\theta_{water} + k_{oc} \cdot f_{oc} \cdot B + \theta_{air} \cdot H\right)}}\right)(10^3)$$

$$VF_{S\text{-}OA} = \frac{W \cdot B \cdot d}{U_{air} \cdot \delta_{air} \cdot t} \times 10^3$$

$$VF_{S\text{-}TA} = \left(\frac{2 \cdot \left(W_{tr} \cdot L_{tr} + 2 \cdot L_{tr} \cdot D_{tr} + 2 \cdot W_{tr} \cdot D_{tr}\right) \cdot B}{V_{tr} \cdot AXR}\right)\left(\sqrt{\frac{D_{soil}^{eff} \cdot H}{\pi \cdot t \cdot \left(\theta_{water} + k_{oc} \cdot f_{oc} \cdot B + \theta_{air} \cdot H\right)}}\right)(10^3)$$

$$VF_{GW\text{-}OA} = \frac{H}{1 + \left(\frac{U_{air} \cdot \delta_{air} \cdot L_{gw}}{D_{gw}^{eff} \cdot W}\right)} \times 10^3$$

$$VF_{GW\text{-}TA} = \frac{H}{1 + \left(\frac{U_{air} \cdot F_{tr} \cdot \delta_{air} \cdot L_{tr\text{-}gw}}{D_{gw}^{eff} \cdot W}\right)} \times 10^3$$

Where:

$VF_{S\text{-}OA}$	=	Volatilization factor for soil-to-outdoor air (kg/m^3)
$VF_{S\text{-}TA}$	=	Volatilization factor for soil-to-trench air (kg/m^3)
$VF_{GW\text{-}OA}$	=	Volatilization factor for groundwater-to-outdoor air (L/m^3)
$VF_{GW\text{-}TA}$	=	Volatilization factor for groundwater-to-trench air (L/m^3)
$D_{eff\text{-}soil}$	=	Effective molecular diffusion coefficient for vadose zone soil (cm^2/sec)
$D_{eff\text{-}gw}$	=	Effective molecular diffusion coefficient above groundwater table (cm^2/sec)
θ_{air}	=	Air-filled soil porosity, vadose zone (unitless)
θ_{water}	=	Water-filled soil porosity, vadose zone (unitless)
k_{oc}	=	Organic carbon-water sorption coefficient (cm^3-water/g-carbon)
f_{oc}	=	Fraction organic carbon
H	=	Henry's Law coefficient (unitless)
10^3	=	Conversion factor (1000 L/m^3)
t	=	Averaging time for flux (s)
L_{gw}	=	Depth below grade to groundwater contamination (cm);
$L_{tr\text{-}gw}$	=	Depth below trench to groundwater contamination (cm);
B	=	Soil bulk density (g/cm^3)
d	=	Depth (thickness) of contamination (cm; 200 cm is default for this model)
W	=	Width of contamination = width of breathing zone for outdoor model (cm)
δ_{air}	=	Mixing zone height of breathing zone for outdoor model (cm)
W_{tr}	=	Width of trench (cm)
L_{tr}	=	Length of trench (cm) (breathing zone for trench model)
D_{tr}	=	Depth of trench (cm) (mixing zone height for trench model)
V_{tr}	=	Volume of trench (cm)
U_{air}	=	Mean annual wind speed (cm/sec)
F_{tr}	=	Fraction of mean annual wind speed that occurs in trench (unitless)
AXR	=	Air exchange rate (1/sec); calculated as AXR = (UxFxLxD)/V_{trench}

Equations for Calculating D_{eff} (Effective Molecular Diffusion Coefficients)

$$D_{soil}^{eff} = \frac{D_{air} \times \theta_{air}^{3.33}}{\theta_{total}^{2}} + \frac{D_{water} \times \theta_{water}^{3.33}}{H \times \theta_{total}^{2}}$$

$$D_{gw}^{eff} = (h_{cap} + h_{vad}) \times \left(\frac{h_{cap}}{D_{cap}^{eff}} + \frac{h_{vad}}{D_{vad}^{eff}} \right)^{-1}$$

Where:

Where:	D_{soil}^{eff}	=	Effective molecular diffusion coefficient for soil, used to calculate both - D_{eff} for vadose zone soil (cm^2/sec) - D_{eff} for capillary zone soil (cm^2/sec)
	D_{gw}^{eff}	=	Effective molecular diffusion coefficient above groundwater table (cm^2/sec)
	D_{vad}^{eff}	=	Effective molecular diffusion coefficient for vadose zone soil (cm^2/sec)
	D_{cap}^{eff}	=	Effective molecular diffusion coefficient for capillary zone soil (cm^2/sec)
	D_{air}	=	Molecular diffusion constant in air (cm^2/sec)
	D_{water}	=	Molecular diffusion constant in water (cm^2/sec)
	θ_{air}	=	Air-filled soil porosity (unitless)
	θ_{water}	=	Water-filled soil porosity (unitless)
	θ_{total}	=	Total soil porosity (unitless)
	H	=	Henry's Law Coefficient (unitless)
	h_{vad}	=	thickness of vadose zone (cm)
	h_{cap}	=	thickness of capillary zone (cm)

As shown in the above diagrams and equations, a volatilization factor depends on the following:

(i) COC-specific diffusivity characteristics (through air and water) and soil-specific porosity characteristics (air- and water-filled pore spaces in the soil). These characteristics are taken into account in the D^{eff} equations, which are subsequently incorporated into each of the VF equations. The overall *effective* molecular diffusivity of a chemical through soil is calculated using the D^{eff} equations shown previously. D_{soil}^{eff} is the equation used to calculate molecular diffusion through capillary zone soil (i.e., D_{cap}^{eff}) and vadose zone soil (D_{vad}^{eff}); D_{gw}^{eff} shows how the D^{eff} values for these different soil zones can be combined to give an overall D^{eff} value for above the groundwater table.

(ii) The size of the source of contamination. All else being equal, more vapours will enter the air from a larger source of contamination than from a smaller source of contamination, and each of the VF equations take this into account (via the "width of contaminant source", W). The upper limit for the width of the contaminant source, however, is the size of the "breathing zone" of the receptor. NovaTox has set the width of contamination at a constant 10 m, which is the default value recommended by Atlantic PIRI (2003), and is justified as follows:

- If the actual size of contamination at the site is *less* than than 10 m wide, then setting the default value at 10 m is conservative.

- If the actual size of contamination at the site is *greater* than 10 m wide, it becomes a moot point because the breathing zone of any receptor will not reasonably be influenced by vapours emitted from father than 5 m away on either side of him or her. The breathing zone can be thought of as a "box of air", which continuously surrounds the receptor as he or she moves around the site. Therefore if the site-specific width of contamination is greater than 10 m, the fact that the breathing zone is mobile and follows the receptor around the site accounts for any large sources of contamination.

- Note: Emphasizing the importance of the size of the breathing zone (in this case setting it as the upper limit of the width of the contaminant source) can also be clearly demonstrated when one examines the other dimension of the breathing zone required as a parameter for the VF equations (the mixing zone height; refer to bullet (v) below).

(iii) <u>The distance the vapours have to migrate from the source to the surface</u>. All else being equal, more vapours will enter the air from shallower sources of contamination than from deeper sources of contamination, and each of the VF equations take this into account:

- Soil-to-outdoor air modelling: Atlantic PIRI (2003) guidance provides two possible VF equations for *surface* soil-to-outdoor air (with the smaller of the two VFs being recommended for any particular COC), as well as two possible VF equations for *sub-surface* soil-to-outdoor air (again, with the smaller of the two VFs being recommended for any particular COC). NovaTox conservatively only uses the surface soil equations (they have no variable denoting the "depth below grade to contaminated soil", essentially setting it at 0).

- Soil-to-trench air modelling: NovaTox similarly assumes surface contamination.

- Groundwater-to-outdoor air modelling: NovaTox models these vapours by using the site-specific depth to groundwater ("depth below grade to contaminated groundwater", L_{gw}).

- Groundwater-to-trench air modelling: NovaTox models these vapours by assuming that excavation of soil at the site will logically shorten the vapour migration path between the groundwater source and the exposed receptor. NovaTox conservatively always sets groundwater as being 1 cm below the underside of the trench ("depth below trench to contaminated groundwater", $L_{tr\text{-}gw}$).

(iv) <u>The surface area from which vapours can enter the breathing zone</u>. All else being equal, more vapours will enter the air from sources of contamination with a higher surface area than from sources of contamination with a smaller surface area. The VF equations take this into account as follows:

- Soil-to-trench air modelling: The soil-to-trench air VF equation is essentially the same as the first of the soil-to-outdoor air VF equations, except that it accounts for the fact that soil vapours can migrate from the floor as well as from the walls of the trench. The outdoor model has a term for "W"; the trench model replaces this with "WL + 2LD + 2WD".

(v) <u>The atmospheric conditions into which the vapours are migrating</u>. Vapours will be dispersed and diluted as they enter the air. The extent to which this occurs will depend on prevailing meteorological conditions, with excavations/trenches notably having the potential to contain stagnant air in which vapours could concentrate. The extent to which air will stagnate in an excavation will depend on its dimensions (e.g., whether it is a wide and shallow excavation vs a narrow and deep trench), and, in the case of a trench, also its orientation (e.g., whether its long axis is parallel or perpendicular to prevailing winds). The VF equations take this into account as follows:

- Soil-to-trench air modelling: The soil-to-trench air VF equation is essentially the same as the first of the soil-to-outdoor air VF equations, except that it accounts for the reduced air flow in a trench relative to the site as a whole. The trench model has a term for "air exchange rate" (AXR), which is calculated as AXR = (U x F x L x D) / V. With a windspeed (U) of 410 cm/sec, a "fraction of windspeed that occurs in the trench" (F) of 0.25, and trench dimensions (L x W x D) of 10m x 2m x 2m (for a trench volume, V, of 40,000,000

m^3), the AXR is calculated to be 0.5125 sec^{-1}. This essentially means that NovaTox has set the long axis of the trench as being parallel to prevailing winds. If the same trench was instead perpendicular to the wind (i.e., L x W x D of 2m x 10m x 2m), then the AXR would be 5X lower (0.1025 sec^{-1}), meaning that any associated final VF would be 5X higher, and in turn any final trench vapour concentration would be 5X higher. While it is possible that any trench at the site could have these dimensions and be perpendicular to the wind, it is considered equally possible that the same trench could be parallel to the wind, and importantly, equally as possible that a wider/shallower excavation with a higher F value, and a correspondingly higher AXR value could be at the site. Overall, the type of trench modelled by NovaTox is considered to be a suitably conservative point estimate representation of the various types of potential trenches/excavations at any construction site.

- Groundwater-to-trench air modelling: The soil-to-trench air VF equation is essentially the same as the groundwater-to-outdoor air VF equation, except that it accounts for the reduced air flow in a trench relative to the site as a whole. (The trench model only incorporates the "fraction of windspeed that occurs in the trench", F).

- Note: Consideration of atmospheric conditions re-emphasizes the importance of the "breathing zone" of the receptor being a critical piece of the analysis when using these outdoor/trench models. The outdoor/trench models *do not* model vapours "in the atmosphere", which would require the (absurd) application of the height of the entire atmosphere as the mixing zone height, which would in turn artificially underestimate any final estimate of vapour concentrations. Instead, the outdoor/trench models are used to estimate vapour concentrations *in the breathing zone of the receptor*. NovaTox has set this dimension at a constant 2 m, which is the default value recommended by Atlantic PIRI (2003) and is a reasonable upper limit of the height of any adult outdoor worker or construction worker.

Input parameters for outdoor and trench vapour modelling are provided in Appendices B1(a) (soil concentrations), B1(c) (site-specific characteristics, such as depth to groundwater), B1(d) (receptor characteristics), and B1(e) (COC-specific parameters such as Henry's Law coefficients, Koc values, molecular diffusion constants in air and water).

'Intermediate' outputs (i.e., effective molecular diffusion coefficients, volatilization factors, and non-pro-rated vapour concentrations in outdoor air and trench air) are provided in Appendix B3(f).

'Final' outputs (i.e., vapour concentrations in outdoor air and trench air that have been pro-rated for receptor exposure) are presented in the Exposure Assessment of the HHRA, with example calculations being provided in Appendix B3(f).

References

Atlantic PIRI. 2003. Risk-Based Corrective Action (RBCA) Tool Kit for Atlantic Canada: Software Guidance Manual. Prepared for the Atlantic Canada Partners in RBCA Implementation (PIRI) Group. Prepared by Groundwater Services, Inc., Houston, Texas.

U.S. EPA. 2004. Johnson and Ettinger (1991) Model for Subsurface Vapor Intrusion into Buildings. Models and user's guide available for download from: http://www.epa.gov/oswer/riskassessment/airmodel/johnson_ettinger.htm. United States Environmental Protection Agency, Office of Emergency and Remedial Response.

Inhalation of vapours arising from soil and/or groundwater COCs and migrating to indoor air is considered a complete exposure pathway for receptors who spend the majority of their time indoors. Indoor vapour concentrations are estimated using the Johnson and Ettinger (J&E) subsurface vapour intrusion model (Johnson and Ettinger 2001), which is generally accepted and recommended by the scientific community as well as the Ontario MECP and many other regulatory communities, and is publicly available from the U.S. EPA (Version 3.1; US EPA 2004). The model calculates the concentration of COC vapour at the contaminant source in different ways, depending on whether the COC source is in soil or groundwater. The model then converts this maximum "source vapour" concentration to a reduced "indoor vapour" concentration by accounting for the attenuation that occurs as the vapour (i) diffuses through soil, (ii) undergoes advective transport through cracks or other permeable areas of the building foundation, and (iii) is ultimately diluted by indoor air and normal building ventilation processes. Site-specific soil- and building- characteristics can be accounted for in the model. The J&E models for predicting indoor vapour concentrations from soil and groundwater sources are summarized in the equations below. Both equations have been adapted to include a bio-attentuation factor (as allowed by MECP; described below); in addition, the soil equation has been adapted to include a source-depletion multiplier term (as allowed by MECP; described below). Indoor vapour concentrations are pro-rated for a receptor's exposure frequency and duration as shown.

Equation for Calculating Effective Exposure Concentration of COC Vapour in Indoor Air

$$C_{\text{effective-indoor}} = C_{\text{indoor air}} \times \frac{\text{hours}}{24} \times \frac{\text{days}}{365}$$

Where:

$C_{\text{effective indoor}}$	=	Effective exposure concentration of COC in indoor air (µg/m^3)
$C_{\text{indoor air}}$	=	COC concentration in indoor air (µg/m^3)
hours	=	Hours per day exposed to the vapours
days	=	Days per year exposed to the vapours

Note: for assessment of carcinogenic risks, an additional exposure adjustment factor is applied: $\left(\frac{\text{years exposed}}{\text{amortization period}}\right)$

Equation for predicting indoor vapour concentration from soil contamination

$$C_{\text{indoor air}} = C_{\text{soil}} \times \left(\frac{H \times B \times CF1}{\theta_{\text{water}} + (Koc \cdot foc) \times B + H \times \theta_{\text{air}}}\right) \times \alpha \times BAF \times \frac{1}{SDM}$$

Equation for predicting indoor vapour concentration from groundwater contamination

$$C_{\text{indoor air}} = C_{gw} \times (H \times CF2) \times \alpha \times BAF$$

Where:

$C_{\text{indoor-air}}$	=	COC concentration in indoor air (µg/m^3)
C_{soil}	=	COC concentration in soil (µg/g)
C_{gw}	=	COC concentration in groundwater (µg/L)
H	=	Henry's Law coefficient (unitless);
B	=	Soil bulk density (g/cm^3)
CF1	=	Conversion factor (10^6 cm^3/m^3)
CF2	=	Conversion factor (10^3 L/m^3)
θ_{air}	=	Air-filled soil porosity (unitless)
θ_{water}	=	Water-filled soil porosity (unitless);
K_{oc}	=	Organic carbon-water sorption coefficient (cm^3-water/g-carbon)
f_{oc}	=	Fraction organic carbon
α	=	attenuation factor (unitless)
BAF	=	bio-attenuation factor (unitless)
SDM	=	source depletion multiplier (unitless)

Attenuation Factor

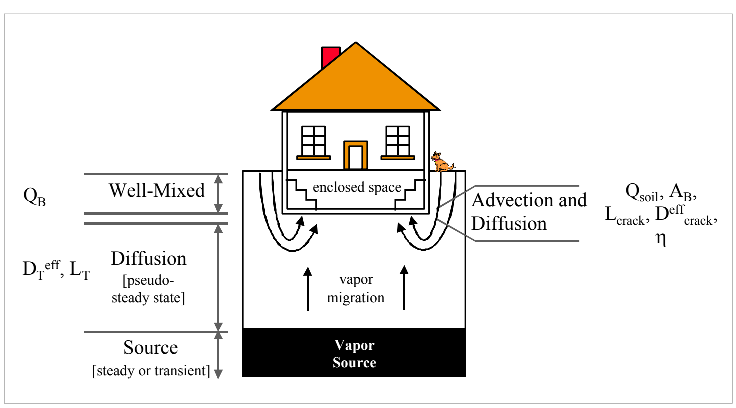
The attenuation factor, alpha (α), is calculated by the J&E model using the following equation. It is as shown in Section 7.3.3 of the MOE (2011) Rationale Document. NovaTox notes the following:

- *Soil vapour modelling*: Always uses attenuation factors as calculated by the J&E model.

- *Groundwater vapour modelling*: There is some uncertainty regarding the approach to be used during groundwater vapour modelling. According to Section 7.6.3 of the MOE (2011) Rationale Document, attenuation factors calculated by the J&E model are to be used in instances where groundwater is *beneath* the gravel crush, while conservative default attenuation factors (0.02 for residential buildings and 0.004 for commercial buildings) are to be used in instances where groundwater is *penetrating* the gravel crush. However, according to a MOECC (2018) MGRA Tool Training Manual, the conservative default attenuation factors are to be used in instances where there is a "separation distance < 1 m" between the groundwater and the concrete slab/foundation of the building. NovaTox is following the MOECC (2018) recommendation as it is more conservative than the MOE (2011) recommendation.

Equation for calculating attenuation factor			
$$\alpha=\frac{\left(\frac{D_T * A_B}{Q_{building} * L_T}\right) * \exp\left(\frac{Q_{soil} * L_{crack}}{D_{crack} * A_{crack}}\right)}{\left(\exp\left(\frac{Q_{soil} * L_{crack}}{D_{crack} * A_{crack}}\right)+\left(\frac{D_T * A_B}{Q_{building} * L_T}\right)+\frac{D_T * A_B}{Q_{soil} * L_T} * \left[\exp\left(\frac{Q_{soil} * L_{crack}}{D_{crack} * A_{crack}}\right)-1\right]\right)}$$			
Where:	α	=	attenuation factor (unitless)
	L_T	=	Distance from building to source of contamination (cm)
	L_{crack}	=	Thickness of floor/building foundation/concrete slab (cm)
	A_B	=	Area of the building below grade (i.e., floor plus 4 walls) (cm^2)
	A_{crack}	=	Area of total cracks in A_B (cm^2)
	D_T	=	Diffusion coefficient for soil (total overall coefficient, which takes into account varying diffusion through different soil types) (cmP^{2}P/secP)
	D_{crack}	=	Diffusion coefficient for floor/cracks (assumed to be equivalent to diffusion coefficient of the soil type closest to the floor) (cm^2/sec)
	Q_{soil}	=	Flow rate of soil vapour into the building (cm^3/s)
	$Q_{building}$	=	Flow rate of outdoor air into the building (i.e., ventilation rate) (cm^3/sec)

A conceptual diagram showing vapour migration from a source of subsurface contamination to indoor air (and also shows the processes/system components/inputs required for calculation of the attenuation factor) is shown in the figure below (taken from Johnson 2002).



