Rationale Document for Development of Excess Soil Quality Standards

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Ontario

Ontario Ministry of Environment, Conservation and Parks

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1. INTRODUCTION

The Ministry of the Environment, Conservation and Parks (the “Ministry”) has developed tables of generic standards to enable the reuse of excess soil (the “excess soil quality standards”) along with associated rules for the application of these standards at a site at which excess soil is used for a beneficial purpose (the “reuse site”). The excess soil quality standards are intended to address risks associated with chemical impacts in soil and are not meant to address issues of radioactivity, explosive conditions, soil fertility, or geotechnical considerations. It should also be noted that these standards do not replace the determination of hazardous and nonhazardous wastes, or what is appropriate for shore infilling.

While a number of assumptions and exposure pathways used in the development of Ontario Regulation 153/04 (O. Reg. 153/04) brownfield site condition standards for soil (the “brownfield soil standards”) are applicable in an excess soil reuse context, there are some differences in how the excess soil quality standards were derived. For example, one major difference includes the consideration of larger volumes of impacted soil and potential impacts to groundwater. As a result, two sets of excess soil quality standards (based on soil volume) have been developed: small soil volumes, which rely on the applicable brownfield soil standards, and large soil volumes, which rely on the volume independent excess soil quality standards (details provided in Section 3).

The generic excess soil quality standards have been developed and organized based on a number of predefined categories, including property use, groundwater potability, overburden thickness, distance to the nearest water body and soil placement volume. The standards are presented in a series of tables (e.g., Tables 2.1 to 9.1), similar to the tables used to present the brownfield soil standards (i.e., Tables 2 to 9). Table 1 is the same for both brownfields and excess soil quality standards. As such, appropriate soil quality can be readily determined by matching reuse site conditions with the appropriate table of standards. This is intended to enable greater utilization of soil as a resource, while protecting human health and the environment.

This document provides an overview of the standard derivation process, associated assumptions and placement considerations for reuse of excess soil. To avoid duplication, this document relies on key information provided in the MOE (2011) document, entitled “*Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario”* (the “MOE (2011) rationale document”) to support how the excess soil quality standards were developed. The Ministry has also developed a technical tool to facilitate the generation of site specific excess soil quality standards, referred to as the Beneficial Reuse Assessment Tool (BRAT). This tool is based on the same approach used to develop the tables of generic standards and is discussed further in Section 6.

2. OVERVIEW OF EXCESS SOIL QUALITY STANDARD DEVELOPMENT

Similar to the approach taken to develop the brownfield soil standards, a stepwise process is used to derive excess soil quality standards:

- Step 1 - a risk-based concentration for each chemical is derived for a series of 11 component values for human and/or ecological receptors (as listed in Section 2.1 below). Each component value represents an exposure pathway where people, terrestrial organisms (e.g., plants, mammals, and birds), or aquatic organisms (e.g., fish) can be exposed to that chemical.

- Step 2 - the lowest concentration from the 11 component values is selected as it represents the exposure pathway that has the highest concern. All other exposure pathways will be protected at this concentration.

- Step 3 - the final excess soil quality standard is set at the risk-based concentration derived above in Step 2 unless it is lower than either the analytical reporting limit (RL) or the typical background soil concentration found in Ontario, or it is higher than the free phase product formation threshold for the chemical. In these cases, the final excess soil quality standard is set at either the RL, the background concentration, or the free phase product formation threshold (as appropriate).

2.1 Components Considered for the Development of Excess Soil Quality Standards

The component values considered for the development of excess soil quality standards are:

1) S1 - Soil for protection of an agricultural or residential, parkland or institutional (R/P/I) receptor from direct contact (dermal exposure and incidental ingestion) with surface soil;

2) S2 - Soil for protection of an industrial, commercial or community (I/C/C) receptor from direct contact (dermal exposure and incidental ingestion) with surface soil;

3) S3 - Soil for protection of a worker digging in the soil from direct contact (dermal exposure, incidental ingestion and particulate inhalation) with soil, only considered for I/C/C land use;

4) S-IA - Soil for protection of vapour movement to indoor air and human exposure;

5) S-OA - Soil for protection of vapour movement to outdoor air and human exposure;

6) S-Odour - Soil for protection from excessive odours;

7) S-GW1 - Soil for protection of movement to ground water used for drinking water purposes;

8) S-GW2 - Soil for protection of movement to ground water and then vapour migration from ground water to indoor air;

9) S-GW3 - Soil for protection of movement to ground water and then migration to surface water (aquatic life);

10) Plants and Soil Organisms - Soil for protection against adverse effects to plants and soil dwelling organisms; and,

11) Mammals and Birds - Soil for protection against adverse effects through direct soil contact (ingestion) and food/prey ingestion to mammals and birds.

With the exception of the S-GW2 component value, descriptions of these soil component values and exposure pathways can be found in Section 1.3.2 of the MOE (2011) rationale document. It should be noted that the S-GW2 component value was not included in the development of the brownfield soil standards. A brief explanation of the derivation of the S-GW2 component value is presented in Section 3.2 and full details are provided in Appendix I.

While the methods used to develop the excess soil component values are broadly similar to those used to develop the brownfield standards, some modifications were made to make the excess soil component values more applicable to excess soil reuse scenarios. These modifications are discussed in greater detail in Section 3.

2.2 Components Not Considered in the Development of Excess Soil Quality Standards

Pathways not considered in the development of brownfield or excess soil quality standards include the following:

1) consumption of garden products cultivated at a reuse site;

2) agricultural land use specific exposure scenarios, such as:

    - livestock watering;

    - irrigation water;

- dust inhalation;
- consumption of milk or diary product produced at a reuse site;
- consumption of plants or animals cultivated at a reuse site; and

3) protection of reptiles and amphibians.

A more comprehensive discussion of the human health pathways not considered in soil standard development can be found in Section 2.3.2 of the MOE (2011) rationale document. Section D.2 of Part I of the MECP (2020) document, entitled *“Rules for Soil Management and Excess Soil Quality Standards”* (the “MECP (2020) Soil Rules and Excess Soil Standards”) outlines additional protections for certain reuse sites (e.g., where soil is used as a growing medium for crops). This information is also summarized in Section 7.

3. DEVIATIONS FROM BROWNFIELD SOIL STANDARD DEVELOPMENT

Brownfield soil standards are based on a redevelopment scenario and rely on some assumptions (such as the assumed size of the contaminated area) that may be different in an excess soil reuse scenario. As a result, excess soil quality standards were developed based on how the brownfield soil standards were developed but with some modifications to reflect changes to some of the assumptions and inputs used to develop the brownfield soil standards. There are also some differences in the associated requirements for using these standards. These differences are discussed in the following subsections.

3.1 Volume of Excess Soil

Under a brownfield context, a typical “spill” scenario was modelled as a volume of contaminated soil with dimensions of 13 m in length, 13 m in width, and 2 m in thickness (approximately 350 m^3 in total volume). This source size assumption influences the fate and transport of chemicals in soil and groundwater (and what concentrations human and ecological receptors are exposed to from chemicals in soil and groundwater); a “spill” scenario assumes a finite contamination volume that depletes over time and/or employs dilution/mixing of chemicals that is affected by the source size (refer to Section 7 of the MOE (2011) rationale document for further details).

When a volume of soil is larger than that used to derive a brownfield soil standard, there may be increased potential exposure via some pathways, due to lower levels of source depletion and dilution. As such, the use of generic brownfield soil standards may be inappropriate and unprotective when large volumes of soil (>350 m^3) are placed at a reuse site. The sensitivity of the component values associated with each exposure pathway to source dimensions is summarized in Table 3.1.