Bio-Attenuation Factor

Ontario MECP allows for the application of a bio-attenuation factor (BAF) to account for certain contaminants (naphthalene, BTEX, PHC F1/F2, hexane) being susceptible to biodegradation as they migrate as a vapour through aerobic soil. BAFs can be briefly summarized as follows:

- *Soil vapour modelling*: If there is at least 1 m of clean fill between the soil contamination and the underside of the crushed gravel layer under the building, then a BAF of 0.1 can be applied. If there is at least 3 m of clean fill, then the BAF can be 0.01. (Reference: Section 7.4.6 of the MOE (2011) Rationale Document).

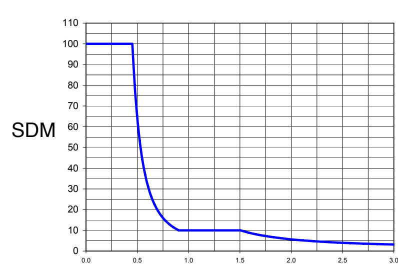
- *Groundwater vapour modelling*: If there is at least 0.74 m of *unsaturated* clean fill (vadose zone soil) between the top of the saturated capillary zone and the underside of the crushed gravel layer under the building, then a BAF of 0.1 can be applied. If there is at least 3 m of unsaturated clean fill, then the BAF can be 0.01. (Reference: Section 7.6.3 of the MOE (2011) Rationale Document).

Source Depletion Multiplier

Ontario MECP allows for the application of a source depletion multiplier (SDM) to account for the fact that a finite contaminant source in soil will progressively deplete over time as the contaminant volatilizes away (i.e., simple mass balance rationalization). SDMs can be briefly summarized as follows:

- *Soil vapour modelling*: A SDM value depends on how rapidly a contaminant source depletes, i.e., is a function of the contaminant's depletion *half-life*. A contaminant's allowable SDM exponentially declines as its half-life increases: the continuous range of "theoretical" SDM values is approximated by MECP by using (i) a default maximum SDM of 100 for contaminants with a high rate of depletion (i.e., a short half-life, assumed by MECP to be ≤0.4515 years), (ii) an exponential decay equation for contaminants with half-lives between >0.4515 years and <0.905 years, (iii) a default SDM value of 10 for contaminants with half-lives between 0.905 years and <1.505 years, and (iv) another exponential decay equation for contaminants with half-lives ≥1.505 years. The depletion half-life is calculated by MECP by taking into account the initial mass of the contaminant source (found in a default volume of soil of 13m x 13m x 2m, minus the volume of soil that must be excavated to allow placement of a building*), and the mass of contaminant that remains after 1 week of depletion/volatilization. The 1-week half-life is subsequently extrapolated to an annual half-life. (Reference: Section 7.4.4, subsections (3) through (8) of the MOE (2011) Rationale Document).

- *Groundwater vapour modelling*: Does not allow application of a SDM due to the difficulties in estimating a contaminant source mass in groundwater. (Reference: Section 7.3.5.1 of the MOE (2011) Rationale Document).



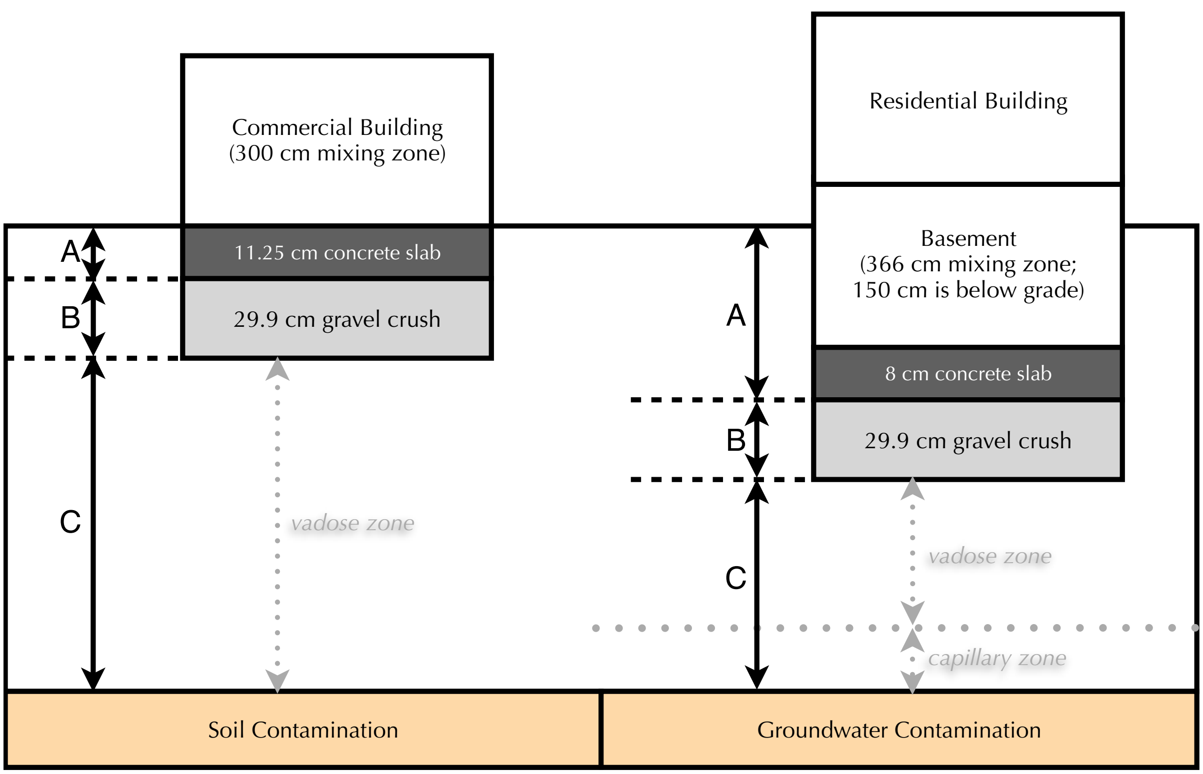
---

* For the purposes of calculating the SDM, NovaTox assumes that the maximum dimensions of soil that can possibly be excavated for placement of a building are 12.99m x 12.99m x 1.99m. Otherwise a SDM may not be able to be calculated at all in certain instances (e.g., a site-specific building with dimensions that exceed 13m x 13m x 2m).

Building Proximity to Contaminant Source

With regard to the building's proximity to subsurface sources of contamination and the soil layers / "strata" required by the J&E model:

- "Soil Stratum A" represents the layer of soil extending from the surface to the underside of the concrete foundation slab (11.25 cm for "generic" commercial slab-on-grade buildings; 158 cm for "generic" residential buildings with basements). The default soil "type" is typically *sand* (i.e., the most conservative type, which is associated with the highest potential for vapours to migrate through the soil and into the building).
- "Soil Stratum B" represents the layer of crushed gravel under the foundation (required by the Ontario Building Code and in turn therefore required in J&E modelling per MECP guidance). In the soil model it has a full thickness of 29.9 cm. In the groundwater model its effective thickness is anywhere from 0.1 cm to 29.9 cm (i.e., anything less than the full thickness of 29.9 cm represents groundwater penetrating the gravel).
- "Soil Stratum C" represents the layer of soil / clean fill between the contaminant source and the underside of the crushed gravel. The default soil type is typically sand. In the soil model, the entirety of this layer is vadose zone soil (i.e., unsaturated). In the groundwater model, this layer consists of vadose zone soil as well as capillary zone soil immediately above the groundwater table (i.e., saturated due to water being drawn into pore spaces due to capillary action).



Building Characteristics

Ontario MECP provides default characteristics for a "generic" commercial slab-on-grade scenario and a "generic" residential building-with-basement scenario. Those default characteristics were also used by NovaTox to derive a "generic" commercial building-with-basement scenario and a "generic" residential slab-on-grade scenario.

Building Characteristics	Residential Building-with-Basement	Residential Slab-on-Grade	Commercial Building-with-Basement	Commercial Slab-on-Grade
Depth below grade to bottom of floor (a)	158	8	161.25	11.25
Length (a)	1,225	1,225	2,000	2,000
Width (a)	1,225	1,225	1,500	1,500
Height (a)	366	366	300	300
Slab Thickness (a)	8	8	11.25	11.25
Crack Width (a)	0.1	0.1	0.1	0.1
Pressure Differential, Building - Soil (a)	40	40	20	20
Air Exchange Rate (a)	0.3	0.3	1.0	1.0
Crack depth below grade (a)	158	8	161.25	11.25
Flow rate of soil vapour into building (a)	8.5 (coarse soil) 1.0 (fine soil)	8.5 (coarse soil) 1.0 (fine soil)	9.8 (coarse soil) 1.5 (fine soil)	9.8 (coarse soil) 1.5 (fine soil)
Floor-wall seam perimeter (b)	4,900	4,900	7,000	7,000
Building ventilation rate (b)	4.58E+04	4.58E+04	2.50E+05	2.50E+05
Area of enclosed space below grade (b)	2.27E+06	1.50E+06	4.13E+06	3.00E+06
Crack-to-total area ratio (b)	2.15E-04	3.27E-04	1.70E-04	2.33E-04

Notes:
- Residential building-with-basement and commercial slab-on-grade buildings are MECP default building types.
- Commercial building-with-basement assumed to be same dimensions and characteristics as commercial slab-on-grade building, but with a basement that extends to 150 cm (i.e., same as residential building-with-basement), and a default commercial slab thickness of 11.25 cm, for a total depth to bottom of floor of 161.25 cm.
- Residential slab-on-grade building assumed to be same dimensions and characteristics as residential building-with-basement, but no basement means that the total depth below grade to bottom of floor is 8 cm.

(a) MECP default values.
(b) Calculated per J&E model equation.

Soil Characteristics

The Soil Conservation Service (SCS) of the U.S. Department of Agriculture (USDA) provides default characteristics for 12 different "types" of soil that have varying compositions of sand, silt, and clay. Ontario MECP provides default characteristics for crushed gravel. Characteristics relevant to the migration of vapours through soil have been encoded into the J&E model.

Soil Properties										
SCS Soil Type	**K_s (cm/h)**	**α_1 (1/cm)**	**N (unitless)**	**M (unitless)**	**n (cm^3/ cm^3)**	**θ_r (cm^3/ cm^3)**	**Mean Grain Diameter (cm)**	**Bulk density (g/cm^3)**	**θ_w (cm^3/ cm^3)**	**f_{OC}**
Clay	0.61	0.01496	1.253	0.2019	0.459	0.098	0.0092	1.43	0.215	0.005
Clay Loam	0.34	0.01581	1.416	0.2938	0.442	0.079	0.016	1.48	0.168	0.005
Loam	0.50	0.01112	1.472	0.3207	0.399	0.061	0.020	1.59	0.148	0.005
Loamy Sand	4.38	0.03475	1.746	0.4273	0.390	0.049	0.040	1.62	0.076	0.005
Gravel Crush	36,000				0.400		1.000	1.60	0.010	
Sand	26.78	0.03524	3.177	0.6852	0.375	0.053	0.044	1.66	0.054	0.005
Sandy Clay	0.47	0.03342	1.208	0.1722	0.385	0.117	0.025	1.63	0.197	0.005
Sandy Clay Loam	0.55	0.02109	1.330	0.2481	0.384	0.063	0.029	1.63	0.146	0.005
Silt	1.82	0.00658	1.679	0.4044	0.489	0.050	0.0046	1.35	0.167	0.005
Silty Clay	0.40	0.01622	1.321	0.2430	0.481	0.111	0.0039	1.38	0.216	0.005
Silty Clay Loam	0.46	0.00839	1.521	0.3425	0.482	0.090	0.0056	1.37	0.198	0.005
Silt Loam	0.76	0.00506	1.663	0.3987	0.439	0.065	0.011	1.49	0.180	0.005
Sandy Loam	1.60	0.02667	1.449	0.3099	0.387	0.039	0.030	1.62	0.103	0.005

Notes:
- Ks = hydraulic conductivity (does not actually factor into model calculations)
- α_1 = van Genuchten point of inflection in the water retention curve (does not actually factor into model calculations)
- N = van Genuchten curve shape parameter (essentially the ability of soil to retain water; higher value = less retention)
- M = van Genuchten parameter = 1 - (1/N)
- n = total porosity
- θr = residual water content (factors into the calculation of θw)
- θw = water-filled porosity
- f_{OC} = fraction organic carbon
- Values for the 12 SCS soil types obtained from J&E model
- Values for gravel crush obtained from MECP guidance memorandum: Ks, n, θw, bulk density
- Value for gravel crush assumed by NovaTox: mean grain diameter (assumed 1 cm diameter of typical piece of gravel)

Model Input

Input parameters for indoor vapour modelling are provided in Appendices B1(a) (soil concentrations), B1(c) (site-specific characteristics, such as depths to soil and groundwater contamination, and building dimensions etc.), B1(d) (receptor characteristics), and B1(e) (COC-specific parameters such as Henry's Law coefficients, Koc values, molecular diffusion constants in air and water). Note that COC-specific parameters are *as specified by the Ontario MECP MGRA model*, and are not the default values originally encoded in the U.S. EPA J&E model.

Model Output

J&E model output (including source vapour concentrations, attenuation factors, bio-attenuation factors, source depletion multipliers, and *non-pro-rated* vapour concentrations in indoor air) are provided in Appendix B3(g). Final "effective" exposure concentrations in indoor air that have been *pro-rated* for receptor exposure are also presented in Appendix B3(g) (as well as in the Exposure Assessment of the HHRA).

References

Johnson, P. C. 2002. Identification of Critical Parameters for the Johnson and Ettinger (1991) Vapor Intrusion Model. American Petroleum Institute Bulletin No. 17, Washington, DC.

Johnson, P. C. and R. A. Ettinger. 1991. Heuristic model for predicting the intrusion rate of contaminant vapors in buildings. Environ. Sci. Technol. 25: 1445-1452.

U.S. EPA. 2004. Johnson and Ettinger (1991) Model for Subsurface Vapor Intrusion into Buildings. Models and user's guide available for download from: http://www.epa.gov/oswer/riskassessment/airmodel/johnson_ettinger.htm. United States Environmental Protection Agency, Office of Emergency and Remedial Response.

Note:

NovaTox has re-created the J&E models publicly available from the U.S. EPA (Version 3.1; US EPA 2004) in its own proprietary model. All input parameters (i.e., the U.S. EPA "DATENTER" sheets), and all intermediate calculations and final output (i.e., the U.S. EPA "INTERCALCS" sheets) are fully accounted for in NovaTox's model.

As a quality assurance / quality control measure, the following pages compare NovaTox's J&E model to U.S. EPA's J&E models, using benzene as an example contaminant. Vapour intrusion was modelled as follows:

- Benzene in soil at a concentration of 10 μg/g, and from a depth of 100 cm below grade.
- Benzene in groundwater at a concentration of 10 μg/L, and from a depth of 100 cm below grade.
- The soil and groundwater models each assessed a commercial slab-on-grade building, with generic parameters as defined by MECP.

Appendices G1(a) and G1(b) of the RA provide concentrations of COCs in soil and groundwater, respectively. Benzene is shown below as an example. Contaminant concentrations are typically entered on the "DATENTER" sheets of the EPA J&E models.

Soil COCs COC	Soil conc. (μg/g)
Benzene	10

Groundwater COCs COC	GW conc. (μg/L)
Benzene	10

Appendix G1(c) of the RA provides input parameters specific to the site (e.g., depth to contamination, soil strata characteristics, building characteristics, etc). An example is shown on the following page. These inputs are typically entered on the "DATENTER" sheets of the EPA J&E models.

Category	Site Characteristic	Symbol	Units	Value
Water Potability	Potability of groundwater		–	Potable
J&E Building Inputs	Type of Building		–	Commercial Slab-on-Grade
	Slab Thicknss	Lcrack	cm	11.25
	Depth below grade to bottom of floor	L_F	cm	11.25
J&E Soil Inputs	Depth below grade to top of contaminated soil	zsoil or L_t	cm	100
	Depth to contaminated soil used in model	zsoil or L_t	cm	100
	Soil Source-bldg. separation	L_T	cm	88.75
	Depth below grade to bottom of contaminated soil	L_b	cm	0
	Soil Stratum A - Thickness	h_A	cm	11.25
	Soil Stratum B - Thickness (Soil model)	h_B	cm	29.9
	Soil Stratum C - Thickness (Soil model)	h_C	cm	58.9
J&E GW Inputs	Depth below grade to contaminated GW	zgw or L_{WT}	cm	100.00
	Depth to contaminated GW used in model	zgw or L_{WT}	cm	100.00
	GW Source-bldg. separation	L_T	cm	88.75
	Soil Stratum A - Thickness	h_A	cm	11.25
	Soil Stratum B - Thickness (GW model)	h_B	cm	29.9
	Soil Stratum C - Thickness (GW model)	h_C	cm	58.9
	Soil stratum directly above water table	–	–	C
	SCS soil type directly above water table	–	–	Sand
Building Characteristics	Length		cm	2000
	Width		cm	1500
	Height		cm	300
	Crack Width	w	cm	0.1
	Pressure Differential, Building - Soil	Δp	g/cm-sec2	20
	Air Exchange Rate	ER	1/hour	1
	Crack depth below grade	$X_{crack\ or\ Zcrack}$	cm	11.25
	Flow rate of soil vapour into building (or leave blank)	Q_{SOIL}	L/min	9.8
	Floor-wall seam perimeter	X_{crack}	cm	7,000
	Building ventilation rate	$Q_{building}$	cm^3/s	2.50E+05
	Area of enclosed space below grade	A_B	cm^2	3.00E+06
	Crack-to-total area ratio	η	–	2.33E-04
Soil Stratum A	Stratum A SCS soil type			Sand
	Stratum A soil air-filled porosity	θ_a^A	cm^3/cm^3	0.321
	Stratum A water filled porosity	θ_W^A	cm^3/cm^3	0.054
	Stratum A soil total porosity	n^A	–	0.375
	Stratum A soil dry bulk density	ρ_b^A	g/cm^3	1.66
	Stratum A soil organic carbon fraction	f_{OC}^A	–	0.005
	User defined stratum A soil vapour permeability	k_V	cm^2	
	Stratum A effective total fluid saturation	S_{te}	cm^3/cm^3	0.003
	Stratum A soil intrinsic permeability	k_i	cm^2	1.00E-07
	Stratum A soil relative air permeability	k_{rg}	cm^2	0.998
	Stratum A soil effective vapour permeability	k_v	cm^2	9.99E-08
Soil Stratum B	Stratum B SCS soil type			Gravel Crush
	Stratum B soil air-filled porosity	θ_a^B	cm^3/cm^3	0.390
	Stratum B water filled porosity	θ_W^B	cm^3/cm^3	0.010
	Stratum B soil total porosity	n^B	–	0.400
	Stratum B soil dry bulk density	ρ_b^B	g/cm^3	1.60
	Stratum B soil organic carbon fraction	f_{OC}^B		0.000
Soil Stratum C	Stratum C SCS soil type			Sand
	Stratum C soil air-filled porosity	θ_a^C	cm^3/cm^3	0.321
	Stratum C water filled porosity	θ_W^C	cm^3/cm^3	0.054
	Stratum C soil total porosity	n^C	–	0.375
	Stratum C soil dry bulk density	ρ_b^C	g/cm^3	1.66
	Stratum C soil organic carbon fraction	f_{OC}^C		0.005
	Soil/Groundwater temperature		oC	15
	Length of contaminant source	L_c	cm	200
	Width of contaminant source	W_c	cm	1,000
	Depth of contaminant source	D_c	cm	200
	Capillary fringe - thickness	h_c	cm	0.05
	Capillary zone - thickness	L_{CZ}	cm	17.05
	Capillary zone - total porosity	n_{CZ}	cm^3/cm^3	0.375

Category	Site Characteristic	Symbol	Units	Value
Miscellaneous Intercalcs for vapour modelling	Capillary zone - air-filled porosity	$\theta_{a,cz}$	cm^3/cm^3	0.122
	Capillary zone - water-filled porosity	$\theta_{w,cz}$	cm^3/cm^3	0.253
	Vadose zone - thickness	h_v	cm	99.95
	Vadose zone - total porosity	E_t	cm^3/cm^3	0.360
	Vadose zone - air-filled porosity	Θ_{as}	cm^3/cm^3	0.241
	Vadose zone - water-filled porosity	Θ_{ws}	cm^3/cm^3	0.119
	Fraction organic carbon	f_{oc}	–	0.005
	Soil bulk density	B	g/cm^3	1.70
	Exposure duration		y	56
	Exposure duration	τ	s	1.77E+09
	Conversion factor	C	cm^3-kg/m^3-g	1,000
Trench Characteristics	Length of trench	L	cm	1,000
	Width of trench	W	cm	200
	Depth of trench	D	cm	200
	Volume of trench	V_t	cm^3	40,000,000
	Fraction of total wind speed that occurs in trench	F_t	–	0.25
	Air exchange rate in trench	A	s^{-1}	0.520
	Depth below trench to contaminated GW	z_{TRENCH}	cm	1
Atmospheric Characteristics	Mean annual wind speed	U	cm/s	416
	Ambient air mixing zone height	δ_{AIR}	cm	200
	Averaging time for flux	t	s	31,536,000

"DATENTER" sheet of the EPA J&E soil vapour intrusion model:

SL-ADV
Version 3.1; 02/04

Reset to Defaults

CALCULATE RISK-BASED SOIL CONCENTRATION (enter "X" in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL SOIL CONCENTRATION (enter "X" in "YES" box and initial soil conc. below)

YES [X]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial soil conc., C_R (μg/kg)	Chemical
71432	1.00E+04	Benzene

MORE ↓

Totals must add up to value of L_t (cell G28) — applies to h_A, h_B, h_C.

ENTER Average soil temperature, T_S (°C)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to top of contamination, L_t (cm)	ENTER Depth below grade to bottom of contamination, (enter value of 0 if value is unknown) L_b (cm)	ENTER Thickness of soil stratum A, h_A (cm)	ENTER Thickness of soil stratum B, (Enter value or 0) h_B (cm)	ENTER Thickness of soil stratum C, (Enter value or 0) h_C (cm)	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
15	11.25	100	0	11.25	29.9	58.85	S		

MORE ↓

ENTER Stratum A SCS soil type (Lookup Soil Parameters)	ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum A soil organic carbon fraction, f_{oc}^A (unitless)	ENTER Stratum B SCS soil type (Lookup Soil Parameters)	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum B soil organic carbon fraction, f_{oc}^B (unitless)	ENTER Stratum C SCS soil type (Lookup Soil Parameters)	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)	ENTER Stratum C soil organic carbon fraction, f_{oc}^C (unitless)
S	1.66	0.375	0.054	0.005		1.6	0.4	0.01	0	S	1.66	0.375	0.054	0.005

MORE ↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP (g/cm-s^2)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)	ENTER Average vapor flow rate into bldg. OR Leave blank to calculate Q_{soil} (L/m)
11.25	20	2000	1500	300	0.1	1	9.8

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	30	30	350	1.0E-06	1

Used to calculate risk-based soil concentration.

END

"DATENTER" sheet of the EPA J&E groundwater vapour intrusion model:

GW-ADV
Version 3.1; 02/04

Reset to Defaults

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION (enter "X" in "YES" box and initial groundwater conc. below)

YES [X]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial groundwater conc., C_W (μg/L)	Chemical
71432	1.00E+01	Benzene

MORE ↓

ENTER Average soil/ groundwater temperature, T_S (°C)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Thickness of soil stratum A, h_A (cm)	ENTER Thickness of soil stratum B, (Enter value or 0) h_B (cm)	ENTER Thickness of soil stratum C, (Enter value or 0) h_C (cm)	ENTER Soil stratum directly above water table, (Enter A, B, or C)	ENTER SCS soil type directly above water table	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
15	11.25	100	11.25	29.9	58.85	C	S	S		

Totals must add up to value of L_{WT} (cell G28)

MORE ↓

ENTER Stratum A SCS soil type (Lookup Soil Parameters)	ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum B SCS soil type (Lookup Soil Parameters)	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum C SCS soil type (Lookup Soil Parameters)	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)
S	1.66	0.375	0.054	S	1.6	0.4	0.01	S	1.66	0.375	0.054

MORE ↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP (g/cm-s^2)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)	ENTER Average vapor flow rate into bldg. OR Leave blank to calculate Q_{soil} (L/m)
11.25	20	2000	1500	300	0.1	1	9.8

MORE ↓

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
56	56	56	250	1.0E-06	0.2

Used to calculate risk-based groundwater concentration.

END

Appendix G3(g) of the RA provides the output from NovaTox's J&E soil vapour intrusion model. These results are typically provided on the "INTERCALCS" sheet of the EPA J&E soil vapour intrusion model. Benzene is provided below as an example from both the NovaTox and the EPA model.

NovaTox:

COC	Enthalpy of vap. at ave. soil temp. $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temp. H_{TS} (atm-m^3/mol)	Henry's law constant at ave. soil temp. H'_{TS} (unitless)	Vapour viscosity at average soil temp. μ_{TS} (g/cm-s)	Stratum A effective diffusion coefficient D^{eff}_A (cm^2/s)	Stratum B effective diffusion coefficient D^{eff}_B (cm^2/s)	Stratum C effective diffusion coefficient D^{eff}_C (cm^2/s)	Total overall effective diffusion coefficient D^{eff}_T (cm^2/s)	Diff-usion path length L_d (cm)	Con-vec-tion path length L_p (cm)	Soil-water partition coefficient K_d (cm^3/g)	Soil Source vapour conc. C_{source} (µg/m^3)	Crack radius r_{crack} (cm)	Average vapour flow rate into building Q_{soil} (cm^3/s)	Crack effective diffusion coefficient D^{crack} (cm^2/s)	Area of crack A_{crack} (cm^2)
Benzene in soil	8,066	3.46E-03	1.46E-01	1.77E-04	1.42E-02	2.39E-02	1.42E-02	1.65E-02	88.75	11.25	1.66E+00	8.53E+05	0.10	1.63E+02	1.42E-02	700

COC	Exponent of equivalent foundation Peclet number exp(Pe^f) (unitless)	Infinite source indoor attenuation coefficient α (unitless)	MOE Bio-Attenuation Factor α (unitless)	Infinite source bldg. conc. $C_{building}$ (µg/m^3)	Finite source B term (unitless)	Finite source ψ term (sec)$^{-1}$	Time for source depletion τ_D (sec)	Exposure duration > time for source (Y/N)	Finite source indoor attenuation coefficient <α> (unitless)	Mass limit building conc. $C_{building}$ (µg/m^3)	Finite source bldg. conc. $C_{building}$ (µg/m^3)	Final finite source bldg. conc. $C_{building}$ (µg/m^3)	Soil saturation conc. C_{sat} (µg/kg)
Benzene in soil	1.37E+80	5.05E-04	1.00E+00	4.31E+02	NA	NA	NA	NA	NA	NA	NA	NA	3.07E+06

EPA:

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm^3/cm^3)	Stratum B soil air-filled porosity, θ_a^B (cm^3/cm^3)	Stratum C soil air-filled porosity, θ_a^C (cm^3/cm^3)	Stratum A effective total fluid saturation, S_{te} (cm^3/cm^3)	Stratum A soil intrinsic permeability, k_i (cm^2)	Stratum A soil relative air permeability, k_{rg} (cm^2)	Stratum A effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Initial soil concentration used, C_R (µg/kg)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
9.46E+08	88.75	0.321	0.390	0.321	0.003	1.00E-07	0.998	9.99E-08	7,000	1.00E+04	2.50E+05

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Stratum A effective diffusion coefficient, D^{eff}_A (cm^2/s)	Stratum B effective diffusion coefficient, D^{eff}_B (cm^2/s)	Stratum C effective diffusion coefficient, D^{eff}_C (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)	Diffusion path length, L_d (cm)	Convection path length, L_p (cm)
3.00E+06	2.33E-04	11.25	8,066	3.46E-03	1.46E-01	1.77E-04	1.42E-02	2.39E-02	1.42E-02	1.65E-02	88.75	11.25

Soil-water partition coefficient, K_d (cm^3/g)	Source vapor conc., C_{source} (µg/m^3)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, exp(Pe^f) (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (µg/m^3)	Finite source β term (unitless)	Finite source ψ term (sec)$^{-1}$	Time for source depletion, τ_D (sec)	Exposure duration > time for source depletion (YES/NO)
1.66E+00	8.53E+05	0.10	1.63E+02	1.42E-02	7.00E+02	1.37E+80	5.05E-04	4.31E+02	NA	NA	NA	NA

Finite source indoor attenuation coefficient, <α> (unitless)	Mass limit bldg. conc., $C_{building}$ (µg/m^3)	Finite source bldg. conc., $C_{building}$ (µg/m^3)	Final finite source bldg. conc., $C_{building}$ (µg/m^3)	Unit risk factor, URF (µg/m^3)$^{-1}$	Reference conc., RfC (mg/m^3)
NA	NA	NA	NA	7.8E-06	3.0E-02

END

NovaTox

Appendix G3(g) of the RA also provides the output from NovaTox's J&E groundwater vapour intrusion model. These results are typically provided on the "INTERCALCS" sheet of the EPA J&E groundwater vapour intrusion model. Benzene is provided below as an example from both the NovaTox and the EPA model.

NovaTox:

COC	Enthalpy of vaporization at ave. GW temperature $\Delta Hv,TS$ (cal/mol)	Henry's law constant at ave. GW temp. H_{TS} (atm-m³/mol)	Henry's law constant at ave. GW temp. H'_{TS} (unitless)	Vapour viscosity at average soil temp. μ_{TS} (g/cm-s)	Stratum A effective diffusion coefficient D^{eff}_A (cm²/s)	Stratum B effective diffusion coefficient D^{eff}_B (cm²/s)	Stratum C effective diffusion coefficient D^{eff}_C (cm²/s)	Capillary zone effective diffusion coefficient D^{eff}_{cz} (cm²/s)	Total overall effective diffusion coefficient D^{eff}_T (cm²/s)	Diff-usion path length L_d (cm)	Con-vection path length L_p (cm)	GW Source vapour conc. C_{source} (µg/m³)	Crack radius r_{crack} (cm)	Average vapour flow rate into building Q_{soil} (cm³/s)	Crack effective diffusion coefficient D^{crack} (cm²/s)	Area of crack A_{crack} (cm²)
Benzene in GW	8,066	3.46E-03	1.46E-01	1.77E-04	1.42E-02	2.39E-02	1.42E-02	5.68E-04	2.60E-03	88.75	11.25	1.46E+03	0.10	1.63E+02	1.42E-02	7.00E+02

COC	Exponent of equivalent foundation Peclet number $exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient α (unitless)	MOE Default Attenuation Factor α (unitless)	MOE Bio-Attenuation Factor α (unitless)	Infinite source bldg. conc. $C_{building}$ (µg/m³)
Benzene in GW	1.37E+80	2.28E-04		1.00E+00	3.34E-01

EPA:

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm³/cm³)	Stratum B soil air-filled porosity, θ_a^B (cm³/cm³)	Stratum C soil air-filled porosity, θ_a^C (cm³/cm³)	Stratum A effective total fluid saturation, S_{te} (cm³/cm³)	Stratum A soil intrinsic permeability, k_i (cm²)	Stratum A soil relative air permeability, k_{rg} (cm²)	Stratum A soil effective vapor permeability, k_v (cm²)	Thickness of capillary zone, L_{cz} (cm)	Total porosity in capillary zone, n_{cz} (cm³/cm³)	Air-filled porosity in capillary zone, $\theta_{a,cz}$ (cm³/cm³)	Water-filled porosity in capillary zone, $\theta_{w,cz}$ (cm³/cm³)	Floor-wall seam perimeter, X_{crack} (cm)
1.77E+09	88.75	0.321	0.390	0.321	0.003	1.00E-07	0.998	9.99E-08	17.05	0.375	0.122	0.253	7,000

Bldg. ventilation rate, $Q_{building}$ (cm³/s)	Area of enclosed space below grade, A_B (cm²)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. groundwater temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. groundwater 1.00E+01 H_{TS} (atm-m³/mol)	Henry's law constant at ave. groundwater temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Stratum A effective diffusion coefficient, D^{eff}_A (cm²/s)	Stratum B effective diffusion coefficient, D^{eff}_B (cm²/s)	Stratum C effective diffusion coefficient, D^{eff}_C (cm²/s)	Capillary zone effective diffusion coefficient, D^{eff}_{cz} (cm²/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm²/s)	Diffusion path length, L_d (cm)
2.50E+05	3.00E+06	2.33E-04	11.25	8,066	3.46E-03	1.46E-01	1.77E-04	1.42E-02	2.39E-02	1.42E-02	5.68E-04	2.60E-03	88.75

Convection path length, L_p (cm)	Source vapor conc., C_{source} (µg/m³)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm³/s)	Crack effective diffusion coefficient, D^{crack} (cm²/s)	Area of crack, A_{crack} (cm²)	Exponent of equivalent foundation Peclet number, 1.00E+02 (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (µg/m³)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m³)
11.25	1.46E+03	0.10	1.63E+02	1.42E-02	7.00E+02	1.37E+80	2.28E-04	3.34E-01	7.8E-06	3.0E-02

END

For chemicals that cause adverse health effects other than cancer, health risks are assessed by calculating a hazard quotient (HQ). It is calculated by dividing a receptor's exposure estimate by a toxicological reference value (TRV) that represents the "threshold" at or below which no appreciable health risk from a chemical is anticipated, even after chronic exposure. The unitless HQ represents the fraction of the TRV to which a typical person is exposed.

Categories of HQ include:

1. **Soil COC Oral/Dermal HQ**: representing the hazard from three combined exposure pathways: (i) incidental ingestion of soil (described in Appendix B2(a)); (ii) dermal contact with soil (described in Appendix B2(b)); and (iii) inhalation of soil particulates that are coughed and ingested (described in Appendix B2(c)). Each of these exposure estimates is in *dose* units of mg/kg-day, with the dermal dose being added with the ingested doses due to the general absence of TRVs for the dermal pathway.

2. **Soil COC Inhalation HQ**: representing the hazard from up to two combined exposure pathways: (i) inhalation of soil particulates that are retained in the lungs (described in Appendix B2(c)); and (ii) inhalation of soil vapours (described in Appendices B2(f & g)). Each of these exposure estimates is in *concentration* units of mg/m^3.

Generally, MECP recommends that exposure to an environmental contaminant at any individual site can be no more than 20% of the threshold TRV (i.e., the acceptable HQ is set at 0.2). This is to conservatively provide an allowance for 80% of the acceptable exposure to come from other sources (e.g., consumer products in the home, commercial sources, other off-Site environmental sources). The acceptable HQ for PHCs is set at 0.5. Note that HQ values for PHC sub-fractions are assumed to be additive, so that a HQ value for parent PHC fractions can be determined (and a health-based standard for the parent fraction to be in turn calculated).

HQ Calculation

$$HQ = \frac{\text{Exposure Estimate}}{TRV_{threshold}}$$

Where:	HQ	=	Hazard Quotient
	Exposure Estimate	=	Total oral/dermal dose in units of mg/kg-day; or Total inhaled concentration in units of mg/m^3.
	$TRV_{threshold}$	=	Threshold-based TRV via the oral pathway in units of mg/kg-day; or Threshold-based TRV via the inhalation pathway in units of mg/m^3.

For chemicals that cause cancer, health risks are assessed by calculating an incremental lifetime cancer risk (ILCR). It is calculated by taking a receptor's exposure estimate, amortizing it for lifetime exposure, and multiplying the resulting *lifetime* average daily dose by a *non-threshold* toxicological reference value (TRV). This is because chemicals that cause cancer, in theory, have no threshold for potential effects. The ILCR is a unitless value that expresses the probability of developing cancer for a specified level of exposure averaged over a lifetime.

Categories of ILCR include:

1. **Soil COC Oral/Dermal ILCR**: representing the risk from three combined exposure pathways: (i) incidental ingestion of soil (described in Appendix B2(a)); (ii) dermal contact with soil (described in Appendix B2(b)); and (iii) inhalation of soil particulates that are coughed and ingested (described in Appendix B2(c)). Each of these exposure estimates is in *dose* units of mg/kg-day, with the dermal dose being added with the ingested doses due to the general absence of TRVs for the dermal pathway.

2. **Soil COC Inhalation ILCR**: representing the risk from up to two combined exposure pathways: (i) inhalation of soil particulates that are retained in the lungs (described in Appendix B2(c)); and (ii) inhalation of soil vapours (described in Appendices B2(f & g)). Each of these exposure estimates is in *concentration* units of mg/m^3.

The risk is considered to be negligible ("de minimis") by MECP if the ILCR is less than 1×10^{-6} (i.e., one-in-one-million, or 0.0001%).

ILCR Calculation

$$ILCR = \text{Exposure Estimate} \times \text{Amortization} \times TRV_{\text{non-threshold}}$$

Where:	ILCR	=	Incremental Lifetime Cancer Risk
	Exposure Estimate	=	Total oral/dermal dose in units of mg/kg-day; or Total inhaled concentration in units of mg/m^3.
	Amortization	=	Amortization factor, representing years of exposure divided by amortization period (e.g., either the 56 duration of adult working life or the 76 year average expected lifespan).
	$TRV_{\text{non-threshold}}$	=	Non-threshold-based TRV via the oral pathway in units of $(mg/kg\text{-}day)^{-1}$; or Non-threshold-based TRV via the inhalation pathway in units of $(mg/m^3)^{-1}$.