Comments received during consultation on the excess soil quality standards indicated that large volumes (e.g., much greater than 350 m^3) of excess soil were often relocated and reused and that there was a need for development of standards for large volumes. As such, the Ministry developed excess soil quality standards for two (2) different soil volumes to allow for greater flexibility in soil reuse options:

1. For small volumes of excess soil (those with excess soil volumes up to 350 m^3), the brownfield soil standards (specified for coarse-textured soils) can be applied. These standards are referred to as “small volume standards”. The small volume standards can also be applied to larger volumes of soil if site specific standards developed using the BRAT justify this approach.

2. For larger volumes of excess soil (those with excess soil volumes of greater than 350 m^3), another set of generic standards were derived. These generic standards were developed by assuming the excess soil volume was sufficiently large to negate the effects of both dilution and source depletion. As such, these standards are referred to as “volume independent standards” and are applicable to any volume of excess soil being placed at a reuse site.

Details on how to select an appropriate soil volume are provided Section 5.

Table 3.1. Effect of Source Dimensions on Component Values

Component Value	Attenuation Mechanism	Effect of Larger Source Dimensions on Component Value (Relative to the Typical Brownfield Spill Scenario Utilized)
S-GW1	Wellbore Dilution	Component values may decrease by more than 50 times when the areal extent of the source increases. No further impact occurs once the source area reaches approximately 14,000 m^2.
	Source Depletion	Component values may decrease by 10 to 50 times when the source thickness increases. Impacts are chemical specific, with minimal further impacts for most chemicals once the source thickness reaches approximately 10 m to 30 m.

Component Value	Attenuation Mechanism	Effect of Larger Source Dimensions on Component Value (Relative to the Typical Brownfield Spill Scenario Utilized)
S-GW2	Aquifer Mixing	Component values may decrease by less than 2 times when the source length increases.
	Source Depletion	Component values may decrease by more than 50 times when the source thickness increases. Impacts are chemical specific, with minimal further impacts for most chemicals once the source thickness reaches approximately 10 m to 30 m.
S-GW3	Aquifer Mixing	Component values may decrease by less than 2 times when the source length increases.
	Lateral Mixing	Component values may decrease by less than 2 times when the source length increases.
	Surface Water Mixing	Component values may decrease by approximately 5 times when the source width increases. No further impacts occur once the source width reaches 65 m.
S-IA	Source Depletion	Component values may decrease by more than 50 times when the volumetric extent of the source increases. Impacts are chemical specific, with minimal further impacts to most substances once the source volume reaches approximately 5,000 m^3 to 20,000 m^3.
S-Odour	Source Depletion	Component values may decrease by 10 to 50 times when the source thickness increases. Impacts are chemical specific, with minimal further impacts for most chemicals once the source thickness reaches 10 m to 30 m.
S-OA	Atmospheric Mixing	Component values may decrease by more than 50 times when the source length increases. Impacts are chemical specific.
	Source Depletion (Vapour)	Component values may decrease by 10 to 50 times when the source thickness increases. Impacts are chemical specific, with minimal further impacts for most chemical once the source thickness reaches 10 m to 30 m.

3.2 Soil to Groundwater to Indoor Air Pathways (S-GW2 and S-GW2 Odour)

Volatile chemicals from impacted soil can leach to underlying groundwater, move with groundwater, and then migrate as vapours from groundwater to overlying buildings. This exposure pathway, referred to as “S-GW2”, may pose some adverse effects to building occupants as a result of vapour inhalation.

The S-GW2 component value is not included in the development of the brownfield soil standards. This is because the S-IA component value is generally lower than the S-GW2 component value, and therefore protective of both pathways. In addition, the S-GW2 pathway may be evaluated more directly via groundwater sampling as part of the brownfield site assessment.

In an excess soil reuse scenario, the S-IA component value may no longer be protective of the S-GW2 component value. For situations where the impacted soil volume is much larger than the volume assumed in a brownfield scenario, the S-GW2 component value may be numerically lower than the S-IA component value. Also, groundwater sampling may not be required at the reuse site, which removes an additional line of evidence to evaluate the GW2 pathway. It should be noted that the GW2 pathways is similar to the S-GW2 pathway, but it is based on vapour migration from groundwater to indoor air. The S-GW2 pathway is based on predicting chemical leaching from soil to ground water and then vapour migration from ground water to indoor air. As such, the S-GW2 component value is derived as part of the development of excess soil quality standards.

The S-GW2 component values for Industrial/Commercial/Community (I/C/C) land uses default to the Residential/Parkland/Institutional (R/P/I) component values. This is done to prevent situations where groundwater from an I/C/C site that meets the I/C/C standard flows onto an adjacent R/P/I property and fails to meet the R/P/I standard. This assumption is similar to one used for the GW2 component value in the derivation of the brownfield groundwater standards.

The S-GW2 component value is derived using a partitioning model and vertical migration model coupled with GW2 values to produce soil values that are protective of human health of indoor receptors. Source depletion is also considered in the derivation of this component value. Further details on the derivation process are presented in Appendix I.

3.3 Soil Texture

The generic brownfield soil standards are derived for two (2) soil texture categories, (1) coarse and (2) medium/fine. While some human health component values for direct soil contact (S1, S2, S3) and ecological component values are generally independent of soil texture, the remaining component values are sensitive to the soil texture in both the vadose zone and saturated zone.

Generally, coarse textured soil results in higher vapour transport and partitioning/ leaching rates, resulting in more stringent component values. However, component values for which source depletion is considered may have numerically higher component values for coarse textured soil due to the faster degradation rate for coarse textured soils. Sensitivity analyses indicate that soil standards driven by vapour transport component values (e.g., S-IA, S-OA) are the most sensitive to soil texture. Table 3.2 presents the effect of soil texture (i.e., coarse versus medium/fine) on each component value as a function of the inputs for the vadose zone and capillary fringe.

Table 3.2. Effect of Soil Textures on Component Values

Pathway	Vadose Zone	Capillary Fringe
S-GW1	Minimal Effect	-
S-GW2	Significant Effect	Significant Effect
S-GW3	Minimal Effect	-
S-IA	Significant Effect	-
S-Nose	Significant Effect	-
S-OA	Significant Effect	-
S-Odour	Significant Effect	-
S1, S2, S3	-	-
Plants and Organisms	Minimal Effect	-
Mammals and Birds	-	-

Note that in Table 3.2, significant effects are defined as component values that are reduced by more than 50% for coarse textured soil as compared to medium and fine textured soils, whereas minimal effects are defined as component values reduced by 20 to 50% for coarse textured soil as compared to medium and fine textured soils. "-" denotes "no effect".

In an excess soil reuse scenario, soil disturbance during excavation, transport and deposition may change soil structures, including porosity and vapour permeability. Medium/fine textured soil moved to a reuse site may potentially allow increased vapour transport into overlying buildings and/or leaching into groundwater as a result of these disturbances. As such, the generic excess soil quality standards are developed using coarse textured soil inputs, regardless of whether the excess soil originally met the medium/fine textured soil definition set in O. Reg. 153/04.

Tables of generic excess soil quality standards are considered soil texture independent and may be applied at a reuse site with either coarse textured or medium/fine textured soils. However, a grain size analysis can be undertaken to determine the particle size fractions and to allow for developing site specific excess soil quality standards based on site specific soil texture. Further details pertaining to determination of site specific soil textures are presented in the MECP (2020) user guide document, entitled “*A Guide for Developing Site Specific Excess Soil Quality Standards Using the Beneficial Reuse Assessment Tool (BRAT)*” (the “MECP (2020) BRAT User Guide”).

3.4 Changes to Component Value Derivation Methods and Selection of Final Standards

A review of the brownfield soil standard development approach identified a few simplified processes and assumptions that may not be applicable in an excess soil reuse context. As such, a few adjustments were made to methodologies used in the derivation of the component values and in the selection of final excess soil quality standard. These adjustments are discussed below.

3.4.1 Odour Based Component Values

All odour based component values, including S-IA Odour for sub-surface soil, S-GW1 Odour, and S-GW2 Odour, were derived for excess soil. Derivation approaches for these component values were the same as those used to derive human health components values (S-IA, S-GW1, and S-GW2) and are provided in the MOE (2011) rationale document.

3.4.2 S-GW3 Shallow Soil Component Value

For development of the brownfield soil standards, the S-GW3 component value for the shallow soil scenario was set at that derived for the non-shallow soil scenario, as the anticipated difference between the component value for the non-shallow and shallow soil scenarios was considered to be within the anticipated range of sampling error and partitioning uncertainties. In addition, the S-GW3 pathway could be evaluated more directly via groundwater sampling as part of the brownfield site assessment.

Since groundwater sampling may not be a part of the evaluation of excess soils that will be placed at a reuse site, the S-GW3 component value for the shallow soil scenario was re-calculated as part of developing the excess soil quality standards. This was done to better reflect the differences between the shallow soil scenario and the non-shallow soil scenario for this pathway. The S-GW3 component values for sites with a shallow soil condition (Tables 6.1 and 7.1) are the same as those for site within 30 m of a water body (Table 8.1 and 9.1), as the scenarios corresponding to these tables assume no dilution in the aquifer. The same assumption is made for the GW3 component value used in developing brownfield groundwater standards.

3.4.3 Final Standards within 30 m of a Water Body

Table 8 and 9 generic brownfield soil standards are derived for one soil texture (coarse) and two land use categories, specifically (1) agriculture and other; and (2) all other property types. For the excess soil quality standards, these tables are derived for one soil texture (coarse) and three land use categories (agriculture and other, R/P/I and I/C/C). As noted in the previous section, the S-GW3 shallow soil component value was also re-calculated and incorporated into these standards, where appropriate.

3.4.4 Standards for Electrical Conductivity and Sodium Adsorption Ratio

The component values for electrical conductivity (EC) and sodium adsorption ratio (SAR) are derived primarily for the protection of plants and soil organisms. As such, in the brownfield scenarios, they are removed from the soil standards for sub-surface soil (below 1.5 m depth).

In an excess soil scenario, there may be concerns regarding the potential migration of sodium and chloride from soil to groundwater. Such concerns would generally be related to the S-GW1 and S-GW3 pathways. As (1) groundwater sampling may not be required at a reuse site; and (2) sodium and chloride are not typically measured for soil, EC and SAR are used as “surrogates” for these parameters in soil (e.g., used to evaluate the S-GW1 and S-GW3 pathways for sodium and chloride related concerns). As such, EC and SAR are retained when developing soil standards for sub-surface soil to maintain protection of the S-GW pathways for sodium and chloride.

3.5 Leachate Analysis

In some situations, leachate analysis has been incorporated into the excess soil quality standards as a mandatory component. This was done to provide a more direct line of evidence to assess whether excess soil placed at a reuse site could result in unacceptable impacts to groundwater, which may then migrate to drinking water wells, under buildings or to surface water bodies.

Within the brownfield redevelopment scenarios, groundwater sampling results may be used as an additional line of evidence to confirm, or rule out, the presence of adverse impacts to groundwater. As groundwater sampling may not be required as part of an excess soil reuse project, this option may not be available to evaluate potential impacts associated with excess soil reuse.

Generally, leachate analysis is required if a chemical identified as a chemical of potential concern (COPC) meets both of the following conditions:

1. The chemical has a superscript “a” following the excess soil quality standard. Further discussions with respect to leachate analysis are provided in Appendix II; and,
2. The analysis of the chemical is not being conducted solely for the reason that it is being required by the mandatory sampling and analysis requirements set out in paragraph 14 of subsection 2 (3) of section B of Part I of the MECP (2020) Soil Rules and Excess Soil Standards.

Despite the conditions above, leachate analysis is not required if the soil analysis result is less than Table 1 standard that is based on background soil concentration and not based on the RL. Leachate analysis is also required for metals and hydride-forming metals (referred to herein as “metals”) for soil samples collected from stormwater management ponds, regardless of whether metals are considered a COPC or not. Otherwise, if excess soil does not originate from an APEC, then leachate analysis is not a required element of meeting the excess soil quality standards (i.e., leachate analysis is not required as part of the minimum sampling of soil described items i, ii and iii of paragraph 14 of subsection 2 (3) of section B of Part I of the MECP (2020) Soil Rules and Excess Soil Standards). Leachate analysis is also not required if the small volume standards (Table 1 or Tables 2 to 9 brownfield soil standards) are applied to an excess soil volume of less than or equal to 350 m^3. However, leachate analysis is required for some COPC in soil when using the volume independent standards (Table 1 or Tables 2.1 to 9.1). It is noted that the small volume standards can be applied to an excess soil volume of greater than 350 m^3, if site specific standards have been developed using the BRAT to justify this approach. If the site specific standard generated in the BRAT includes a leachate screening level (LSL), then leachate analysis should be completed.

Chemicals which require leachate analysis are denoted with an “^{a}” on the tables of generic excess soil quality standards and a LSL is provided on the corresponding LSL table. The derivation of LSLs is described in Appendix II.

The additional line of evidence provided by leachate analysis will help address potential risks to groundwater and to ensure the protection of human health and the environment. Should leachate analysis results meet the relevant LSLs, a 1000 times multiplier may be applied to the soil to groundwater component values (e.g., S-GW1, S-GW2, SGW3) under some circumstances, potentially resulting in a numerically higher soil standard. Conditions for applying the multiplier to the soil to groundwater component values are detailed in Appendix II.

3.6 Attainment of Standards

Traditionally, the attainment of environmental standards has been based on single point compliance, whereby a standard is deemed to be met if, and only if, it is met at each relevant sampling point. This approach is currently required under the brownfield soil standards.

More recently, some jurisdictions have developed approaches that attempt to address variability in soil sampling results through statistical analyses of larger datasets (e.g., all results for a particular parameter in a comparable setting). Under such approaches, a standard may be deemed to be met even when some samples do not meet the applicable single-point compliance standard, providing certain other criteria are met. These approaches are often referred to as ‘statistical compliance’ methods.

The excess soil quality standards incorporate both a single point compliance approach and a statistical compliance approach. The statistical approach is developed to increase soil reuse flexibility when there is a sufficient soil data set to allow for a statistical assessment of the soil quality.

3.6.1 Statistical Compliance Approach

Under the statistical approach, excess soil is deemed to meet applicable standards if all following requirements are met:

1. The 90th percentile of the data set (90% of the samples) is less than the applicable excess soil quality standard.
2. No single sample within the data set exceeds the applicable ceiling value (discussed in Appendix III).
3. The 95% upper confidence limit of the mean (95% UCLM) concentration of the samples must be less than the applicable excess soil quality standard.