Construction Worker COC	REM C_{Soil} (mg/kg)	IR_{soil} (kg/day)	$RAF_{soil-oral}$ (unitless)	BW (kg)	Days/365 days	Soil Ingestion Dose (mg/kg-day)	Developmental Soil Ing. Dose - Adult Female BW - No pro-rating (mg/kg-day)
Antimony	5.00E+01	1.00E-04	1.00E+00	7.07E+01	5.34E-01	3.78E-05	–
Arsenic	6.53E+01	1.00E-04	5.00E-01	7.07E+01	5.34E-01	2.47E-05	–
Cadmium	4.68E+00	1.00E-04	1.00E+00	7.07E+01	5.34E-01	3.54E-06	–
Mercury	1.37E+00	1.00E-04	5.00E-01	7.07E+01	5.34E-01	5.17E-07	–
Benz[a]anthracene	1.07E+00	1.00E-04	1.00E+00	7.07E+01	5.34E-01	8.05E-07	–
Benzo[a]pyrene	1.30E+00	1.00E-04	1.00E+00	7.07E+01	5.34E-01	9.79E-07	–
Benzo[b]fluoranthene	1.64E+00	1.00E-04	1.00E+00	7.07E+01	5.34E-01	1.24E-06	–
Dibenz[a h]anthracene	2.04E-01	1.00E-04	1.00E+00	7.07E+01	5.34E-01	1.54E-07	–
Indeno[1 2 3-cd]pyrene	9.19E-01	1.00E-04	1.00E+00	7.07E+01	5.34E-01	6.95E-07	–
TOTAL CARC. PAHs	1.95E+00	1.00E-04	1.00E+00	7.07E+01	5.34E-01	1.48E-06	–

Notes:
- Soil ingestion pathway described in Appendix G2(a).
- Refer to Appendix G1(d) for receptor characteristics used to calculate developmental dose.

Outdoor Worker COC	REM C_{Soil} (mg/kg)	IR_{soil} (kg/day)	$RAF_{soil-oral}$ (unitless)	BW (kg)	Days/365 days	Soil Ingestion Dose (mg/kg-day)	Developmental Soil Ing. Dose - Adult Female BW - No pro-rating (mg/kg-day)
Antimony	5.00E+01	1.00E-04	1.00E+00	7.07E+01	5.34E-01	3.78E-05	–
Arsenic	6.53E+01	1.00E-04	5.00E-01	7.07E+01	5.34E-01	2.47E-05	–
Cadmium	4.68E+00	1.00E-04	1.00E+00	7.07E+01	5.34E-01	3.54E-06	–
Mercury	1.37E+00	1.00E-04	5.00E-01	7.07E+01	5.34E-01	5.17E-07	–
Benz[a]anthracene	1.07E+00	1.00E-04	1.00E+00	7.07E+01	5.34E-01	8.05E-07	–
Benzo[a]pyrene	1.30E+00	1.00E-04	1.00E+00	7.07E+01	5.34E-01	9.79E-07	–
Benzo[b]fluoranthene	1.64E+00	1.00E-04	1.00E+00	7.07E+01	5.34E-01	1.24E-06	–
Dibenz[a h]anthracene	2.04E-01	1.00E-04	1.00E+00	7.07E+01	5.34E-01	1.54E-07	–
Indeno[1 2 3-cd]pyrene	9.19E-01	1.00E-04	1.00E+00	7.07E+01	5.34E-01	6.95E-07	–
TOTAL CARC. PAHs	1.95E+00	1.00E-04	1.00E+00	7.07E+01	5.34E-01	1.48E-06	–

Notes:
- Soil ingestion pathway described in Appendix G2(a).
- Refer to Appendix G1(d) for receptor characteristics used to calculate developmental dose.

Toddler (e.g., Resident) COC	REM C_{Soil} (mg/kg)	IR_{soil} (kg/day)	$RAF_{soil-oral}$ (unitless)	BW (kg)	Days/365 days	Soil Ingestion Dose (mg/kg-day)	Developmental Soil Ing. Dose - Adult Female BW - Adult Female IR - No pro-rating (mg/kg-day)
Antimony	5.00E+01	2.00E-04	1.00E+00	1.65E+01	7.48E-01	4.54E-04	–
Arsenic	6.53E+01	2.00E-04	5.00E-01	1.65E+01	7.48E-01	2.96E-04	–
Cadmium	4.68E+00	2.00E-04	1.00E+00	1.65E+01	7.48E-01	4.24E-05	–
Mercury	1.37E+00	2.00E-04	5.00E-01	1.65E+01	7.48E-01	6.20E-06	–
Benz[a]anthracene	1.07E+00	2.00E-04	1.00E+00	1.65E+01	7.48E-01	9.66E-06	–
Benzo[a]pyrene	1.30E+00	2.00E-04	1.00E+00	1.65E+01	7.48E-01	1.17E-05	–
Benzo[b]fluoranthene	1.64E+00	2.00E-04	1.00E+00	1.65E+01	7.48E-01	1.49E-05	–
Dibenz[a h]anthracene	2.04E-01	2.00E-04	1.00E+00	1.65E+01	7.48E-01	1.85E-06	–
Indeno[1 2 3-cd]pyrene	9.19E-01	2.00E-04	1.00E+00	1.65E+01	7.48E-01	8.33E-06	–
TOTAL CARC. PAHs	1.95E+00	2.00E-04	1.00E+00	1.65E+01	7.48E-01	1.77E-05	–

Notes:
- Soil ingestion pathway described in Appendix G2(a).
- Refer to Appendix G1(d) for receptor characteristics used to calculate developmental dose.

Full-Life Composite (e.g., Resident) COC	REM C_{Soil} (mg/kg)	IR_{soil} (kg/day)	$RAF_{soil-oral}$ (unitless)	BW (kg)	Days/365 days	Soil Ingestion Dose (mg/kg-day)	Developmental Dose (not applicable)
Antimony	5.00E+01	5.88E-05	1.00E+00	6.24E+01	7.48E-01	3.52E-05	–
Arsenic	6.53E+01	5.88E-05	5.00E-01	6.24E+01	7.48E-01	2.30E-05	–
Cadmium	4.68E+00	5.88E-05	1.00E+00	6.24E+01	7.48E-01	3.29E-06	–
Mercury	1.37E+00	5.88E-05	5.00E-01	6.24E+01	7.48E-01	4.81E-07	–
Benz[a]anthracene	1.07E+00	5.88E-05	1.00E+00	6.24E+01	7.48E-01	7.50E-07	–
Benzo[a]pyrene	1.30E+00	5.88E-05	1.00E+00	6.24E+01	7.48E-01	9.12E-07	–
Benzo[b]fluoranthene	1.64E+00	5.88E-05	1.00E+00	6.24E+01	7.48E-01	1.16E-06	–
Dibenz[a h]anthracene	2.04E-01	5.88E-05	1.00E+00	6.24E+01	7.48E-01	1.44E-07	–
Indeno[1 2 3-cd]pyrene	9.19E-01	5.88E-05	1.00E+00	6.24E+01	7.48E-01	6.47E-07	–
TOTAL CARC. PAHs	1.95E+00	5.88E-05	1.00E+00	6.24E+01	7.48E-01	1.38E-06	–

Notes:
- Soil ingestion pathway described in Appendix G2(a).
- Developmental dose not applicable as full-life/composite receptor only used to assess carcinogenic risk.

Construction Worker COC	REM C_{Soil} (mg/kg)	SA (cm^2)	R_{adher} (kg/cm^2-day)	$RAF_{soil-derm}$ (unitless)	BW (kg)	Days/365 days	Soil Dermal Contact Dose (mg/kg-day)	Developmental Soil Derm Contact Dose - Adult Female BW - Adult Female SA - No pro-rating (mg/kg-day)
Antimony	5.00E+01	3.400E+03	2.00E-07	1.00E-01	7.07E+01	5.34E-01	2.57E-05	–
Arsenic	6.53E+01	3.400E+03	2.00E-07	3.00E-02	7.07E+01	5.34E-01	1.01E-05	–
Cadmium	4.68E+00	3.400E+03	2.00E-07	1.00E-02	7.07E+01	5.34E-01	2.40E-07	–
Mercury	1.37E+00	3.400E+03	2.00E-07	1.00E-01	7.07E+01	5.34E-01	7.03E-07	–
Benz[a]anthracene	1.07E+00	3.400E+03	2.00E-07	1.30E-01	7.07E+01	5.34E-01	7.12E-07	–
Benzo[a]pyrene	1.30E+00	3.400E+03	2.00E-07	1.30E-01	7.07E+01	5.34E-01	8.66E-07	–
Benzo[b]fluoranthene	1.64E+00	3.400E+03	2.00E-07	1.30E-01	7.07E+01	5.34E-01	1.10E-06	–
Dibenz[a h]anthracene	2.04E-01	3.400E+03	2.00E-07	1.30E-01	7.07E+01	5.34E-01	1.36E-07	–
Indeno[1 2 3-cd]pyrene	9.19E-01	3.400E+03	2.00E-07	1.30E-01	7.07E+01	5.34E-01	6.14E-07	–
TOTAL CARC. PAHs	1.95E+00	3.400E+03	2.00E-07	1.30E-01	7.07E+01	5.34E-01	1.31E-06	–

Notes:
- Soil dermal contact pathway described in Appendix G2(b).
- Refer to Appendix G1(d) for receptor characteristics used to calculate developmental dose.

Outdoor Worker COC	REM C_{Soil} (mg/kg)	SA (cm^2)	R_{adher} (kg/cm^2-day)	$RAF_{soil-derm}$ (unitless)	BW (kg)	Days/365 days	Soil Dermal Contact Dose (mg/kg-day)	Developmental Soil Derm Contact Dose - Adult Female BW - Adult Female SA - No pro-rating (mg/kg-day)
Antimony	5.00E+01	3.400E+03	2.00E-07	1.00E-01	7.07E+01	5.34E-01	2.57E-05	–
Arsenic	6.53E+01	3.400E+03	2.00E-07	3.00E-02	7.07E+01	5.34E-01	1.01E-05	–
Cadmium	4.68E+00	3.400E+03	2.00E-07	1.00E-02	7.07E+01	5.34E-01	2.40E-07	–
Mercury	1.37E+00	3.400E+03	2.00E-07	1.00E-01	7.07E+01	5.34E-01	7.03E-07	–
Benz[a]anthracene	1.07E+00	3.400E+03	2.00E-07	1.30E-01	7.07E+01	5.34E-01	7.12E-07	–
Benzo[a]pyrene	1.30E+00	3.400E+03	2.00E-07	1.30E-01	7.07E+01	5.34E-01	8.66E-07	–
Benzo[b]fluoranthene	1.64E+00	3.400E+03	2.00E-07	1.30E-01	7.07E+01	5.34E-01	1.10E-06	–
Dibenz[a h]anthracene	2.04E-01	3.400E+03	2.00E-07	1.30E-01	7.07E+01	5.34E-01	1.36E-07	–
Indeno[1 2 3-cd]pyrene	9.19E-01	3.400E+03	2.00E-07	1.30E-01	7.07E+01	5.34E-01	6.14E-07	–
TOTAL CARC. PAHs	1.95E+00	3.400E+03	2.00E-07	1.30E-01	7.07E+01	5.34E-01	1.31E-06	–

Notes:
- Soil dermal contact pathway described in Appendix G2(b).
- Refer to Appendix G1(d) for receptor characteristics used to calculate developmental dose.

Toddler (e.g., Resident) COC	REM C_{Soil} (mg/kg)	SA (cm^2)	R_{adher} (kg/cm^2-day)	$RAF_{soil-derm}$ (unitless)	BW (kg)	Days/365 days	Soil Dermal Contact Dose (mg/kg-day)	Developmental Soil Derm Contact Dose - Adult Female BW - Adult Female SA - Adult Female Radher - No pro-rating (mg/kg-day)
Antimony	5.00E+01	1.745E+03	2.00E-07	1.00E-01	1.65E+01	7.48E-01	7.92E-05	–
Arsenic	6.53E+01	1.745E+03	2.00E-07	3.00E-02	1.65E+01	7.48E-01	3.10E-05	–
Cadmium	4.68E+00	1.745E+03	2.00E-07	1.00E-02	1.65E+01	7.48E-01	7.40E-07	–
Mercury	1.37E+00	1.745E+03	2.00E-07	1.00E-01	1.65E+01	7.48E-01	2.16E-06	–
Benz[a]anthracene	1.07E+00	1.745E+03	2.00E-07	1.30E-01	1.65E+01	7.48E-01	2.19E-06	–
Benzo[a]pyrene	1.30E+00	1.745E+03	2.00E-07	1.30E-01	1.65E+01	7.48E-01	2.67E-06	–
Benzo[b]fluoranthene	1.64E+00	1.745E+03	2.00E-07	1.30E-01	1.65E+01	7.48E-01	3.38E-06	–
Dibenz[a h]anthracene	2.04E-01	1.745E+03	2.00E-07	1.30E-01	1.65E+01	7.48E-01	4.20E-07	–
Indeno[1 2 3-cd]pyrene	9.19E-01	1.745E+03	2.00E-07	1.30E-01	1.65E+01	7.48E-01	1.89E-06	–
TOTAL CARC. PAHs	1.95E+00	1.745E+03	2.00E-07	1.30E-01	1.65E+01	7.48E-01	4.02E-06	–

Notes:
- Soil dermal contact pathway described in Appendix G2(b).
- Refer to Appendix G1(d) for receptor characteristics used to calculate developmental dose.

Full-Life Composite (e.g., Resident) COC	REM C_{Soil} (mg/kg)	SA (cm^2)	R_{adher} (kg/cm^2-day)	$RAF_{soil-derm}$ (unitless)	BW (kg)	Days/365 days	Soil Dermal Contact Dose (mg/kg-day)	Developmental Dose (not applicable)
Antimony	5.00E+01	3.977E+03	8.97E-08	1.00E-01	6.24E+01	7.48E-01	2.14E-05	–
Arsenic	6.53E+01	3.977E+03	8.97E-08	3.00E-02	6.24E+01	7.48E-01	8.37E-06	–
Cadmium	4.68E+00	3.977E+03	8.97E-08	1.00E-02	6.24E+01	7.48E-01	2.00E-07	–
Mercury	1.37E+00	3.977E+03	8.97E-08	1.00E-01	6.24E+01	7.48E-01	5.84E-07	–
Benz[a]anthracene	1.07E+00	3.977E+03	8.97E-08	1.30E-01	6.24E+01	7.48E-01	5.92E-07	–
Benzo[a]pyrene	1.30E+00	3.977E+03	8.97E-08	1.30E-01	6.24E+01	7.48E-01	7.20E-07	–
Benzo[b]fluoranthene	1.64E+00	3.977E+03	8.97E-08	1.30E-01	6.24E+01	7.48E-01	9.13E-07	–
Dibenz[a h]anthracene	2.04E-01	3.977E+03	8.97E-08	1.30E-01	6.24E+01	7.48E-01	1.13E-07	–
Indeno[1 2 3-cd]pyrene	9.19E-01	3.977E+03	8.97E-08	1.30E-01	6.24E+01	7.48E-01	5.10E-07	–
TOTAL CARC. PAHs	1.95E+00	3.977E+03	8.97E-08	1.30E-01	6.24E+01	7.48E-01	1.09E-06	–

Notes:
- Soil dermal contact pathway described in Appendix G2(b).
- Developmental dose not applicable as full-life/composite receptor only used to assess carcinogenic risk.

Construction Worker COC	REM C_{Soil} (mg/kg)	C_{Part} (kg/m^3)	Fraction coughed and ingested (unitless)	Fraction retained in lungs (unitless)	IR_{air} (m^3/day)	$RAF_{soil-inh}$ (unitless)	BW (kg)	Hours/24 Hours	Days/365 days	Soil Particulate Inhalation Dose (followed by coughing/ ingestion) (mg/kg-day)	Developmental Soil Partic. Inhal. Dose - Adult Female BW - No pro-rating (mg/kg-day)	Soil Particulate Exposure Conc (fraction retained in lungs) (mg/m3)	Developmental Soil Partic. Exposure Conc - Adult Female BW - No pro-rating (mg/m3)
Antimony	5.00E+01	1.00E-07	1.40E+00	6.00E-01	3.60E+01	1.00E+00	7.07E+01	4.08E-01	5.34E-01	7.78E-07	–	1.17E-06	–
Arsenic	6.53E+01	1.00E-07	1.40E+00	6.00E-01	3.60E+01	1.00E+00	7.07E+01	4.08E-01	5.34E-01	1.02E-06	–	1.52E-06	–
Cadmium	4.68E+00	1.00E-07	1.40E+00	6.00E-01	3.60E+01	1.00E+00	7.07E+01	4.08E-01	5.34E-01	7.28E-08	–	1.09E-07	–
Mercury	1.37E+00	1.00E-07	1.40E+00	6.00E-01	3.60E+01	1.00E+00	7.07E+01	4.08E-01	5.34E-01	2.13E-08	–	3.19E-08	–
Benz[a]anthracene	1.07E+00	1.00E-07	1.40E+00	6.00E-01	3.60E+01	1.00E+00	7.07E+01	4.08E-01	5.34E-01	1.66E-08	–	2.49E-08	–
Benzo[a]pyrene	1.30E+00	1.00E-07	1.40E+00	6.00E-01	3.60E+01	1.00E+00	7.07E+01	4.08E-01	5.34E-01	2.02E-08	–	3.02E-08	–
Benzo[b]fluoranthene	1.64E+00	1.00E-07	1.40E+00	6.00E-01	3.60E+01	1.00E+00	7.07E+01	4.08E-01	5.34E-01	2.56E-08	–	3.83E-08	–
Dibenz[a h]anthracene	2.04E-01	1.00E-07	1.40E+00	6.00E-01	3.60E+01	1.00E+00	7.07E+01	4.08E-01	5.34E-01	3.17E-09	–	4.76E-09	–
Indeno[1 2 3-cd]pyrene	9.19E-01	1.00E-07	1.40E+00	6.00E-01	3.60E+01	1.00E+00	7.07E+01	4.08E-01	5.34E-01	1.43E-08	–	2.14E-08	–
TOTAL CARC. PAHs	1.95E+00	1.00E-07	1.40E+00	6.00E-01	3.60E+01	1.00E+00	7.07E+01	4.08E-01	5.34E-01	3.04E-08	–	4.56E-08	–

Notes:
- Soil particulate inhalation pathway described in Appendix G2(c).
- Refer to Appendix G1(d) for receptor characteristics used to calculate developmental dose/concentration.