These requirements may allow for some exceedances of the applicable excess soil quality standard but only if the frequency of these exceedances is small and the magnitude of these exceedances are limited. Requirement 1 is intended to account for the potential variability in soil sampling and analysis through the use of a statistical approach yet ensure that the overall soil quality meets the applicable excess soil quality standard. It permits some soil (up to 10% of the samples) to be higher than the standard. Requirement 2 is intended to both help identify unique populations of soil quality within the overall data set (which may indicate areas of impact), and to ensure that even small volumes of soil do not pose unacceptable risks to human health and the environment (as discussed in Appendix III). Requirement 3 is intended to provide some certainties that the overall soil quality is meeting the standard, and that the statistics used to demonstrate this is supported with a comparable data set (i.e., the results do not indicate a large variance in the data, indicating the possibility of poor representation of true soil quality and/or unique populations of soil quality within the overall data set).

The use of this attainment approach requires that all mandatory leachate analysis results must be lower than or equal to the applicable LSLs. The attainment approach also requires at least 20 discrete soil samples. This requirement is independent of the number of soil samples required by sampling frequencies detailed in Section B of Part I of the MECP (2020) Soil Rules and Excess Soil Standards, which may require more than 20 soil samples for characterization of larger soil volumes (or fewer soil samples for smaller volumes). If the sample set contains less than 20 samples, single point compliance must be used for each sample.

Meeting these requirements should ensure that high concentrations of COPC in small volumes of soil (i.e., “hot spots”) are not being diluted out by mixing with cleaner soils. As an additional check, the qualified person must ensure that all samples used in the statistical approach come from a dataset that represents a single statistical population. The following should be considered, at a minimum, to determine if the dataset represents a single population:

- Whether excess soil has similar characteristics and is interpreted to be impacted by a similar process.
- Whether there is any potential for distinct statistical populations (e.g., mixed background and contaminated soil data).

Other key considerations when using the statistical approach are provided in Sections 3.6.2.

3.6.2 Other Considerations for Using the Statistical Compliance Approach

The individual evaluating excess soil results utilizing the statistical compliance approach should be familiar with statistical methods and/or consult with someone having this expertise. The individual undertaking the assessment may wish to utilize a statistical software package such as ProUCL (free software available from US EPA: https://www.epa.gov/land-research/proucl-software) or equivalent to generate statistical results. For example, there are several methods available for calculating the 95% UCLM for different population distributions and the resulting values could be significantly different. Therefore, it is very important to select the most appropriate method that reflects the appropriate distribution of the underlying data. For example, ProUCL takes into consideration the data distribution, sample size, skewness and percentage of non-detect values in the data set.

When presented with soil sample data, it is important to first consider the distribution of the data set, as the nature of the distribution can provide valuable information in terms of soil quality characteristics, as well as informing the best approach for calculating the statistics used to evaluate whether the standard attainment requirements have been met. For example, an examination of the data set may indicate that it is either normally distributed or non-normally distributed; proper assessment of these different types of data distributions relies on different statistical calculations.

The calculated statistical metrics (e.g., the 90th percentile and the 95% UCLM) can vary if there is some volume of excess soil (e.g., from a specific area of the source property containing impacted soil) that has a significantly different concentration than the rest of the property. Similar variability may occur in these statistical metrics when sampling at different soil depths or in different soil types. Where these situations occur, distinct statistical populations may be present in the dataset (e.g., mixed background and hot spot data) and an evaluation of the dataset by someone with the necessary statistical expertise, using appropriate statistical software (such as ProUCL), will lead to more defensible conclusions and support appropriate reuse of the excess soil. As an example, the segregation and removal/disposal of a particular volume of soil that may be impacted by COPCs, as represented by a few data points (e.g., an area or "hot spot" on the site where a spill occurred), may permit the remaining volume of soil to meet the attainment requirements (e.g., less variability in the calculated 95% UCLM and elimination of soil with concentrations above the applicable ceiling value). Alternatively, the data may be separated into two distinct populations and managed differently (e.g., some of the soil is deemed to meet one standard while the remaining soil meets another).

4. UPDATES TO KEY INPUTS

As part of the process for developing these excess soil quality standards, the Ministry reviewed available science on key input parameters to ensure that the standards are scientifically defensible and reflect the most current science. With respect to the derivation of the brownfield soil standards, several updates were identified for key input parameters and used in the derivation of the generic excess soil quality standards. These are described in greater detail below.

4.1 Toxicity Reference Values

The majority of the toxicity reference values (TRVs) used in the development of the generic excess soil quality standards are the same as those used to develop the brownfield soil standards in 2011; however, a number of TRVs have been updated since 2011. A brief description of the TRV update process and new TRV values used in the development of the generic excess soil quality standards are outlined in Appendix IV.

4.2 Ecotoxicity Values

The Canadian Council of Ministers of the Environment (CCME) Soil Quality Guidelines include an environmental health guideline for soil contact that was used in the derivation of the plants and soil organism's component values for the generic brownfield soil standards (CCME, 1999 and as updated). The same component value derivation method was used for developing the excess soil quality standards. Since the development of the most recent generic brownfield soil standards in 2011, some of the environmental health guidelines for soil contact values have been updated by CCME. These values are listed in Table 4.1 below.

Table 4.1. Updated CCME (1999) Soil Quality Guidelines for Soil Invertebrates and Plants

Chemical	Agricultural		R/P/I		I/C/C	
	Coarse	Medium/ Fine	Coarse	Medium/ Fine	Coarse	Medium/ Fine
Nickel	45	-	45	-	89	-
Selenium	1	-	1	-	2.9	-
Toluene	75	110	75	110	250	330
Trichloroethylene	3	-	3	-	50	-
Uranium	500	-	500	-	2000	-
Xylene Mixture	95	65	95	65	350	230
Zinc	250	-	250	-	450	-

Note: “-” values for medium/fine soil type are same as those for coarse. Values in mg/kg.

4.3 Source Allocation Factors for Inhalation Exposure Pathways

As part of the derivation of excess soil quality standards, the use of a default source allocation factor (SAF) of 20% (or 0.2) for the inhalation pathway was reviewed. This work was conducted to better understand and quantify risks for some chemicals for which vapour intrusion component values (i.e. S-IA, S-GW2) are often well below corresponding laboratory reporting limits. An updated approach for developing a SAF for these chemicals was also developed and outlined in Appendix V. Updates to SAFs were used in developing the excess soil quality standards for the following chemicals:

- A revised SAF of 0.5 for the inhalation pathways (i.e., S-IA and S-GW2) was identified for bromomethane, chloroform, tetrachloroethylene and trichloroethylene.
- A revised SAF of 0.8 for the inhalation pathways (i.e., S-IA and S-GW2) was identified for 1,1-dichloroethane, 1,2-dichloroethane, 1,1-dichloroethene), trans-1,2-dichloroethene, 1,2-dichloropropane, 1,3-dichloropropene, ethylene dibromide, hexane and vinyl chloride.

4.4 Updates to the GW1 Component Values

The derivation process of the GW1 component values is similar to that used in the brownfield program (refer to Section 2.7.5 of the MOE (2011) rationale document for further details). As part of developing the excess soil quality standards, the Ministry reviewed drinking water standards or guidelines established by selected jurisdictions and several updates were identified, as follows.

New and revised Ontario Drinking Water Quality Standards (ODWQS) and aesthetic objectives (AO) for various chemicals came into effect in 2017 and 2018. This included updated ODWQS for a number of chemicals for which excess soil quality standards have been developed, as shown in Table 4.2.