Outdoor Worker COC	REM C_{Soil} (mg/kg)	C_{Part} (kg/m^3)	Fraction coughed and ingested (unitless)	Fraction retained in lungs (unitless)	IR_{air} (m^3/day)	$RAF_{soil-inh}$ (unitless)	BW (kg)	Hours/24 Hours	Days/365 days	Soil Particulate Inhalation Dose (followed by coughing/ ingestion) (mg/kg-day)	Developmental Soil Partic. Inhal. Dose - Adult Female BW - No pro-rating (mg/kg-day)	Soil Particulate Exposure Conc (fraction retained in lungs) (mg/m3)	Developmental Soil Partic. Exposure Conc - Adult Female BW - No pro-rating (mg/m3)
Antimony	5.00E+01	1.00E-07	1.40E+00	6.00E-01	3.60E+01	1.00E+00	7.07E+01	4.08E-01	5.34E-01	7.78E-07	–	1.17E-06	–
Arsenic	6.53E+01	1.00E-07	1.40E+00	6.00E-01	3.60E+01	1.00E+00	7.07E+01	4.08E-01	5.34E-01	1.02E-06	–	1.52E-06	–
Cadmium	4.68E+00	1.00E-07	1.40E+00	6.00E-01	3.60E+01	1.00E+00	7.07E+01	4.08E-01	5.34E-01	7.28E-08	–	1.09E-07	–
Mercury	1.37E+00	1.00E-07	1.40E+00	6.00E-01	3.60E+01	1.00E+00	7.07E+01	4.08E-01	5.34E-01	2.13E-08	–	3.19E-08	–
Benz[a]anthracene	1.07E+00	1.00E-07	1.40E+00	6.00E-01	3.60E+01	1.00E+00	7.07E+01	4.08E-01	5.34E-01	1.66E-08	–	2.49E-08	–
Benzo[a]pyrene	1.30E+00	1.00E-07	1.40E+00	6.00E-01	3.60E+01	1.00E+00	7.07E+01	4.08E-01	5.34E-01	2.02E-08	–	3.02E-08	–
Benzo[b]fluoranthene	1.64E+00	1.00E-07	1.40E+00	6.00E-01	3.60E+01	1.00E+00	7.07E+01	4.08E-01	5.34E-01	2.56E-08	–	3.83E-08	–
Dibenz[a h]anthracene	2.04E-01	1.00E-07	1.40E+00	6.00E-01	3.60E+01	1.00E+00	7.07E+01	4.08E-01	5.34E-01	3.17E-09	–	4.76E-09	–
Indeno[1 2 3-cd]pyrene	9.19E-01	1.00E-07	1.40E+00	6.00E-01	3.60E+01	1.00E+00	7.07E+01	4.08E-01	5.34E-01	1.43E-08	–	2.14E-08	–
TOTAL CARC. PAHs	1.95E+00	1.00E-07	1.40E+00	6.00E-01	3.60E+01	1.00E+00	7.07E+01	4.08E-01	5.34E-01	3.04E-08	–	4.56E-08	–

Notes:
- Soil particulate inhalation pathway described in Appendix G2(c).
- Refer to Appendix G1(d) for receptor characteristics used to calculate developmental dose/concentration.

Toddler (e.g., Resident) COC	REM C_{Soil} (mg/kg)	C_{Part} (kg/m^3)	Fraction coughed and ingested (unitless)	Fraction retained in lungs (unitless)	IR_{air} (m^3/day)	$RAF_{soil-inh}$ (unitless)	BW (kg)	Hours/24 Hours	Days/365 days	Soil Particulate Inhalation Dose (followed by coughing/ ingestion) (mg/kg-day)	Developmental Soil Partic. Inhal. Dose - Adult Female BW - No pro-rating (mg/kg-day)	Soil Particulate Exposure Conc (fraction retained in lungs) (mg/m3)	Developmental Soil Partic. Exposure Conc - Adult Female BW - No pro-rating (mg/m3)
Antimony	5.00E+01	3.00E-08	1.40E+00	6.00E-01	8.30E+00	1.00E+00	1.65E+01	1.00E+00	7.48E-01	7.91E-07	–	1.19E-06	–
Arsenic	6.53E+01	3.00E-08	1.40E+00	6.00E-01	8.30E+00	1.00E+00	1.65E+01	1.00E+00	7.48E-01	1.03E-06	–	1.55E-06	–
Cadmium	4.68E+00	3.00E-08	1.40E+00	6.00E-01	8.30E+00	1.00E+00	1.65E+01	1.00E+00	7.48E-01	7.40E-08	–	1.11E-07	–
Mercury	1.37E+00	3.00E-08	1.40E+00	6.00E-01	8.30E+00	1.00E+00	1.65E+01	1.00E+00	7.48E-01	2.16E-08	–	3.24E-08	–
Benz[a]anthracene	1.07E+00	3.00E-08	1.40E+00	6.00E-01	8.30E+00	1.00E+00	1.65E+01	1.00E+00	7.48E-01	1.68E-08	–	2.53E-08	–
Benzo[a]pyrene	1.30E+00	3.00E-08	1.40E+00	6.00E-01	8.30E+00	1.00E+00	1.65E+01	1.00E+00	7.48E-01	2.05E-08	–	3.07E-08	–
Benzo[b]fluoranthene	1.64E+00	3.00E-08	1.40E+00	6.00E-01	8.30E+00	1.00E+00	1.65E+01	1.00E+00	7.48E-01	2.60E-08	–	3.90E-08	–
Dibenz[a h]anthracene	2.04E-01	3.00E-08	1.40E+00	6.00E-01	8.30E+00	1.00E+00	1.65E+01	1.00E+00	7.48E-01	3.23E-09	–	4.84E-09	–
Indeno[1 2 3-cd]pyrene	9.19E-01	3.00E-08	1.40E+00	6.00E-01	8.30E+00	1.00E+00	1.65E+01	1.00E+00	7.48E-01	1.45E-08	–	2.18E-08	–
TOTAL CARC. PAHs	1.95E+00	3.00E-08	1.40E+00	6.00E-01	8.30E+00	1.00E+00	1.65E+01	1.00E+00	7.48E-01	3.09E-08	–	4.63E-08	–

Notes:
- Soil particulate inhalation pathway described in Appendix G2(c).
- Refer to Appendix G1(d) for receptor characteristics used to calculate developmental dose/concentration.

Full-Life Composite (e.g., Resident) COC	REM C_{Soil} (mg/kg)	C_{Part} (kg/m^3)	Fraction coughed and ingested (unitless)	Fraction retained in lungs (unitless)	IR_{air} (m^3/day)	$RAF_{soil\text{-}inh}$ (unitless)	BW (kg)	Hours/24 Hours	Days/365 days	Soil Particulate Inhalation Dose (followed by coughing/ ingestion) (mg/kg-day)	Developmental Dose (not applicable)	Soil Particulate Exposure Conc (fraction retained in lungs) (mg/m3)	Developmental Dose (not applicable)
Antimony	5.00E+01	3.00E-08	1.40E+00	6.00E-01	1.57E+01	1.00E+00	6.24E+01	9.38E-01	7.48E-01	3.71E-07	–	5.57E-07	–
Arsenic	6.53E+01	3.00E-08	1.40E+00	6.00E-01	1.57E+01	1.00E+00	6.24E+01	9.38E-01	7.48E-01	4.84E-07	–	7.26E-07	–
Cadmium	4.68E+00	3.00E-08	1.40E+00	6.00E-01	1.57E+01	1.00E+00	6.24E+01	9.38E-01	7.48E-01	3.47E-08	–	5.21E-08	–
Mercury	1.37E+00	3.00E-08	1.40E+00	6.00E-01	1.57E+01	1.00E+00	6.24E+01	9.38E-01	7.48E-01	1.01E-08	–	1.52E-08	–
Benz[a]anthracene	1.07E+00	3.00E-08	1.40E+00	6.00E-01	1.57E+01	1.00E+00	6.24E+01	9.38E-01	7.48E-01	7.90E-09	–	1.19E-08	–
Benzo[a]pyrene	1.30E+00	3.00E-08	1.40E+00	6.00E-01	1.57E+01	1.00E+00	6.24E+01	9.38E-01	7.48E-01	9.61E-09	–	1.44E-08	–
Benzo[b]fluoranthene	1.64E+00	3.00E-08	1.40E+00	6.00E-01	1.57E+01	1.00E+00	6.24E+01	9.38E-01	7.48E-01	1.22E-08	–	1.83E-08	–
Dibenz[a h]anthracene	2.04E-01	3.00E-08	1.40E+00	6.00E-01	1.57E+01	1.00E+00	6.24E+01	9.38E-01	7.48E-01	1.51E-09	–	2.27E-09	–
Indeno[1 2 3-cd]pyrene	9.19E-01	3.00E-08	1.40E+00	6.00E-01	1.57E+01	1.00E+00	6.24E+01	9.38E-01	7.48E-01	6.82E-09	–	1.02E-08	–
TOTAL CARC. PAHs	1.95E+00	3.00E-08	1.40E+00	6.00E-01	1.57E+01	1.00E+00	6.24E+01	9.38E-01	7.48E-01	1.45E-08	–	2.17E-08	–

Notes:
- Soil particulate inhalation pathway described in Appendix G2(c).
- Developmental dose not applicable as full-life/composite receptor only used to assess carcinogenic risk.

NovaTox

Construction Worker COC	REM C_{Soil} (mg/kg)	Effective diffusivity in vadose zone soil Dseff (cm2/s)	VF_{S-TA} ([mg/m^3]/[mg/kg])	Trench Vapour Conc (soil source) (ug/m3)	Pro-Rated Vapour Exposure Conc (soil source) (mg/m3)	Developm Vapour Exposure Conc (soil source) - No pro-rating (mg/m3)	Hours/24 Hours	Days/365 days
Mercury	1.37E+00	4.96E-03	5.11E-06	6.98E-03	3.91E-07	–	4.08E-01	1.37E-01
Benz[a]anthracene	1.07E+00	8.27E-03	3.60E-07	3.84E-04	2.15E-08	–	4.08E-01	1.37E-01
TOTAL CARC. PAHs (5 volatile carcinogenic PAHs were adjusted for B(a)P equivalence and then summed. See table (i) on the Appendix G3(f) sheet for calculation of non-pro-rated trench vapour concentrations)				6.48E-05	3.63E-09		4.08E-01	1.37E-01

Notes:
- Trench vapour pathway described in Appendix G2(f).
- Refer to Appendix G1(d) for receptor characteristics used to calculate developmental dose.

Outdoor Worker COC	REM C_{Soil} (mg/kg)	Effective diffusivity in vadose zone soil Dseff (cm2/s)	VF_{S-OA} (CM-1a) ([mg/m^3]/[mg/kg])	VF_{S-OA} (CM-1b) ([mg/m^3]/[mg/kg])	Outdoor Vapour Conc (soil source) (ug/m3)	Pro-Rated Vapour Exposure Conc (soil source) (mg/m3)	Developm Vapour Exposure Conc (soil source) - No pro-rating (mg/m3)	Hours/24 Hours	Days/365 days
Mercury	1.37E+00	4.96E-03	1.88E-06	1.28E-04	2.57E-03	5.60E-07	–	4.08E-01	5.34E-01
Benz[a]anthracene	1.07E+00	8.27E-03	1.32E-07	1.28E-04	1.41E-04	3.08E-08	–	4.08E-01	5.34E-01
TOTAL CARC. PAHs (5 volatile carcinogenic PAHs were adjusted for B(a)P equivalence and then summed. See table (ii) on the Appendix G3(f) sheet for calculation of non-pro-rated outdoor vapour concentrations)					2.38E-05	5.20E-09		4.08E-01	5.34E-01

Notes:
- Outdoor vapour pathway described in Appendix G2(f).
- Refer to Appendix G1(d) for receptor characteristics used to calculate developmental dose.

Lookup Table (ii)

Carcinogenic PAH	TEF	Soil-to-Trench Air (ug/m3) REM	Soil-to-Trench Air (ug/m3) BaP Equiv.	Soil-to-Outdoor Air (ug/m3) REM	Soil-to-Outdoor Air (ug/m3) BaP Equiv.
Acenaphthene	0.001	4.68E-04	4.68E-07	1.72E-04	1.72E-07
Acenaphthylene	0.01	2.17E-03	2.17E-05	7.99E-04	7.99E-06
Anthracene	0.01	3.43E-04	3.43E-06	1.26E-04	1.26E-06
Benz(a)anthracene	0.1	3.84E-04	3.84E-05	1.41E-04	1.41E-05
Benzo(a)pyrene	1	–	–	–	–
Benzo(b/j)fluoranthene	0.1	–	–	–	–
Benzo(g,h,i)perylene	0.01	–	–	–	–
Benzo(k)fluoranthene	0.1	–	–	–	–
Chrysene	0.01	–	–	–	–
Dibenzo[a,h]anthracene	1	–	–	–	–
Fluoranthene	0.01	–	–	–	–
Indeno(1,2,3-cd)pyrene	0.1	–	–	–	–
Pyrene	0.001	8.20E-04	8.20E-07	3.02E-04	3.02E-07
TOTAL Carcinogenic PAHs			6.48E-05		2.38E-05

Notes:
- TEFs obtained from MOE (2011) Rationale Document (citing Kalberlah et al., 1995)
- Outdoor/trench vapour pathway described in Appendix G2(f).
- The vapour model was run with REM concentrations, for the four volatile carcinogenic PAHs. Summing the four values gives the REM concentration of 'Total Carcinogenic PAHs' in vapour, which was carried through risk calculations.

Lookup Table (i)

PAH	Henry's Law (atm-m3/mol)	H Less than 10^{-5}?	Vapour Pressure (mm Hg)	Vap Less than 0.05?	Requires Vapour Modelling?
Acenaphthene	1.82E-04	–	2.50E-03	Yes	Yes
Acenaphthylene	1.25E-04	–	9.12E-04	Yes	Yes
Anthracene	5.55E-05	–	2.67E-06	Yes	Yes
Benz[a]anthracene	1.20E-05	–	1.90E-06	Yes	Yes
Benzo[a]pyrene	4.58E-07	Yes	5.49E-09	Yes	–
Benzo[b]fluoranthene	6.58E-07	Yes	5.00E-07	Yes	–
Benzo[ghi]perylene	3.30E-07	Yes	1.00E-10	Yes	–
Benzo[k]fluoranthene	5.85E-07	Yes	9.65E-10	Yes	–
Chrysene	5.24E-06	Yes	6.23E-09	Yes	–
Dibenz[a h]anthracene	1.23E-07	Yes	1.39E-11	Yes	–
Fluoranthene	8.86E-06	Yes	9.22E-06	Yes	–
Indeno[1 2 3-cd]pyrene	3.47E-07	Yes	1.25E-10	Yes	–
Pyrene	1.19E-05	–	4.50E-06	Yes	Yes

Notes:
- According to MECP, any COC may be screened out of a vapour intrusion assessment if both (i) its Henry's Law Constant is <10^{-5} and (ii) its vapour pressure is <0.05 Torr (equivalent to 0.05 mm Hg).

J&E Soil Model (re-created from U.S. EPA)	Enthalpy of vap. at ave. soil temp.	Henry's law constant at ave. soil temp.	Henry's law constant at ave. soil temp.	Vapour viscosity at average soil temp.	Stratum A effective diffusion coeffic.	Stratum B effective diffusion coeffic.	Stratum C effective diffusion coeffic.	Total overall effective diffusion coeffic.	Diffusion path length	Convect-ion path length	Soil-water partition coeffic.	Crack radius	Average vapour flow rate into building	Crack effective diffusion coeffic.	Area of crack	Exponent of equival-ent foundat-ion Peclet number
	$\Delta H_{v,TS}$	H_{TS}	H'_{TS}	μ_{TS}	D^{eff}_{A}	D^{eff}_{B}	D^{eff}_{C}	D^{eff}_{T}	L_d	L_p	K_d	r_{crack}	Q_{soil}	D^{crack}	A_{crack}	$\exp(Pe^f)$
COC	(cal/mol)	(atm-m³/ mol)	(unitless)	(g/cm-s)	(cm²/s)	(cm²/s)	(cm²/s)	(cm²/s)	(cm)	(cm)	(cm³/g)	(cm)	(cm³/s)	(cm²/s)	(cm²)	(unitless)
Mercury	1.53E+04	4.70E-03	1.99E-01	1.77E-04	4.96E-03	8.34E-03	4.96E-03	8.32E-03	3.00E+01	1.58E+02	5.20E+01	1.00E-01	1.41E+02	4.96E-03	4.90E+02	1.61E+201
Benz[a]anthracene	2.30E+04	3.12E-06	1.32E-04	1.77E-04	8.27E-03	1.39E-02	8.27E-03	1.38E-02	3.00E+01	1.58E+02	2.31E+03	1.00E-01	1.41E+02	8.27E-03	4.90E+02	4.93E+120
TOTAL CARC. PAHs (5 volatile carcinogenic PAHs were adjusted for B(a)P equivalence and then summed. See table (ii) on the Appendix G3(g) sheet for calculation.)																

Lookup Table (i)

PAH	Henry's Law (atm-m3/ mol)	H Less than 10^{-5}?	Vapour Pressure (mm Hg)	Vap Less than 0.05?	Requires Vapour Modelling?
Acenaphthene	1.82E-04	–	2.50E-03	Yes	Yes
Acenaphthylene	1.25E-04	–	9.12E-04	Yes	Yes
Anthracene	5.55E-05	–	2.67E-06	Yes	Yes
Benz[a]anthracene	1.20E-05	–	1.90E-06	Yes	Yes
Benzo[a]pyrene	4.58E-07	Yes	5.49E-09	Yes	–
Benzo[b]fluoranthene	6.58E-07	Yes	5.00E-07	Yes	–
Benzo[ghi]perylene	3.30E-07	Yes	1.00E-10	Yes	–
Benzo[k]fluoranthene	5.85E-07	Yes	9.65E-10	Yes	–
Chrysene	5.24E-06	Yes	6.23E-09	Yes	–
Dibenz[a h]anthracene	1.23E-07	Yes	1.39E-11	Yes	–
Fluoranthene	8.86E-06	Yes	9.22E-06	Yes	–
Indeno[1 2 3-cd]pyrene	3.47E-07	Yes	1.25E-10	Yes	–
Pyrene	1.19E-05	–	4.50E-06	Yes	Yes

Notes:
- According to MECP, any COC may be screened out of a vapour intrusion assessment if both (i) its Henry's Law Constant is $<10^{-5}$ and (ii) its vapour pressure is <0.05 Torr (equivalent to 0.05 mm Hg).

Lookup Table (ii)		No source depletion		with source depletion	
		Soil-to-Indoor Air (ug/m3)		Soil-to-Indoor Air (ug/m3)	
Carcinogenic PAH	**TEF**	**REM**	**BaP Equiv.**	**REM**	**BaP Equiv.**
Acenaphthene	0.001	7.75E-03	7.75E-06	7.67E-03	7.67E-06
Acenaphthylene	0.01	2.93E-02	2.93E-04	2.91E-02	2.91E-04
Anthracene	0.01	1.66E-03	1.66E-05	1.66E-03	1.66E-05
Benz(a)anthracene	0.1	1.65E-04	1.65E-05	1.65E-04	1.65E-05
Benzo(a)pyrene	1	–	–	–	–
Benzo(b/j)fluoranthene	0.1	–	–	–	–
Benzo(g,h,i)perylene	0.01	–	–	–	–
Benzo(k)fluoranthene	0.1	–	–	–	–
Chrysene	0.01	–	–	–	–
Dibenzo[a,h]anthracene	1	–	–	–	–
Fluoranthene	0.01	–	–	–	–
Indeno(1,2,3-cd)pyrene	0.1	–	–	–	–
Pyrene	0.001	9.11E-04	9.11E-07	9.11E-04	9.11E-07
TOTAL Carcinogenic PAHs			3.35E-04		3.33E-04

Notes:
- TEFs obtained from MOE (2011) Rationale Document (citing Kalberlah et al., 1995)
- Indoor vapour pathway described in Appendix G2(g).
- The vapour model was run with REM concentrations, for the four volatile carcinogenic PAHs. Summing the four values gives the REM concentration of 'Total Carcinogenic PAHs' in vapour, which was carried through risk calculations.

Lookup Table (iii) Source Depletion Multiplier Calculation	Csoil	Soil Bulk Density	Volume of source zone (Default = 13m x 13m x 2m)	Volume of source zone (Adjusted)	Mass 1: Initial Mass	Initial $C_{indoor\ air}$	Volume of building	Air Exchange Rate	Mass 2: Mass Remaining after 1 Week of Soil Gas Entering Building	Half Life	SDM (Source Depletion Multiplier)	Final $C_{indoor\ air}$
COC	**(mg/kg)**	**(g/cm³)**	**(cm³)**	**(cm³)**	**(g)**	**(ug/m³)**	**(m³)**	**(1/hour)**	**(g)**	**(years)**		**(ug/m³)**
Mercury	1.37	1.66	3.38E+08	5.60E+07	127.2	1.31E+01	549	0	126.9	4.64	2.1	6.23E+00
Benz[a]anthracene	1.07	1.66	3.38E+08	5.60E+07	99.1	1.65E-04	549	0	99.1	288,350.86	1.0	1.65E-04

J&E Soil Model (re-created from U.S. EPA) COC	Soil Source vapour conc. C_{source} (µg/m³)	Infinite source indoor attenuation coefficient α (unitless)	MOE Bio-Attenuation Factor BAF (unitless)	Indoor Building Conc. NO source depletion Residential Building-with-Basement REM $C_{building}$ (µg/m³) (Infinite Source Vapour X J&E Atten. Factor X MOE Bio-Atten. Factor)	MOE Source Depletion Multiplier SDM (unitless) See table (iii) on the Appendix G3(g) sheet for calculation)	Indoor Building Conc. WITH source depletion Residential Building-with-Basement REM $C_{building}$ (µg/m³) (Initial Bldg. Conc. X MOE SDM)	Indoor Building Concentration Carried Forward in Exposure & Risk Calcs: Indoor Building Conc. WITH source depletion; Residential Building-with-Basement REM $C_{building}$ (µg/m³)
Mercury	5.22E+03	2.52E-03	1.00E+00	1.31E+01	2.11E+00	6.23E+00	6.23E+00
Benz[a]anthracene	6.08E-02	2.71E-03	1.00E+00	1.65E-04	1.00E+00	1.65E-04	1.65E-04
TOTAL CARC. PAHs (5 volatile carcinogenic PAHs were adjusted for B(a)P equivalence and then summed. See table (ii) on the Appendix G3(g) sheet for calculation.)				3.35E-04		3.33E-04	3.33E-04

J&E Soil Model (re-created from U.S. EPA)	Finite source	Finite source	Time for source depletion	Exposure duration > time for source	Finite source indoor attenuation coefficient	Mass limit building conc.	Finite source bldg. conc.	Final finite source bldg. conc.	Soil saturation conc.
	B term	ψ term	τ_D		<α>	$C_{building}$	$C_{building}$	$C_{building}$	C_{sat}
COC	(unitless)	$(sec)^{-1}$	(sec)	(Y/N)	(unitless)	($\mu g/m^3$)	($\mu g/m^3$)	($\mu g/m^3$)	($\mu g/kg$)
Mercury	NA	NA	NA	NA	NA	NA	NA	NA	3.12E+03
Benz[a]anthracene	NA	NA	NA	NA	NA	NA	NA	NA	2.17E+04
TOTAL CARC. PAHs (5 volatile carcinogenic PAHs were adjusted for B(a)P equivalence and then summed. See table (ii) on the Appendix G3(g) sheet for calculation.)									

Toddler (e.g., Resident) COC	Source Vapour Conc. (soil) (ug/m3)	Attenuation Factor (Soil-to-indoor air)	Bio-Attenuation Factor (Soil-to-indoor air)	Source Depletion Multiplier (Soil source)	Indoor Vapour Conc. (soil source) (ug/m3)	Pro-Rated Vapour Exposure Conc. (soil source) (mg/m3)	Developm Exposure Conc - No pro-rating (mg/m3)	Hours/24 Hours	Days/365 days
Mercury	5.22E+03	2.52E-03	1.00E+00	2.11E+00	6.23E+00	5.97E-03	–	1.00E+00	9.59E-01
Benz[a]anthracene	6.08E-02	2.71E-03	1.00E+00	1.00E+00	1.65E-04	1.58E-07	–	1.00E+00	9.59E-01
TOTAL CARC. PAHs									

Notes:
- Indoor vapour pathway described in Appendix G2(g).
- Refer to Appendix G1(d) for receptor characteristics used to calculate developmental dose.

Full-Life Composite (e.g., Resident) COC	Source Vapour Conc. (soil) (ug/m3)	Attenuation Factor (Soil-to-indoor air)	Bio-Attenuation Factor (Soil-to-indoor air)	Source Depletion Multiplier (Soil source)	Indoor Vapour Conc. (soil source) (ug/m3)	Pro-Rated Vapour Exposure Conc. (soil source) (mg/m3)	Developm Exposure Conc - No pro-rating (mg/m3)	Hours/24 Hours	Days/365 days
Mercury	5.22E+03	2.52E-03	1.00E+00	2.11E+00	6.23E+00	5.60E-03	–	9.38E-01	9.59E-01
Benz[a]anthracene	6.08E-02	2.71E-03	1.00E+00	1.00E+00	1.65E-04	1.48E-07	–	9.38E-01	9.59E-01
TOTAL CARC. PAHs (5 volatile carcinogenic PAHs were adjusted for B(a)P equivalence and then summed. See tables (ii) and (iii) on the Appendix G3(g) sheet for calculation of non-pro-rated indoor vapour concentrations.)					3.33E-04	2.99E-07		9.38E-01	9.59E-01

Notes:
- Indoor vapour pathway described in Appendix G2(g).
- Developmental dose not applicable as full-life/composite receptor only used to assess carcinogenic risk.

Construction Worker COC	Threshold Oral TRV (mg/kg-day)	Threshold Inhalation TRV (mg/m3)	Soil Ingestion Dose (mg/kg-day)	Soil Dermal Contact Dose (mg/kg-day)	Soil Particulate Inhalation Dose (followed by coughing/ ingestion) (mg/kg-day)	Soil Total Oral/ Dermal Dose (mg/kg-day)	Soil Particulate Exposure Conc (fraction retained in lungs) (mg/m3)	Pro-Rated Vapour Exposure Conc (soil source) (mg/m3)	Soil Total Inhaled Conc (mg/m3)	Devel. Soil Ing. Dose (mg/kg-day)	Devel. Soil Derm Contact Dose (mg/kg-day)	Devel. Soil Partic. Inhal. Dose (mg/kg-day)	Devel. Soil Total Oral/ Dermal Dose (mg/kg-day)	Devel Soil Partic. Exposure Conc (mg/m3)	Devel. Vapour Exposure Conc (soil source) (mg/m3)	Devel. Soil Total Inhaled Conc (mg/m3)	Soil Oral/ Dermal HQ	Soil Inhal. HQ	Devel. Soil Oral/ Dermal HQ	Devel. Soil Inhal. HQ
Antimony	4.00E-04	2.00E-04	3.78E-05	2.57E-05	7.78E-07	6.43E-05	1.17E-06	0.00E+00	1.17E-06	–	–	–	0.00E+00	–	–	0.00E+00	1.61E-01	5.84E-03	0.00E+00	0.00E+00
Arsenic	3.00E-04	1.50E-05	2.47E-05	1.01E-05	1.02E-06	3.57E-05	1.52E-06	0.00E+00	1.52E-06	–	–	–	0.00E+00	–	–	0.00E+00	1.19E-01	1.02E-01	0.00E+00	0.00E+00
Cadmium	3.20E-05	3.00E-05	3.54E-06	2.40E-07	7.28E-08	3.85E-06	1.09E-07	0.00E+00	1.09E-07	–	–	–	0.00E+00	–	–	0.00E+00	1.20E-01	3.64E-03	0.00E+00	0.00E+00
Mercury	3.00E-04	9.00E-05	5.17E-07	7.03E-07	2.13E-08	1.24E-06	3.19E-08	3.91E-07	4.23E-07	–	–	–	0.00E+00	–	–	0.00E+00	4.14E-03	4.70E-03	0.00E+00	0.00E+00
Benz[a]anthracene	0.00E+00	0.00E+00	8.05E-07	7.12E-07	1.66E-08	1.53E-06	2.49E-08	2.15E-08	4.63E-08	–	–	–	0.00E+00	–	–	0.00E+00	–	–	–	–
Benzo[a]pyrene	3.00E-04	2.00E-06	9.79E-07	8.66E-07	2.02E-08	1.87E-06	3.02E-08	0.00E+00	3.02E-08	–	–	–	0.00E+00	–	–	0.00E+00	6.22E-03	1.51E-02	0.00E+00	0.00E+00
Benzo[b]fluoranthene	0.00E+00	0.00E+00	1.24E-06	1.10E-06	2.56E-08	2.37E-06	3.83E-08	0.00E+00	3.83E-08	–	–	–	0.00E+00	–	–	0.00E+00	–	–	–	–
Dibenz[a h]anthracene	0.00E+00	0.00E+00	1.54E-07	1.36E-07	3.17E-09	2.94E-07	4.76E-09	0.00E+00	4.76E-09	–	–	–	0.00E+00	–	–	0.00E+00	–	–	–	–
Indeno[1 2 3-cd]pyrene	0.00E+00	0.00E+00	6.95E-07	6.14E-07	1.43E-08	1.32E-06	2.14E-08	0.00E+00	2.14E-08	–	–	–	0.00E+00	–	–	0.00E+00	–	–	–	–
TOTAL CARC. PAHs	0.00E+00	0.00E+00	1.48E-06	1.31E-06	3.04E-08	2.81E-06	4.56E-08	3.63E-09	4.92E-08	–	–	–	0.00E+00	–	0.00E+00	0.00E+00	–	–	–	–

Notes:
- Bold and yellow-highlighting indicates exceedance of allowable HQ of 0.2 (0.5 for PHCs).

Outdoor Worker COC	Threshold Oral TRV (mg/kg-day)	Threshold Inhalation TRV (mg/m3)	Soil Ingestion Dose (mg/kg-day)	Soil Dermal Contact Dose (mg/kg-day)	Soil Particulate Inhalation Dose (followed by coughing/ ingestion) (mg/kg-day)	Soil Total Oral/ Dermal Dose (mg/kg-day)	Soil Particulate Exposure Conc (fraction retained in lungs) (mg/m3)	Pro-Rated Vapour Exposure Conc (soil source) (mg/m3)	Soil Total Inhaled Conc (mg/m3)	Devel. Soil Ing. Dose (mg/kg-day)	Devel. Soil Derm Contact Dose (mg/kg-day)	Devel. Soil Partic. Inhal. Dose (mg/kg-day)	Devel. Soil Total Oral/ Dermal Dose (mg/kg-day)	Devel Soil Partic. Exposure Conc (mg/m3)	Devel. Vapour Exposure Conc (soil source) (mg/m3)	Devel. Soil Total Inhaled Conc (mg/m3)	Soil Oral/ Dermal HQ	Soil Inhal. HQ	Devel. Soil Oral/ Dermal HQ	Devel. Soil Inhal. HQ
Antimony	4.00E-04	2.00E-04	3.78E-05	2.57E-05	7.78E-07	6.43E-05	1.17E-06	0.00E+00	1.17E-06	–	–	–	0.00E+00	–	–	0.00E+00	1.61E-01	5.84E-03	0.00E+00	0.00E+00
Arsenic	3.00E-04	1.50E-05	2.47E-05	1.01E-05	1.02E-06	3.57E-05	1.52E-06	0.00E+00	1.52E-06	–	–	–	0.00E+00	–	–	0.00E+00	1.19E-01	1.02E-01	0.00E+00	0.00E+00
Cadmium	3.20E-05	3.00E-05	3.54E-06	2.40E-07	7.28E-08	3.85E-06	1.09E-07	0.00E+00	1.09E-07	–	–	–	0.00E+00	–	–	0.00E+00	1.20E-01	3.64E-03	0.00E+00	0.00E+00
Mercury	3.00E-04	9.00E-05	5.17E-07	7.03E-07	2.13E-08	1.24E-06	3.19E-08	5.60E-07	5.92E-07	–	–	–	0.00E+00	–	–	0.00E+00	4.14E-03	6.58E-03	0.00E+00	0.00E+00
Benz[a]anthracene	0.00E+00	0.00E+00	8.05E-07	7.12E-07	1.66E-08	1.53E-06	2.49E-08	3.08E-08	5.56E-08	–	–	–	0.00E+00	–	–	0.00E+00	–	–	–	–
Benzo[a]pyrene	3.00E-04	2.00E-06	9.79E-07	8.66E-07	2.02E-08	1.87E-06	3.02E-08	0.00E+00	3.02E-08	–	–	–	0.00E+00	–	–	0.00E+00	6.22E-03	1.51E-02	0.00E+00	0.00E+00
Benzo[b]fluoranthene	0.00E+00	0.00E+00	1.24E-06	1.10E-06	2.56E-08	2.37E-06	3.83E-08	0.00E+00	3.83E-08	–	–	–	0.00E+00	–	–	0.00E+00	–	–	–	–
Dibenz[a h]anthracene	0.00E+00	0.00E+00	1.54E-07	1.36E-07	3.17E-09	2.94E-07	4.76E-09	0.00E+00	4.76E-09	–	–	–	0.00E+00	–	–	0.00E+00	–	–	–	–
Indeno[1 2 3-cd]pyrene	0.00E+00	0.00E+00	6.95E-07	6.14E-07	1.43E-08	1.32E-06	2.14E-08	0.00E+00	2.14E-08	–	–	–	0.00E+00	–	–	0.00E+00	–	–	–	–
TOTAL CARC. PAHs	0.00E+00	0.00E+00	1.48E-06	1.31E-06	3.04E-08	2.81E-06	4.56E-08	5.20E-09	5.08E-08	–	–	–	0.00E+00	–	0.00E+00	0.00E+00	–	–	–	–

Notes:
- Bold and yellow-highlighting indicates exceedance of allowable HQ of 0.2 (0.5 for PHCs).

Toddler (e.g., Resident) COC	Threshold Oral TRV (mg/kg-day)	Threshold Inhalation TRV (mg/m3)	Soil Ingestion Dose (mg/kg-day)	Soil Dermal Contact Dose (mg/kg-day)	Soil Particulate Inhalation Dose (followed by coughing/ ingestion) (mg/kg-day)	Soil Total Oral/ Dermal Dose (mg/kg-day)	Soil Particulate Exposure Conc (fraction retained in lungs) (mg/m3)	Pro-Rated Vapour Exposure Conc (soil source) (mg/m3)	Soil Total Inhaled Conc (mg/m3)	Devel. Soil Ing. Dose (mg/kg-day)	Devel. Soil Derm Contact Dose (mg/kg-day)	Devel. Soil Partic. Inhal. Dose (mg/kg-day)	Devel. Soil Total Oral/ Dermal Dose (mg/kg-day)	Devel Soil Partic. Exposure Conc (mg/m3)	Devel. Vapour Exposure Conc (soil source) (mg/m3)	Devel. Soil Total Inhaled Conc (mg/m3)	Soil Oral/ Dermal HQ	Soil Inhal. HQ	Devel. Soil Oral/ Dermal HQ	Devel. Soil Inhal. HQ
Antimony	4.00E-04	2.00E-04	4.54E-04	7.92E-05	7.91E-07	5.34E-04	1.19E-06	–	1.19E-06	–	–	–	0.00E+00	–	–	0.00E+00	***1.33E+00***	5.93E-03	0.00E+00	0.00E+00
Arsenic	3.00E-04	1.50E-05	2.96E-04	3.10E-05	1.03E-06	3.28E-04	1.55E-06	–	1.55E-06	–	–	–	0.00E+00	–	–	0.00E+00	***1.09E+00***	1.03E-01	0.00E+00	0.00E+00
Cadmium	3.20E-05	3.00E-05	4.24E-05	7.40E-07	7.40E-08	4.32E-05	1.11E-07	–	1.11E-07	–	–	–	0.00E+00	–	–	0.00E+00	***1.35E+00***	3.70E-03	0.00E+00	0.00E+00
Mercury	3.00E-04	9.00E-05	6.20E-06	2.16E-06	2.16E-08	8.39E-06	3.24E-08	5.97E-03	5.97E-03	–	–	–	0.00E+00	–	–	0.00E+00	2.80E-02	***6.63E+01***	0.00E+00	0.00E+00
Benz[a]anthracene	0.00E+00	0.00E+00	9.66E-06	2.19E-06	1.68E-08	1.19E-05	2.53E-08	1.58E-07	1.83E-07	–	–	–	0.00E+00	–	–	0.00E+00	–	–	–	–
Benzo[a]pyrene	3.00E-04	2.00E-06	1.17E-05	2.67E-06	2.05E-08	1.44E-05	3.07E-08	–	3.07E-08	–	–	–	0.00E+00	–	–	0.00E+00	4.81E-02	1.54E-02	0.00E+00	0.00E+00
Benzo[b]fluoranthene	0.00E+00	0.00E+00	1.49E-05	3.38E-06	2.60E-08	1.83E-05	3.90E-08	–	3.90E-08	–	–	–	0.00E+00	–	–	0.00E+00	–	–	–	–
Dibenz[a h]anthracene	0.00E+00	0.00E+00	1.85E-06	4.20E-07	3.23E-09	2.27E-06	4.84E-09	–	4.84E-09	–	–	–	0.00E+00	–	–	0.00E+00	–	–	–	–
Indeno[1 2 3-cd]pyrene	0.00E+00	0.00E+00	8.33E-06	1.89E-06	1.45E-08	1.02E-05	2.18E-08	–	2.18E-08	–	–	–	0.00E+00	–	–	0.00E+00	–	–	–	–
TOTAL CARC. PAHs	0.00E+00	0.00E+00	1.77E-05	4.02E-06	3.09E-08	2.18E-05	4.63E-08	0.00E+00	4.63E-08	–	–	–	0.00E+00	–	0.00E+00	0.00E+00	–	–	–	–

Notes:
- Bold and yellow-highlighting indicates exceedance of allowable HQ of 0.2 (0.5 for PHCs).