Table 4.2. Updated Ontario Drinking Water Quality Standards

Chemical	Category	Updated Standard (mg/L)
Arsenic	ODWQS	0.01
Benzene	ODWQS	0.001
Carbon Tetrachloride	ODWQS	0.002
Ethylbenzene	ODWQS	0.14
Ethylbenzene	AO	0.0016
Selenium	ODWQS	0.05
Tetrachloroethylene	ODWQS	0.01
Xylenes	ODWQS	0.09
Xylenes	AO	0.02
Vinyl Chloride	ODWQS	0.001

A review of selected jurisdictions was also completed, using a specific order of preference to determine if a drinking water quality guideline is available or was updated for a given chemical. Several updates were identified from Health Canada (Table 4.3). In addition, the World Health Organization chose not to set a drinking water guideline for molybdenum (WHO, 2011) and therefore the value previously used for derivation of the brownfield standards was removed as a GW1 value input.

Table 4.3. Updated Drinking Water Quality Guidelines

Chemical	Updated Guidelines (mg/L)	Reference
Acenaphthene	0.04	Kalberlah et al. 1995 (TEF=0.001) & Health Canada 2016
Acenaphthylene	0.004	Kalberlah et al. 1995 (TEF=0.01) & Health Canada 2016
Anthracene	0.004	Kalberlah et al. 1995 (TEF=0.01) & Health Canada 2016
Benz[a]anthracene	0.0004	Kalberlah et al. 1995 (TEF=0.1) & Health Canada 2016
Benzo[a]pyrene	0.00004	Health Canada 2016

Chemical	Updated Guidelines (mg/L)	Reference
Benzo[b]fluoranthene	0.0004	Kalberlah et al. 1995 (TEF=0.1) & Health Canada 2016
Benzo[g,h,i]perylene	0.004	Kalberlah et al. 1995 (TEF=0.01) & Health Canada 2016
Benzo[k]fluoranthene	0.0004	Kalberlah et al. 1995 (TEF=0.1) & Health Canada 2016
Chrysene	0.004	Kalberlah et al. 1995 (TEF=0.01) & Health Canada 2016
Dibenz[a,h]anthracene	0.00004	Kalberlah et al. 1995 (TEF=1) & Health Canada 2016
Fluoranthene	0.004	Kalberlah et al. 1995 (TEF=0.01) & Health Canada 2016
Indeno[1,2,3-cd]pyrene	0.0004	Kalberlah et al. 1995 (TEF=0.1) & Health Canada 2016
Pyrene	0.04	Kalberlah et al. 1995 (TEF=0.001) & Health Canada 2016
Bromodichloromethane	0.025	Health Canada 2006
Molybdenum	-	Standard removed

5. APPLICATION OF GENERIC EXCESS SOIL QUALITY STANDARDS

A key objective of the proposed *On-Site and Excess Soil Management Regulation* is to ensure that excess soil quality is properly characterized and only deposited at reuse sites that are appropriate for the soil quality. To achieve this, specific rules for using the excess soil quality standards are provided in the MECP (2020) Soil Rules and Excess Soil Standards. Selection of the appropriate table of excess soil quality standards should be made by a qualified person based on these rules, with appropriate consideration for how the excess soil quality standards were derived. For example, if an important assumption in the standard development process is violated for a particular site, the qualified person should evaluate whether the standards are still appropriate for that site. The qualified person should take particular care when determining the standards at reuse sites in environmentally sensitive areas and on agricultural land, as outlined in Section 7.

The following sections detail some of the key factors that should be considered when determining the appropriate table of generic excess soil quality standards for a reuse site. The following sections also provide key site conditions that should be evaluated when selecting the most appropriate table of excess soil quality standards for a particular reuse site.

5.1 Limitations of Generic Excess Soil Quality Standards

Conditions can exist at a site which are not consistent with the assumptions used to develop the generic excess soil quality standards and which may result in the standards being inappropriate for use in determining excess soil reuse options. The opposite may be also true in that site specific conditions may offer greater protection due to a particular combination of site characteristics. In addition, should the site undergo changes (e.g., change in property use and/or new construction) that may alter some key assumptions, the use of selected excess soil quality standards may no longer be appropriate and protective.

Important factors that should be considered when determining the appropriate excess soil quality standards are listed below.

1. **Impacted Soil Volume and Dimension:** The development of volume specific standards relies on assumptions of a finite volume of impacted soil with specific dimensions (e.g., 13 m by 13 m by 2 m or approximately 350 m^3). As such, if the total impacted zone (once excess soil is placed at the reuse site) has a volume or dimensions that are greater than what are assumed, the exposure pathways that employ source depletion or groundwater transport (e.g., S-IA, S-GW1, S-GW2, S-GW3, and S-Odour) may not be appropriately protected.

2. **Presence of Exposure Pathway Not Considered for the Development of Excess Soil Quality Standard:** If any of the exposure pathways listed in Section 2.2 is applicable for a given site, or if other exposure pathways not considered in the development of the standards are present at the reuse site, then the use of the generic excess soil quality standards may not be protective of those exposure pathways.

3. **Soil with High Permeability:** Excess soil or soil at the reuse site, if highly permeable, can potentially provide a direct preferential pathway for vapours to migrate quickly to a building. Under such circumstances, the soil properties used in determining some generic component values (e.g., S-IA and S-GW2) may be non-conservative.

4. **Buildings with High Susceptibility to Soil Vapour Entry:** If buildings at the reuse site have characteristics that vary significantly from the generic assumptions (e.g., earthen floors, deteriorating basements, crawlspaces, etc.), this could result in a reduction in vapour attenuation between the subsurface and the building. Under such circumstances, the S-IA and S-GW2 component values may be non-conservative and inappropriate for use at a reuse site.

5. **Significant Preferential Pathways:** The development of generic excess soil quality standards assumes that preferential pathways for vapour migration are not present. Preferential pathways may be caused by shallow fractured bedrock, gas under pressure/landfill gas, and/or utility conduits that provide a direct connection to the enclosed space of the building. If preferential pathways are present at the reuse site, the S-IA and S-GW2 component values may not be protective.

6. **Organic Carbon Content:** If the average fraction of organic carbon (foc) of soil above the water table is less than 0.002 g/g, a greater fraction of a chemical may be in the water and gas phases than assumed in the development of generic excess soil quality standards. This may lead to increased chemical mobility.

7. **Continuous Source:** If there is a continuous source of contamination, the component values which assume a depleting source (i.e., S-IA, S-GW1, S-GW2, and S-Odour) may be underestimated in the development of volume specific standards (e.g., small volume), which may be non-conservative.

8. **Acceptable pH Range (from 5.0 and 9.0 for surface soil and from 5.0 to 11.0 for subsurface soil):** Highly acidic or alkaline soil can cause chemicals to behave differently from the manner assumed in the generic model. This could result in generic excess soil quality standards being inappropriate for use when pH levels of excess soil or soil at the reuse site are outside the acceptable pH range. Section D.1 of Part I of the MECP (2020) Soil Rules and Excess Soil Standards outlines specific rules that apply to excess soil and soil at the reuse site that has pH levels outside the acceptable range.

9. **Surface Water Condition:** If there is a surface water body that could be affected as a result of chemical migration via groundwater discharging to surface water, and the surface water has a total hardness level of less than 70 mg/L (as $CaCO_3$) and/or has pH less than 6.7, the aquatic protection values for some metals and pentachlorophenol may be non-conservative. In such cases, a site specific estimate of hardness and pH resulting from mixing of groundwater and surface water is may be needed to estimate an appropriate aquatic protection value for this site.