Construction Worker **COC**	Non-Threshold Oral TRV (mg/kg-day)-1	Non-Threshold Inhalation TRV (mg/m3)-1	Years Exposed / Amortization Period	Soil Ingestion Dose (mg/kg-day)	Soil Dermal Contact Dose (mg/kg-day)	Soil Particulate Inhalation Dose (followed by coughing/ ingestion) (mg/kg-day)	Soil Total Oral/Dermal Dose (mg/kg-day)	Soil AMORTIZED Oral/Dermal Dose (mg/kg-day)	Soil Particulate Exposure Conc (fraction retained in lungs) (mg/m3)	Pro-Rated Vapour Exposure Conc (soil source) (mg/m3)	Soil Total Inhaled Conc (mg/m3)	Soil AMORTIZED Inhaled Conc (mg/m3)	Soil Oral/Dermal ILCR	Soil Inhal. ILCR
Antimony	0.00E+00	0.00E+00	2.68E-02	3.78E-05	2.57E-05	7.78E-07	6.43E-05	1.72E-06	1.17E-06	0.00E+00	1.17E-06	3.13E-08	0.00E+00	0.00E+00
Arsenic	9.50E+00	1.50E-01	2.68E-02	2.47E-05	1.01E-05	1.02E-06	3.57E-05	9.57E-07	1.52E-06	0.00E+00	1.52E-06	4.08E-08	***9.10E-06***	6.12E-09
Cadmium	0.00E+00	9.80E+00	2.68E-02	3.54E-06	2.40E-07	7.28E-08	3.85E-06	1.03E-07	1.09E-07	0.00E+00	1.09E-07	2.92E-09	0.00E+00	2.87E-08
Mercury	0.00E+00	0.00E+00	2.68E-02	5.17E-07	7.03E-07	2.13E-08	1.24E-06	3.32E-08	3.19E-08	3.91E-07	4.23E-07	1.13E-08	0.00E+00	0.00E+00
Benz[a]anthracene	1.00E-01	6.00E-02	2.68E-02	8.05E-07	7.12E-07	1.66E-08	1.53E-06	4.11E-08	2.49E-08	2.15E-08	4.63E-08	1.24E-09	4.11E-09	7.44E-11
Benzo[a]pyrene	1.00E+00	6.00E-01	2.68E-02	9.79E-07	8.66E-07	2.02E-08	1.87E-06	5.00E-08	3.02E-08	0.00E+00	3.02E-08	8.10E-10	5.00E-08	4.86E-10
Benzo[b]fluoranthene	1.00E-01	6.00E-02	2.68E-02	1.24E-06	1.10E-06	2.56E-08	2.37E-06	6.34E-08	3.83E-08	0.00E+00	3.83E-08	1.03E-09	6.34E-09	6.16E-11
Dibenz[a h]anthracene	1.00E+00	6.00E-01	2.68E-02	1.54E-07	1.36E-07	3.17E-09	2.94E-07	7.86E-09	4.76E-09	0.00E+00	4.76E-09	1.27E-10	7.86E-09	7.65E-11
Indeno[1 2 3-cd]pyrene	1.00E-01	6.00E-02	2.68E-02	6.95E-07	6.14E-07	1.43E-08	1.32E-06	3.54E-08	2.14E-08	0.00E+00	2.14E-08	5.74E-10	3.54E-09	3.45E-11
TOTAL CARC. PAHs	1.00E+00	6.00E-01	2.68E-02	1.48E-06	1.31E-06	3.04E-08	2.81E-06	7.53E-08	4.56E-08	3.63E-09	4.92E-08	1.32E-09	7.53E-08	7.91E-10

Notes:
- Bold and yellow-highlighting indicates exceedance of allowable ILCR of 1x10^{-6}.

Outdoor Worker **COC**	Non-Threshold Oral TRV (mg/kg-day)-1	Non-Threshold Inhalation TRV (mg/m3)-1	Years Exposed / Amortization Period	Soil Ingestion Dose (mg/kg-day)	Soil Dermal Contact Dose (mg/kg-day)	Soil Particulate Inhalation Dose (followed by coughing/ ingestion) (mg/kg-day)	Soil Total Oral/Dermal Dose (mg/kg-day)	Soil AMORTIZED Oral/Dermal Dose (mg/kg-day)	Soil Particulate Exposure Conc (fraction retained in lungs) (mg/m3)	Pro-Rated Vapour Exposure Conc (soil source) (mg/m3)	Soil Total Inhaled Conc (mg/m3)	Soil AMORTIZED Inhaled Conc (mg/m3)	Soil Oral/Dermal ILCR	Soil Inhal. ILCR
Antimony	0.00E+00	0.00E+00	1.00E+00	3.78E-05	2.57E-05	7.78E-07	6.43E-05	6.43E-05	1.17E-06	0.00E+00	1.17E-06	1.17E-06	0.00E+00	0.00E+00
Arsenic	9.50E+00	1.50E-01	1.00E+00	2.47E-05	1.01E-05	1.02E-06	3.57E-05	3.57E-05	1.52E-06	0.00E+00	1.52E-06	1.52E-06	***3.40E-04***	2.28E-07
Cadmium	0.00E+00	9.80E+00	1.00E+00	3.54E-06	2.40E-07	7.28E-08	3.85E-06	3.85E-06	1.09E-07	0.00E+00	1.09E-07	1.09E-07	0.00E+00	***1.07E-06***
Mercury	0.00E+00	0.00E+00	1.00E+00	5.17E-07	7.03E-07	2.13E-08	1.24E-06	1.24E-06	3.19E-08	5.60E-07	5.92E-07	5.92E-07	0.00E+00	0.00E+00
Benz[a]anthracene	1.00E-01	6.00E-02	1.00E+00	8.05E-07	7.12E-07	1.66E-08	1.53E-06	1.53E-06	2.49E-08	3.08E-08	5.56E-08	5.56E-08	1.53E-07	3.34E-09
Benzo[a]pyrene	1.00E+00	6.00E-01	1.00E+00	9.79E-07	8.66E-07	2.02E-08	1.87E-06	1.87E-06	3.02E-08	0.00E+00	3.02E-08	3.02E-08	***1.87E-06***	1.81E-08
Benzo[b]fluoranthene	1.00E-01	6.00E-02	1.00E+00	1.24E-06	1.10E-06	2.56E-08	2.37E-06	2.37E-06	3.83E-08	0.00E+00	3.83E-08	3.83E-08	2.37E-07	2.30E-09
Dibenz[a h]anthracene	1.00E+00	6.00E-01	1.00E+00	1.54E-07	1.36E-07	3.17E-09	2.94E-07	2.94E-07	4.76E-09	0.00E+00	4.76E-09	4.76E-09	2.94E-07	2.86E-09
Indeno[1 2 3-cd]pyrene	1.00E-01	6.00E-02	1.00E+00	6.95E-07	6.14E-07	1.43E-08	1.32E-06	1.32E-06	2.14E-08	0.00E+00	2.14E-08	2.14E-08	1.32E-07	1.29E-09
TOTAL CARC. PAHs	1.00E+00	6.00E-01	1.00E+00	1.48E-06	1.31E-06	3.04E-08	2.81E-06	2.81E-06	4.56E-08	5.20E-09	5.08E-08	5.08E-08	***2.81E-06***	3.05E-08

Notes:
- Bold and yellow-highlighting indicates exceedance of allowable ILCR of 1x10^{-6}.

Full-Life Composite (e.g., Resident) **COC**	Non-Threshold Oral TRV (mg/kg-day)-1	Non-Threshold Inhalation TRV (mg/m3)-1	Years Exposed / Amortization Period	Soil Ingestion Dose (mg/kg-day)	Soil Dermal Contact Dose (mg/kg-day)	Soil Particulate Inhalation Dose (followed by coughing/ ingestion) (mg/kg-day)	Soil Total Oral/Dermal Dose (mg/kg-day)	Soil AMORTIZED Oral/Dermal Dose (mg/kg-day)	Soil Particulate Exposure Conc (fraction retained in lungs) (mg/m3)	Pro-Rated Vapour Exposure Conc (soil source) (mg/m3)	Soil Total Inhaled Conc (mg/m3)	Soil AMORTIZED Inhaled Conc (mg/m3)	Soil Oral/Dermal ILCR	Soil Inhal. ILCR
Antimony	0.00E+00	0.00E+00	–	3.52E-05	2.14E-05	3.71E-07	5.70E-05	5.70E-05	5.57E-07	–	5.57E-07	5.57E-07	0.00E+00	0.00E+00
Arsenic	9.50E+00	1.50E-01	–	2.30E-05	8.37E-06	4.84E-07	3.18E-05	3.18E-05	7.26E-07	–	7.26E-07	7.26E-07	***3.02E-04***	1.09E-07
Cadmium	0.00E+00	9.80E+00	–	3.29E-06	2.00E-07	3.47E-08	3.53E-06	3.53E-06	5.21E-08	–	5.21E-08	5.21E-08	0.00E+00	5.10E-07
Mercury	0.00E+00	0.00E+00	–	4.81E-07	5.84E-07	1.01E-08	1.08E-06	1.08E-06	1.52E-08	5.60E-03	5.60E-03	5.60E-03	0.00E+00	0.00E+00
Benz[a]anthracene	1.00E-01	6.00E-02	–	7.50E-07	5.92E-07	7.90E-09	1.35E-06	1.35E-06	1.19E-08	1.48E-07	1.60E-07	1.60E-07	1.35E-07	9.61E-09
Benzo[a]pyrene	1.00E+00	6.00E-01	–	9.12E-07	7.20E-07	9.61E-09	1.64E-06	1.64E-06	1.44E-08	–	1.44E-08	1.44E-08	***1.64E-06***	8.65E-09
Benzo[b]fluoranthene	1.00E-01	6.00E-02	–	1.16E-06	9.13E-07	1.22E-08	2.08E-06	2.08E-06	1.83E-08	–	1.83E-08	1.83E-08	2.08E-07	1.10E-09
Dibenz[a h]anthracene	1.00E+00	6.00E-01	–	1.44E-07	1.13E-07	1.51E-09	2.58E-07	2.58E-07	2.27E-09	–	2.27E-09	2.27E-09	2.58E-07	1.36E-09
Indeno[1 2 3-cd]pyrene	1.00E-01	6.00E-02	–	6.47E-07	5.10E-07	6.82E-09	1.16E-06	1.16E-06	1.02E-08	–	1.02E-08	1.02E-08	1.16E-07	6.14E-10
TOTAL CARC. PAHs	1.00E+00	6.00E-01	–	1.38E-06	1.09E-06	1.45E-08	2.47E-06	2.47E-06	2.17E-08	2.99E-07	3.21E-07	3.21E-07	***2.47E-06***	1.93E-07

Notes:
- Bold and yellow-highlighting indicates exceedance of allowable ILCR of 1x10^{-6}.

NovaTox

Effects-Based Soil Standards (µg/g) Calculated Based on -->	Soil Oral/Dermal Pathway						Soil Inhalation Pathway (Trench/Outdoor)				Soil Inhalation Pathway (Indoor)		MINIMUM Effects-Based Standard			
COC	**HQ for Construction Worker**	**HQ for Outdoor Worker**	**HQ for Resident**	**ILCR for Construction Worker**	**ILCR for Outdoor Worker**	**ILCR for Resident**	**HQ for Construction Worker**	**HQ for Outdoor Worker**	**ILCR for Construction Worker**	**ILCR for Outdoor Worker**	**HQ for Resident**	**ILCR for Resident**	**Soil Oral/ Dermal Pathway**	**Soil Inhalation Pathway (Trench/ Outdoor)**	**Soil Inhalation Pathway (Indoor)**	**OVERALL**
Antimony	6.23E+01	6.23E+01	***7.50E+00***	–	–	–	1.71E+03	1.71E+03	–	–	1.69E+03	–	7.50E+00	1.71E+03	1.69E+03	7.50E+00
Arsenic	1.10E+02	1.10E+02	1.19E+01	7.18E+00	***1.92E-01***	2.16E-01	1.29E+02	1.29E+02	1.07E+04	2.86E+02	1.27E+02	5.99E+02	1.92E-01	1.29E+02	1.27E+02	1.92E-01
Cadmium	7.78E+00	7.78E+00	***6.93E-01***	–	–	–	2.57E+02	2.57E+02	1.63E+02	4.37E+00	2.53E+02	9.17E+00	6.93E-01	4.37E+00	9.17E+00	6.93E-01
Mercury	6.61E+01	6.61E+01	9.79E+00	–	–	–	5.83E+01	4.16E+01	–	–	***4.12E-03***	–	9.79E+00	4.16E+01	4.12E-03	4.12E-03
Benz[a]anthracene	–	–	–	2.59E+02	***6.95E+00***	7.90E+00	–	–	1.43E+04	3.19E+02	–	1.11E+02	6.95E+00	3.19E+02	1.11E+02	6.95E+00
Benzo[a]pyrene	4.17E+01	4.17E+01	5.39E+00	2.59E+01	***6.95E-01***	7.90E-01	1.71E+01	1.71E+01	2.67E+03	7.14E+01	1.69E+01	1.50E+02	6.95E-01	1.71E+01	1.69E+01	6.95E-01
Benzo[b]fluoranthene	–	–	–	2.59E+02	***6.95E+00***	7.90E+00	–	–	2.67E+04	7.14E+02	–	1.50E+03	6.95E+00	7.14E+02	1.50E+03	6.95E+00
Dibenz[a h]anthracene	–	–	–	2.59E+01	***6.95E-01***	7.90E-01	–	–	2.67E+03	7.14E+01	–	1.50E+02	6.95E-01	7.14E+01	1.50E+02	6.95E-01
Indeno[1 2 3-cd]pyrene	–	–	–	2.59E+02	***6.95E+00***	7.90E+00	–	–	2.67E+04	7.14E+02	–	1.50E+03	6.95E+00	7.14E+02	1.50E+03	6.95E+00

Notes:

- Bold and yellow-highlighting indicates minimum overall effects-based standard.

J&E Soil Model (re-created from U.S. EPA) **COC**	**Enthalpy of vap. at ave. soil temp.** **ΔHv,TS** **(cal/mol)**	**Henry's law constant at ave. soil temp.** **H_{TS}** **(atm-m³/ mol)**	**Henry's law constant at ave. soil temp.** **H'_{TS}** **(unitless)**	**Vapour viscosity at average soil temp.** **μ_{TS}** **(g/cm-s)**	**Stratum A effective diffusion coeffic.** **D^{eff}_{A}** **(cm²/s)**	**Stratum B effective diffusion coeffic.** **D^{eff}_{B}** **(cm²/s)**	**Stratum C effective diffusion coeffic.** **D^{eff}_{C}** **(cm²/s)**	**Total overall effective diffusion coeffic.** **D^{eff}_{T}** **(cm²/s)**	**Diffusion path length** **L_d** **(cm)**	**Convect-ion path length** **L_p** **(cm)**	**Soil-water partition coeffic.** **K_d** **(cm³/g)**	**Crack radius** **r_{crack}** **(cm)**	**Average vapour flow rate into building** **Q_{soil}** **(cm³/s)**	**Crack effective diffusion coeffic.** **D^{crack}** **(cm²/s)**	**Area of crack** **A_{crack}** **(cm²)**	**Exponent of equival-ent foundat-ion Peclet number** **$exp(Pe^f)$** **(unitless)**
Mercury	1.53E+04	4.70E-03	1.99E-01	1.77E-04	4.96E-03	8.34E-03	4.96E-03	8.32E-03	3.00E+01	1.58E+02	5.20E+01	1.00E-01	1.41E+02	4.96E-03	4.56E+02	1.62E+216
Benz[a]anthracene	2.30E+04	3.12E-06	1.32E-04	1.77E-04	8.27E-03	1.39E-02	8.27E-03	1.38E-02	3.00E+01	1.58E+02	2.31E+03	1.00E-01	1.41E+02	8.27E-03	4.56E+02	4.91E+129
TOTAL CARC. PAHs (5 volatile carcinogenic PAHs were adjusted for B(a)P equivalence and then summed. See table (ii) on the Appendix G3(g) sheet for calculation.)																

Lookup Table (i)					
PAH	**Henry's Law (atm-m3/ mol)**	**H Less than 10^{-5}?**	**Vapour Pressure (mm Hg)**	**Vap Less than 0.05?**	**Requires Vapour Modelling?**
Acenaphthene	1.82E-04	–	2.50E-03	Yes	Yes
Acenaphthylene	1.25E-04	–	9.12E-04	Yes	Yes
Anthracene	5.55E-05	–	2.67E-06	Yes	Yes
Benz[a]anthracene	1.20E-05	–	1.90E-06	Yes	Yes
Benzo[a]pyrene	4.58E-07	Yes	5.49E-09	Yes	–
Benzo[b]fluoranthene	6.58E-07	Yes	5.00E-07	Yes	–
Benzo[ghi]perylene	3.30E-07	Yes	1.00E-10	Yes	–
Benzo[k]fluoranthene	5.85E-07	Yes	9.65E-10	Yes	–
Chrysene	5.24E-06	Yes	6.23E-09	Yes	–
Dibenz[a h]anthracene	1.23E-07	Yes	1.39E-11	Yes	–
Fluoranthene	8.86E-06	Yes	9.22E-06	Yes	–
Indeno[1 2 3-cd]pyrene	3.47E-07	Yes	1.25E-10	Yes	–
Pyrene	1.19E-05	–	4.50E-06	Yes	Yes

Notes:
- According to MECP, any COC may be screened out of a vapour intrusion assessment if both (i) its Henry's Law Constant is $<10^{-5}$ and (ii) its vapour pressure is <0.05 Torr (equivalent to 0.05 mm Hg).

Lookup Table (ii)		No source depletion		with source depletion	
		Soil-to-Indoor Air (ug/m3)		Soil-to-Indoor Air (ug/m3)	
Carcinogenic PAH	**TEF**	**REM**	**BaP Equiv.**	**REM**	**BaP Equiv.**
Acenaphthene	0.001	8.79E-03	8.79E-06	8.74E-03	8.74E-06
Acenaphthylene	0.01	3.33E-02	3.33E-04	3.32E-02	3.32E-04
Anthracene	0.01	1.88E-03	1.88E-05	1.88E-03	1.88E-05
Benz(a)anthracene	0.1	1.88E-04	1.88E-05	1.88E-04	1.88E-05
Benzo(a)pyrene	1	–	–	–	–
Benzo(b/j)fluoranthene	0.1	–	–	–	–
Benzo(g,h,i)perylene	0.01	–	–	–	–
Benzo(k)fluoranthene	0.1	–	–	–	–
Chrysene	0.01	–	–	–	–
Dibenzo[a,h]anthracene	1	–	–	–	–
Fluoranthene	0.01	–	–	–	–
Indeno(1,2,3-cd)pyrene	0.1	–	–	–	–
Pyrene	0.001	1.03E-03	1.03E-06	1.03E-03	1.03E-06
TOTAL Carcinogenic PAHs			3.80E-04		3.79E-04

Notes:
- TEFs obtained from MOE (2011) Rationale Document (citing Kalberlah et al., 1995)
- Indoor vapour pathway described in Appendix G2(g).
- The vapour model was run with REM concentrations, for the four volatile carcinogenic PAHs. Summing the four values gives the REM concentration of 'Total Carcinogenic PAHs' in vapour, which was carried through risk calculations.