The presence of any of the conditions listed above does not necessarily indicate that the use of generic excess soil quality standards is not valid for a given reuse site. This is also true for the brownfield soil standards. The MOE (2011) rationale document discusses the conditions which, if present at an individual site, may warrant the need for additional consideration before applying generic standards. The following excerpt is taken from the MOE (2011) rationale document and summarizes the issue.

> *“There are many interrelated parameters and factors that were used in the development of the Generic Site Condition Standards, and in many cases one factor, such as any of those above, can be outweighed by differences in other factors in a manner that, overall, there is sufficient natural protection provided by the site. In addition, it must also be considered that the component that drives the standard may not be affected by the particular limiting condition described above (e.g., a terrestrial ecological driver, but there are high permeable zones in the vadose zone). The qualified person should consider these types of factors in assessing appropriateness of the use of the Generic Site Condition Standards.”*

For chemicals for which generic excess soil quality standards are not derived, if they are present in excess soil and known to have the potential to adversely impact human health or the environment, the qualified person must develop site specific standards for those chemicals by conducting a separate risk assessment, as outlined in Section D.4 of Part I of the MECP (2020) Soil Rules and Excess Soil Standards.

5.2 Selection of Appropriate Table of Generic Excess Soil Quality Standards

Once it is established that use of the generic tables of excess soil quality standards is appropriate, it is important that the correct table be selected based on the volume of excess soil and some key conditions of the reuse site. Such site conditions include property use, groundwater potability, identification of whether standards are for the full depth or stratified, overburden thickness, the distance between groundwater and any existing/future building foundation and proximity to a water body.

As presented in Section 3.1, generic excess soil quality standards are available for two (2) different sets of excess soil being brought to a reuse site based on volume. This is done to allow for greater flexibility in soil reuse options:

1. Small volume standards may be used for excess soil volumes up to 350 m^3, or larger if site specific standards developed using BRAT justify this approach; and,

2. Volume independent standards may be used for any volume of excess soil.

When selecting small volume standards, consideration should be given to existing reuse site conditions, including whether existing soil at the reuse site has, or is suspected of being impacted by past and/or current activities (e.g., excess soil previously placed at the reuse site). If warranted, the volume independent excess soil quality standards should be used to reflect the potential cumulative impact of a chemical which is associated with both excess soils being placed at the reuse site and any existing soils that are previously impacted by the same chemical at the reuse site. As such, for situations where the sum of the volume of the excess soil being brought (and already brought) to the reuse site and the volume of known or potentially impacted soil currently at the reuse site is greater than 350 m^3, the use of small volume excess soil quality standards may be inappropriate and non-conservative.

For ease of reference, the tables of generic excess soil quality standards have been labeled in the same order as the tables of brownfield soil standards: Tables 2 through 9 for small volume standards and Tables 2.1 through 9.1 for the volume independent standards (as summarized in Table 5.1). Each table of volume independent standards and Table 1 have two (2) corresponding tables, one containing LSLs and the other ceiling values. All tables of generic excess soil quality standards and corresponding tables of LSLs and ceiling values are found in Appendices 1 to 3 of Part II of the MECP (2020) Soil Rules and Excess Soil Standards.

It should be noted that chemicals marked with a superscript “a” in the table of generic excess soil quality standards must also meet the LSLs provided in the corresponding LSL tables, assuming such chemicals are COPC at the site. In addition, the ceiling values are only used if the statistical compliance approach is incorporated into the assessment of excess soil quality.

Table 5.1. Tables of Generic Excess Soil Quality Standards

Table Description	Small Volume (up to 350 m^3)	Volume Independent
Full Depth, Background	Table 1	Table 1
Full Depth, Potable	Table 2	Table 2.1
Full Depth, Non-Potable	Table 3	Table 3.1
Stratified, Potable	Table 4	Table 4.1
Stratified, Non-Potable	Table 5	Table 5.1
Full Depth, Shallow Soil, Potable	Table 6	Table 6.1
Full Depth, Shallow Soil, Non-Potable	Table 7	Table 7.1
Full Depth, Within 30 m of a Water Body, Potable	Table 8	Table 8.1
Full Depth, Within 30 m of a Water body, Non-Potable	Table 9	Table 9.1

Specific rules and recommendations in support of the selection of an appropriate table of generic excess soil quality standards for a particular reuse site are outlined in Section A of Part II of the MECP (2020) Soil Rules and Excess Soil Standards. Table 5.2 presents key site conditions and how they impact table selection.

Table 5.2. Screening Matrix of Key Site Conditions for Selecting Appropriate Table of Generic Excess Soil Quality Standards

Site Condition	Table								
	Table 1	**Table 2/2.1**	**Table 3/3.1**	**Table 4/4.1**	**Table 5/5.1**	**Table 6/6.1**	**Table 7/7.1**	**Table 8/8.1**	**Table 9/9.1**
Property is an Environmentally Sensitive Area.	✓	x	x	x	x	x	x	x	x
Groundwater use condition is potable.	✓	✓	x	✓	x	✓	x	✓	x
Land Use is Agricultural or Other.	✓	✓	x	x	x	✓	x	✓	x
Overburden thickness is unknown or is less than 2 m.	✓	x	x	x	x	✓	✓	x	x
Depth to groundwater is unknown, is less than 3 m below ground surface or the capillary fringe is <0.8 m from the base of the gravel crush of any existing/future building foundation*.	✓	x	x	x	x	✓	✓	x	x
Nearest water body is unknown or less than 30 m from the property.	✓	x	x	x	x	x	x	✓	✓
Excess soil may be placed at any depth.	✓	✓	✓	x**	x**	✓	✓	✓	✓
Stratified site conditions must be maintained to ensure that surface soil and subsurface soil meets the applicable stratified condition standards.	✓	x	x	✓	✓	x	x	x	x

Note: x This table may not be appropriate.
✓ This table may be acceptable, see Section 5.1 for other considerations.
* This site condition is applied to volatile chemicals only.
** Standards for subsurface soil in Tables 4/4.1 & 5/5.1 must be applied only for soil placed at 1.5 m below ground surface or deeper.

6. SITE SPECIFIC EXCESS SOIL QUALITY STANDARDS DEVELOPMENT

Determining acceptable soil quality for reuse of excess soil at a given site may also be achieved through the development of site specific excess soil quality standards. In general, the generic excess soil quality standards are based on broadly conservative assumptions regarding site conditions. As such, the use of site specific information that better reflects the conditions of a particular reuse site may lead to more appropriate and numerically higher standards, which in turn allow for greater flexibility in soil reuse options.

The Ministry has developed the BRAT, a spreadsheet-based tool, to allow for the convenient development of site specific excess soil quality standards when certain conditions are met.

The BRAT allows for modification of the generic excess soil quality standards using site specific information. This approach relies on more detailed knowledge of the reuse site than is required when applying the generic standards. This approach can significantly change what is deemed to be acceptable soil quality. The BRAT also has the capacity to incorporate selected site use characteristics, such as no building development or a soil cap. The information required to support the modification of soil and site characteristics is similar to that required for the Modified Generic Risk Assessment (MGRA), as outlined in O. Reg. 153/04. Specific requirements and recommendations for the use of the BRAT to generate site specific standards are presented in Section D.3 of Part I of the MECP (2020) Soil Rules and Excess Soil Standards and the MECP (2020) BRAT User Guide.

Other site specific standard development options, which may rely in part on the BRAT, include risk assessments permitted through a site specific instrument. Further requirements for using risk assessments to derive site specific excess soil quality standards are outlined in Section D.4 of Part I of the MECP (2020) Soil Rules and Excess Soil Standards.

7. ADDITIONAL CONSIDERATIONS WHEN USING GENERIC EXCESS SOIL QUALITY STANDARDS

The following sections describe situations where limitations associated with specific excess soil quality standards (1) may warrant additional consideration and/or (2) may necessitate additional requirements to ensure that such standards are applied appropriately.

7.1 Special Rules When Applying Excess Soil Quality Standards

Section D.2 of Part I of the MECP (2020) Soil Rules and Excess Soil Standards outlines rules that apply to excess soil quality standards and the placement of excess soil at particular reuse sites, including agricultural land and environmentally sensitive areas. These types of properties may have unique conditions or exposure scenarios which are not accounted for in the derivation of the excess soil quality standards, and therefore special rules are warranted.

Some of the rules are also intended to account for anticipated challenges in meeting the standards for sodium and chloride as a result of road salting. Other rules are intended to account for pragmatic constraints such as (1) when naturally occurring local background conditions may be elevated relative to the excess soil quality standards and (2) when excess soils are blended with compost materials.

7.2 Application of Agricultural Standards

Excess soil quality standards derived for agricultural land use do not include consideration of plant uptake of chemicals and the subsequent ingestion by people or livestock. The information available at the time of developing the brownfield soil standards and excess soil quality standards was considered insufficient to develop adequate and defensible component values for these exposure scenarios.

Redeveloping brownfields to agricultural land use is not, nor is it expected to be, a common occurrence. As such, this limitation was not considered a significant concern at the time the brownfield soil standards were developed. The reuse of excess soils at agricultural properties is considered far more likely, so the absence of this exposure scenario becomes more relevant and important for excess soil quality standards. The Ministry will continue to review available science and assess whether development of component values to protect for this exposure scenario is feasible during future updates to the standards.

To account for this limitation, where excess soil is to be used as a growing medium for crops or for pasture for animals that will be consumed, the excess soil must meet Table 1 excess soil quality standards. Additionally, if the excess soil is derived from an APEC and there is a superscript “a” in the column adjacent to the soil standard for a COPC, then leachate analysis must be completed, and the results must meet the applicable LSLs. Further information is provided in Section A of Part II of the MECP (2020) Soil Rules and Excess Soil Standards.

Finally, excess soil quality standards derived for agricultural land uses do not include consideration of soil fertility. Soil fertility is considered part of farming best practices. While not considered in the derivation of the standards, information and guidance on the potential impacts of excess soil on soil fertility is available to farmers via a fact sheet prepared by the Ontario Ministry of Agriculture Food and Rural Affairs (OMAFRA) and available here: http://www.omafra.gov.on.ca/english/engineer/facts/16-055.htm.

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APPENDIX I: Consideration of Vapour Intrusion Component Values in Development of Excess Soil Quality Standards

Consideration of Vapour Intrusion Component Values in Development of Excess Soil Quality Standards

I.1. BACKGROUND

Vapours from volatile organic compound (VOC) impacted soil and groundwater can migrate into overlying buildings and may pose adverse effects to building occupants as a result of vapour inhalation. This VOC migration process is referred to as vapour intrusion and is considered in the development of brownfield site condition standards (the “brownfield soil standards”) for soil to indoor air (S-IA) and groundwater to indoor air (GW2) components.

The Ministry of the Environment, Conservation and Parks (the “Ministry”) reviewed key assumptions and modelling approaches used to develop the brownfield soil standards in conjunction with consultation with external stakeholders and jurisdictional review when developing the excess soil quality standards. This work identified two vapour intrusion component values, soil to indoor air (S-IA) and soil to groundwater to indoor air (S-GW2), to ensure that building occupants are protected when excess soils are being placed at a reuse site. Note that the S-GW2 pathway is not included in the development of the brownfield soil standards, as the S-GW2 component generally is higher than the S-IA value under the generic brownfield settings. However, such assumptions may not always be valid, especially for situations when the impacted soil volume is much larger than the volume assumed in a brownfield scenario. Also, groundwater sampling may not be required at the reuse site, which removes an additional line of evidence to evaluate of the GW2 pathway. As such, the S -GW2 component is included in the derivation of excess soil quality standards.

This appendix presents the derivation approaches to determine S-IA and S-GW2 component values along with some key assumptions and input parameters.

I.2. SOIL TO INDOOR AIR (S-IA) COMPONENT

The soil to indoor air (S-IA) component is defined as a soil concentration that is protective of exposure from a chemical in soil that has the potential to migrate through the vadose zone into overlying buildings. The derivation approach to determine S-IA component values is presented in Section 7.4 of the MOE (2011) rationale document, entitled “*Rationale for the Development of Soil and Groundwater Standards for Use at Contaminated Sites in Ontario”* with the following key modelling components:

- A partitioning model coupled with the Johnson-Ettinger model (1991) for vapour intrusion into buildings is used to back calculate a soil concentration that is protective of indoor air toxicity reference values (TRVs) and odour.

- Source depletion due to mass loss from volatilization into buildings is also considered to reflect the potential for reduction of soil contamination over time.

Generally, vapour concentrations decrease with increasing distance from a subsurface vapour source and eventually dissipate to non-detectable levels. The decrease in vapour concentrations is a function of contamination source size and geometry, soil properties, physical-chemical properties of the volatile chemical, and its possible biological or chemical transformations within the subsurface environment. In approximate terms, the vapour intrusion pathway has sufficient natural attenuation to be of negligible concern if the distance between the contamination and buildings of concern (herein referred to as "vapour intrusion inclusion distance") is greater than:

- 30 m for recalcitrant compounds; and,
- 10 m for compounds that readily biodegrade under aerobic conditions. e.g., petroleum hydrocarbons (PHCs).

The generic setting for the S-IA pathway assumes that building structures sit directly within the area where excess soils are deposited and that VOC impacted soil within the vapour intrusion inclusion distance from the building footprint may result in vapour intrusion concerns (referred to as zone of vapour intrusion influence). As such, the mass loss due to volatilization and transport of a volatile chemical into indoor air can be assumed to occur within this zone and is incorporated in the development of source depletion multipliers (SDMs). It should be noted that depending on the size and location of building structures, the zone of vapour intrusion influence may be the same or smaller than the source size. Figure I.1 presents two (2) examples of how to determine the extent of the zone of vapour intrusion influence used in the development of source deletion multiplier with the consideration of a residential scenario and a 50m x 50m x 2m volume of excess soil impacted with (1) recalcitrant compounds (non-PHC compounds) and (2) PHC compounds.