Lookup Table (iii) Source Depletion Multiplier Calculation	**Csoil**	**Soil Bulk Density**	**Volume of source zone (Default = 13m x 13m x 2m)**	**Volume of source zone (Adjusted)**	**Mass 1:** Initial Mass	**Initial $C_{indoor\ air}$**	**Volume of building**	**Air Exchange Rate**	**Mass 2:** Mass Remaining after 1 Week of Soil Gas Entering Building	**Half Life**	**SDM (Source Depletion Multiplier)**	**Final $C_{indoor\ air}$**
COC	**(mg/kg)**	**(g/cm^3)**	**(cm^3)**	**(cm^3)**	**(g)**	**(ug/m^3)**	**(m^3)**	**(1/hour)**	**(g)**	**(years)**		**(ug/m^3)**
Mercury	1.37	1.66	3.38E+08	9.38E+07	213.0	1.48E+01	476	0	212.7	7.95	1.5	9.59E+00
Benz[a]anthracene	1.07	1.66	3.38E+08	9.38E+07	165.9	1.88E-04	476	0	165.9	489,942.38	1.0	1.88E-04

J&E Soil Model (re-created from U.S. EPA) COC	Soil Source vapour conc. C_{source} (µg/m³)	Infinite source indoor attenuation coefficient α (unitless)	MOE Bio-Attenuation Factor BAF (unitless)	Indoor Building Conc. NO source depletion Residential Building-with-Basement REM $C_{building}$ (µg/m³) (Infinite Source Vapour X J&E Atten. Factor X MOE Bio-Atten. Factor)	MOE Source Depletion Multiplier SDM (unitless) See table (iii) on the Appendix G3(g) sheet for calculation)	Indoor Building Conc. WITH source depletion Residential Building-with-Basement REM $C_{building}$ (µg/m³) (Initial Bldg. Conc. X MOE SDM)	Indoor Building Concentration Carried Forward in Exposure & Risk Calcs: Indoor Building Conc. WITH source depletion; Residential Building-with-Basement REM $C_{building}$ (µg/m³)
Mercury	5.22E+03	2.84E-03	1.00E+00	1.48E+01	1.55E+00	9.59E+00	9.59E+00
Benz[a]anthracene	6.08E-02	3.09E-03	1.00E+00	1.88E-04	1.00E+00	1.88E-04	1.88E-04
TOTAL CARC. PAHs (5 volatile carcinogenic PAHs were adjusted for B(a)P equivalence and then summed. See table (ii) on the Appendix G3(g) sheet for calculation.)				3.80E-04		3.79E-04	3.79E-04

J&E Soil Model (re-created from U.S. EPA) COC	Finite source B term (unitless)	Finite source ψ term $(sec)^{-1}$	Time for source depletion τ_D (sec)	Exposure duration > time for source (Y/N)	Finite source indoor attenuation coefficient <α> (unitless)	Mass limit building conc. $C_{building}$ (µg/m³)	Finite source bldg. conc. $C_{building}$ (µg/m³)	Final finite source bldg. conc. $C_{building}$ (µg/m³)	Soil saturation conc. C_{sat} (µg/kg)
Mercury	NA	NA	NA	NA	NA	NA	NA	NA	3.12E+03
Benz[a]anthracene	NA	NA	NA	NA	NA	NA	NA	NA	2.17E+04
TOTAL CARC. PAHs (5 volatile carcinogenic PAHs were adjusted for B(a)P equivalence and then summed. See table (ii) on the Appendix G3(g) sheet for calculation.)									

Toddler (e.g., Resident) COC	Source Vapour Conc. (soil) (ug/m3)	Attenuation Factor (Soil-to-indoor air)	Bio-Attenuation Factor (Soil-to-indoor air)	Source Depletion Multiplier (Soil source)	Indoor Vapour Conc. (soil source) (ug/m3)	Pro-Rated Vapour Exposure Conc. (soil source) (mg/m3)	Developm Exposure Conc - No pro-rating (mg/m3)	Hours/24 Hours	Days/365 days
Mercury	5.22E+03	2.84E-03	1.00E+00	1.55E+00	9.59E+00	9.20E-03	–	1.00E+00	9.59E-01
Benz[a]anthracene	6.08E-02	3.09E-03	1.00E+00	1.00E+00	1.88E-04	1.80E-07	–	1.00E+00	9.59E-01
TOTAL CARC. PAHs									

Notes:
- Indoor vapour pathway described in Appendix G2(g).
- Refer to Appendix G1(d) for receptor characteristics used to calculate developmental dose.

Full-Life Composite (e.g., Resident) COC	Source Vapour Conc. (soil) (ug/m3)	Attenuation Factor (Soil-to-indoor air)	Bio-Attenuation Factor (Soil-to-indoor air)	Source Depletion Multiplier (Soil source)	Indoor Vapour Conc. (soil source) (ug/m3)	Pro-Rated Vapour Exposure Conc. (soil source) (mg/m3)	Developm Exposure Conc - No pro-rating (mg/m3)	Hours/24 Hours	Days/365 days
Mercury	5.22E+03	2.84E-03	1.00E+00	1.55E+00	9.59E+00	8.62E-03	–	9.38E-01	9.59E-01
Benz[a]anthracene	6.08E-02	3.09E-03	1.00E+00	1.00E+00	1.88E-04	1.69E-07	–	9.38E-01	9.59E-01
TOTAL CARC. PAHs (5 volatile carcinogenic PAHs were adjusted for B(a)P equivalence and then summed. See tables (ii) and (iii) on the Appendix G3(g) sheet for calculation of non-pro-rated indoor vapour concentrations.)					3.79E-04	3.41E-07		9.38E-01	9.59E-01

Notes:
- Indoor vapour pathway described in Appendix G2(g).
- Developmental dose not applicable as full-life/composite receptor only used to assess carcinogenic risk.

Toddler (e.g., Resident) **COC**	**Threshold Oral TRV (mg/kg-day)**	**Threshold Inhalation TRV (mg/m3)**	**Soil Ingestion Dose (mg/kg-day)**	**Soil Dermal Contact Dose (mg/kg-day)**	**Soil Particulate Inhalation Dose (followed by coughing/ ingestion) (mg/kg-day)**	**Soil Total Oral/ Dermal Dose (mg/kg-day)**	**Soil Particulate Exposure Conc (fraction retained in lungs) (mg/m3)**	**Pro-Rated Vapour Exposure Conc (soil source) (mg/m3)**	**Soil Total Inhaled Conc (mg/m3)**	**Devel. Soil Ing. Dose (mg/kg-day)**	**Devel. Soil Derm Contact Dose (mg/kg-day)**	**Devel. Soil Partic. Inhal. Dose (mg/kg-day)**	**Devel. Soil Total Oral/ Dermal Dose (mg/kg-day)**	**Devel Soil Partic. Exposure Conc (mg/m3)**	**Devel. Vapour Exposure Conc (soil source) (mg/m3)**	**Devel. Soil Total Inhaled Conc (mg/m3)**	**Soil Oral/ Dermal HQ**	**Soil Inhal. HQ**	**Devel. Soil Oral/ Dermal HQ**	**Devel. Soil Inhal. HQ**
Antimony	4.00E-04	2.00E-04	4.54E-04	7.92E-05	7.91E-07	5.34E-04	1.19E-06	–	1.19E-06	–	–	–	0.00E+00	–	–	0.00E+00	***1.33E+00***	5.93E-03	0.00E+00	0.00E+00
Arsenic	3.00E-04	1.50E-05	2.96E-04	3.10E-05	1.03E-06	3.28E-04	1.55E-06	–	1.55E-06	–	–	–	0.00E+00	–	–	0.00E+00	***1.09E+00***	1.03E-01	0.00E+00	0.00E+00
Cadmium	3.20E-05	3.00E-05	4.24E-05	7.40E-07	7.40E-08	4.32E-05	1.11E-07	–	1.11E-07	–	–	–	0.00E+00	–	–	0.00E+00	***1.35E+00***	3.70E-03	0.00E+00	0.00E+00
Mercury	3.00E-04	9.00E-05	6.20E-06	2.16E-06	2.16E-08	8.39E-06	3.24E-08	9.20E-03	9.20E-03	–	–	–	0.00E+00	–	–	0.00E+00	2.80E-02	***1.02E+02***	0.00E+00	0.00E+00
Benz[a]anthracene	0.00E+00	0.00E+00	9.66E-06	2.19E-06	1.68E-08	1.19E-05	2.53E-08	1.80E-07	2.05E-07	–	–	–	0.00E+00	–	–	0.00E+00	–	–	–	–
Benzo[a]pyrene	3.00E-04	2.00E-06	1.17E-05	2.67E-06	2.05E-08	1.44E-05	3.07E-08	–	3.07E-08	–	–	–	0.00E+00	–	–	0.00E+00	4.81E-02	1.54E-02	0.00E+00	0.00E+00
Benzo[b]fluoranthene	0.00E+00	0.00E+00	1.49E-05	3.38E-06	2.60E-08	1.83E-05	3.90E-08	–	3.90E-08	–	–	–	0.00E+00	–	–	0.00E+00	–	–	–	–
Dibenz[a h]anthracene	0.00E+00	0.00E+00	1.85E-06	4.20E-07	3.23E-09	2.27E-06	4.84E-09	–	4.84E-09	–	–	–	0.00E+00	–	–	0.00E+00	–	–	–	–
Indeno[1 2 3-cd]pyrene	0.00E+00	0.00E+00	8.33E-06	1.89E-06	1.45E-08	1.02E-05	2.18E-08	–	2.18E-08	–	–	–	0.00E+00	–	–	0.00E+00	–	–	–	–
TOTAL CARC. PAHs	0.00E+00	0.00E+00	1.77E-05	4.02E-06	3.09E-08	2.18E-05	4.63E-08	0.00E+00	4.63E-08	–	–	–	0.00E+00	–	0.00E+00	0.00E+00	–	–	–	–

Notes:
- Bold and yellow-highlighting indicates exceedance of allowable HQ of 0.2 (0.5 for PHCs).

Appendix B4: HHRA Calculations (B4(i): Incremental Lifetime Cancer Risk for Soil COCs)

NovaTox

Full-Life Composite (e.g., Resident) **COC**	**Non-Threshold Oral TRV (mg/kg-day)-1**	**Non-Threshold Inhalation TRV (mg/m3)-1**	**Years Exposed / Amortization Period**	**Soil Ingestion Dose (mg/kg-day)**	**Soil Dermal Contact Dose (mg/kg-day)**	**Soil Particulate Inhalation Dose (followed by coughing/ ingestion) (mg/kg-day)**	**Soil Total Oral/Dermal Dose (mg/kg-day)**	**Soil AMORTIZED Oral/Dermal Dose (mg/kg-day)**	**Soil Particulate Exposure Conc (fraction retained in lungs) (mg/m3)**	**Pro-Rated Vapour Exposure Conc (soil source) (mg/m3)**	**Soil Total Inhaled Conc (mg/m3)**	**Soil AMORTIZED Inhaled Conc (mg/m3)**	**Soil Oral/Dermal ILCR**	**Soil Inhal. ILCR**
Antimony	0.00E+00	0.00E+00	–	3.52E-05	2.14E-05	3.71E-07	5.70E-05	5.70E-05	5.57E-07	–	5.57E-07	5.57E-07	0.00E+00	0.00E+00
Arsenic	9.50E+00	1.50E-01	–	2.30E-05	8.37E-06	4.84E-07	3.18E-05	3.18E-05	7.26E-07	–	7.26E-07	7.26E-07	***3.02E-04***	1.09E-07
Cadmium	0.00E+00	9.80E+00	–	3.29E-06	2.00E-07	3.47E-08	3.53E-06	3.53E-06	5.21E-08	–	5.21E-08	5.21E-08	0.00E+00	5.10E-07
Mercury	0.00E+00	0.00E+00	–	4.81E-07	5.84E-07	1.01E-08	1.08E-06	1.08E-06	1.52E-08	8.62E-03	8.62E-03	8.62E-03	0.00E+00	0.00E+00
Benz[a]anthracene	1.00E-01	6.00E-02	–	7.50E-07	5.92E-07	7.90E-09	1.35E-06	1.35E-06	1.19E-08	1.69E-07	1.81E-07	1.81E-07	1.35E-07	1.08E-08
Benzo[a]pyrene	1.00E+00	6.00E-01	–	9.12E-07	7.20E-07	9.61E-09	1.64E-06	1.64E-06	1.44E-08	–	1.44E-08	1.44E-08	***1.64E-06***	8.65E-09
Benzo[b]fluoranthene	1.00E-01	6.00E-02	–	1.16E-06	9.13E-07	1.22E-08	2.08E-06	2.08E-06	1.83E-08	–	1.83E-08	1.83E-08	2.08E-07	1.10E-09
Dibenz[a h]anthracene	1.00E+00	6.00E-01	–	1.44E-07	1.13E-07	1.51E-09	2.58E-07	2.58E-07	2.27E-09	–	2.27E-09	2.27E-09	2.58E-07	1.36E-09
Indeno[1 2 3-cd]pyrene	1.00E-01	6.00E-02	–	6.47E-07	5.10E-07	6.82E-09	1.16E-06	1.16E-06	1.02E-08	–	1.02E-08	1.02E-08	1.16E-07	6.14E-10
TOTAL CARC. PAHs	1.00E+00	6.00E-01	–	1.38E-06	1.09E-06	1.45E-08	2.47E-06	2.47E-06	2.17E-08	3.41E-07	3.63E-07	3.63E-07	***2.47E-06***	2.18E-07

Notes:
- Bold and yellow-highlighting indicates exceedance of allowable ILCR of $1x10^{-6}$.

NovaTox

Effects-Based Soil Standards (µg/g) Calculated Based on -->	Soil Oral/Dermal Pathway						Soil Inhalation Pathway (Trench/Outdoor)				Soil Inhalation Pathway (Indoor)		MINIMUM Effects-Based Standard			
COC	HQ for Construction Worker	HQ for Outdoor Worker	HQ for Resident	ILCR for Construction Worker	ILCR for Outdoor Worker	ILCR for Resident	HQ for Construction Worker	HQ for Outdoor Worker	ILCR for Construction Worker	ILCR for Outdoor Worker	HQ for Resident	ILCR for Resident	Soil Oral/ Dermal Pathway	Soil Inhalation Pathway (Trench/ Outdoor)	Soil Inhalation Pathway (Indoor)	OVERALL
Antimony	6.23E+01	6.23E+01	***7.50E+00***	–	–	–	1.71E+03	1.71E+03	–	–	1.69E+03	–	7.50E+00	1.71E+03	1.69E+03	7.50E+00
Arsenic	1.10E+02	1.10E+02	1.19E+01	7.18E+00	***1.92E-01***	2.16E-01	1.29E+02	1.29E+02	1.07E+04	2.86E+02	1.27E+02	5.99E+02	1.92E-01	1.29E+02	1.27E+02	1.92E-01
Cadmium	7.78E+00	7.78E+00	***6.93E-01***	–	–	–	2.57E+02	2.57E+02	1.63E+02	4.37E+00	2.53E+02	9.17E+00	6.93E-01	4.37E+00	9.17E+00	6.93E-01
Mercury	6.61E+01	6.61E+01	9.79E+00	–	–	–	5.83E+01	4.16E+01	–	–	***2.68E-03***	–	9.79E+00	4.16E+01	2.68E-03	2.68E-03
Benz[a]anthracene	–	–	–	2.59E+02	***6.95E+00***	7.90E+00	–	–	1.43E+04	3.19E+02	–	9.83E+01	6.95E+00	3.19E+02	9.83E+01	6.95E+00
Benzo[a]pyrene	4.17E+01	4.17E+01	5.39E+00	2.59E+01	***6.95E-01***	7.90E-01	1.71E+01	1.71E+01	2.67E+03	7.14E+01	1.69E+01	1.50E+02	6.95E-01	1.71E+01	1.69E+01	6.95E-01
Benzo[b]fluoranthene	–	–	–	2.59E+02	***6.95E+00***	7.90E+00	–	–	2.67E+04	7.14E+02	–	1.50E+03	6.95E+00	7.14E+02	1.50E+03	6.95E+00
Dibenz[a h]anthracene	–	–	–	2.59E+01	***6.95E-01***	7.90E-01	–	–	2.67E+03	7.14E+01	–	1.50E+02	6.95E-01	7.14E+01	1.50E+02	6.95E-01
Indeno[1 2 3-cd]pyrene	–	–	–	2.59E+02	***6.95E+00***	7.90E+00	–	–	2.67E+04	7.14E+02	–	1.50E+03	6.95E+00	7.14E+02	1.50E+03	6.95E+00

Notes:

- Bold and yellow-highlighting indicates minimum overall effects-based standard.

Appendix C
Limitations

Appendix C - Additional Disclaimers and Limitations

1. NovaTox Inc. (NovaTox) provided this report for Mezcon Construction Limited. (our Client) solely for the purpose stated in this report. NovaTox Inc. does not accept any responsibility for the use of this report for any other purpose other than as specified and intended.

2. NovaTox Inc. does not have and does not accept, any responsibility or duty of care whether based in negligence or otherwise, in relation to the use of this report in whole or in part by any third party. Any alternate use, including by a third party, or any reliance on or decision made based on this report, are the sole responsibility of the alternative user or third party. NovaTox Inc. does not accept responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

3. The work performed in the preparation of this RA report and the conclusions presented are subject to the following:
   (a) The Scope of Services;
   (b) Time and Budgetary limitations as described in Contracts with our respective client(s); and
   (c) The Limitations stated herein.

4. No other warranties or representations, either expressed or implied, are made as to the professional services provided, other than that NovaTox has exercised reasonable skill, care and diligence in accordance with accepted practice and usual standards of thoroughness and competence for the profession of toxicology and environmental risk assessment to assess and evaluate information acquired during the preparation of this report.

5. The conclusions and discussion presented in this report were based, in part, on borehole logs that were obtained through visual observations of the Site and attendant structures by our Client. Our conclusions cannot and are not extended to include those portions of the Site or structures that were not reasonably available, in NovaTox's opinion, for direct observation by our Client.

6. The site history research provided by our Client included obtaining information from third parties and employees or agents of the owner. No attempt has been made to verify the accuracy of any information provided, unless specifically noted in our report.

7. Because of the limitations referred to above, different environmental conditions from those stated in our report may exist. Should such different conditions be encountered, NovaTox must be notified in order that it may determine if modifications to the conclusions in the report are necessary.

8. This report is for the sole use of the party to whom it is addressed unless expressly stated otherwise in the report or contract. Any use which any third party makes of the report, in whole or in part, or any reliance thereon or decisions made based on any information or conclusions in the report, is the sole responsibility of such third party. NovaTox accepts no responsibility whatsoever for damages or loss of any nature or kind suffered by any such third party as a result of actions taken or not taken or decisions made in reliance on the report or anything set out therein.

9. This report is not to be given over to any third party for any purpose whatsoever without the written permission of NovaTox Inc, our Client, or their representative.

10. NovaTox Inc. reserves all rights in this report, unless specifically agreed to otherwise in writing with Mezcon Construction Limited.