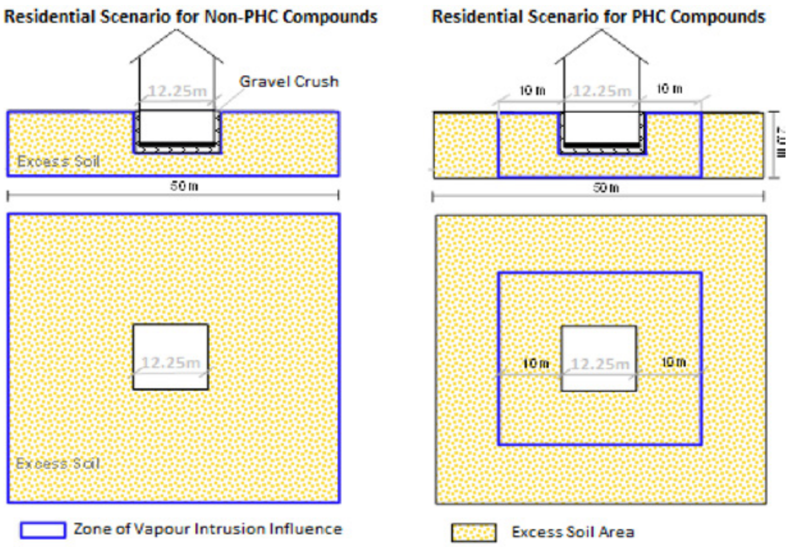

Figure I.1. Site Plan (Lower) and Cross Sectional (Upper) View of Excess Soil Area and Zone of Vapour Intrusion Influence

I.3. SOIL TO GROUNDWATER TO INDOOR AIR (S-GW2) COMPONENT

The soil to groundwater to indoor air (S-GW2) component is defined as a soil value, protective of exposure from a chemical that leaches from soil to groundwater, migrates down-gradient and potentially moves upward to overlying buildings. The conceptual model for the S-GW2 pathway is illustrated in Figure I.2.

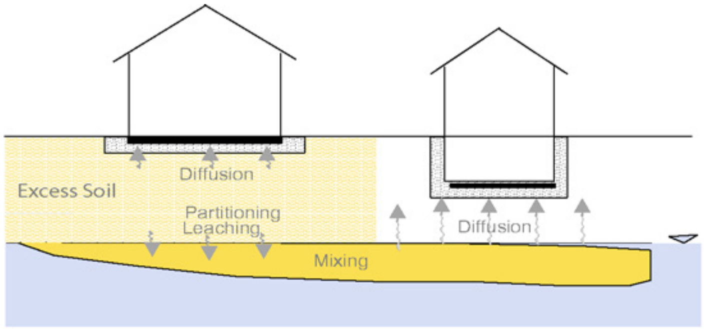

Figure I.2. Conceptual Model for the Soil to Groundwater to Indoor Air (S-GW2) pathway

The derivation approach to determine S-GW2 component values includes the following key modelling components:

- A groundwater to vapour partitioning component coupled with the Johnson & Ettinger (1991) model for vapour intrusion into buildings is used to back-calculate a groundwater value that is protective of indoor air quality (GW2). Details on the development of GW2 components are presented in Section 7.6 of the MOE (2011) rationale document.

- A soil to soil leachate partitioning component coupled with a vertical transport model of leachate to water table and mixing of leachate with groundwater to solve for soil values.
- Source depletion due to mass loss from leaching into groundwater and volatilization into atmosphere considered to reflect the potential depletion of soil contamination over time.

I.3.1 Development of Soil to Groundwater to Indoor Air (S-GW2) Component Value

Recharge through the contaminated soil area leaches dissolved chemicals to an underlying aquifer, where the recharge mixes with groundwater and chemicals are transported downgradient in groundwater. Volatile chemicals in the impacted groundwater may then migrate upward to overlying building structures. Calculation steps consider the following: (1) soil to soil leachate partitioning and vertical transport of leachate to the groundwater table and (2) mixing of leachate with groundwater.

I.3.1.1 Soil to Soil Leachate Partitioning

The soil to soil leachate partitioning includes three-phase partitioning between the substance sorbed to soil, dissolved in leachate and in soil vapour. It is noted that the generic setting (Figure I.1) assumes that the contaminated soil is located directly above the water table, thus the concentration of a substance in leachate is the same at the source and at the water table (therefore, no vertical transport is considered).

The soil concentration is in equilibrium with the soil leachate concentration, determined as below:

$$S - GW2 \ = \ C_{leachate} \cdot \left(K_{oc} \cdot f_{oc} + \frac{\eta_w + H' \cdot \eta_a}{\rho_b} \right) \qquad \text{(Equation I.1)}$$

Where:

S-GW2 = soil to groundwater to indoor air component (μg/g);

$C_{leachate}$ = allowable concentration in leachate at source (mg/L);

K_{oc} = organic carbon-water partition coefficient (cm^3/g);

f_{oc} = fraction organic carbon in soil (dimensionless);

η_w = water-filled porosity (dimensionless);

η_a = air-filled porosity (dimensionless);

H’ = Henry’s Law constant (dimensionless); and,

ρ_b = dry bulk density of the soil (g/cm^3).

I.3.1.2 Dilution Due to Aquifer Mixing Cell

The mixing of leachate with groundwater is based on groundwater velocity, infiltration rate, source length, and mixing zone thickness, as shown below. Please refer to Section 7.6 of the MOE (2011) rationale document for the derivation approach of GW2 component values.

$$C_{leachate} = GW2\left\{1 + \left(\frac{K_h \cdot C \cdot i_h \cdot B}{q_{surface} \cdot L}\right)\right\} \qquad \text{(Equation I.2)}$$

where:

$C_{leachate}$ = allowable concentration in leachate at source (µg/L);
GW2 = groundwater to indoor air component value (µg/L);
K_h = horizontal hydraulic conductivity of aquifer (m/s);
i_h = horizontal hydraulic gradient in aquifer (dimensionless);
B = thickness of mixing cell (m);
$q_{surface}$ = recharge rate through soil to water table (m/year);
L = length of source of contaminated soil in direction of groundwater flow 4(m); and,
C = unit conversion from meter per second (m/s) to meter per year (m/year).

I.3.1.3 Development of Groundwater to Indoor Air (GW2) Component Value

Under the generic setting, the GW2 component is derived with the consideration of two specific scenarios:

- The first scenario assumes that there is a sufficient soil layer present between groundwater and the building foundation for vapour attenuation and biodegradation to occur. In this scenario, the GW2 (and subsequently S-GW2) component values are derived using the Johnson & Ettinger (1991) model for vapour intrusion into buildings and a biodegradation factor of 10 (applied only for biodegradable chemicals). Key assumptions include (1) the water table is three metres below ground surface (bgs) and (2) two types of built form: an industrial/commercial/community (I/C/C) slab on grade building scenario and a residential/parkland/institutional (R/P/I) building scenario with a 1.58 m bgs basement. This results in a minimum separation distance of approximately 80 cm from the top of capillary fringe to the bottom of the gravel crush. This scenario is used to determine the GW2 (and subsequently S-GW2) component value of all tables of generic volume independent excess soil quality standards with the exception of Tables 6.1 and 7.1, where default attenuation factors are used (see below).

- The second scenario assumes that there is little or no soil present between the water table and the floor slab. This assumption is applied for sites with 2 meters (or less) of soil over bedrock (Tables 6.1 and 7.1) and also for sites for which groundwater is located in close proximity to the base of the building foundation. In this scenario, the GW2 (and subsequently S-GW2) component values are derived using a sub slab attenuation factor (0.02 for R/P/I property and 0.004 for I/C/C property).

I.3.2. Source Depletion

The development of S-GW2 component values using the approach presented in Section I.3.1 corresponds to an infinite source of contamination; and is therefore considered overly protective for scenarios where the source size of contaminated soil is well characterized and limited.

To account for source depletion, if there is no on-going release and a finite source (length x width x height), S-GW2 component values can be adjusted with the consideration of a source depletion multiplier (SDM). Source mass depletion is based on the assumption that the soil concentration of a chemical will deplete over time via mass loss from leaching into groundwater and volatilization to the atmosphere. Key components for determination of a source depletion multiplier are shown as below.

I.3.2.1. Determination of Initial Mass of a Chemical in Excess Soil

Initial mass of a chemical in excess soil is determined as below.

$$Mass\ 1 = S - GW2 \cdot \rho_b \cdot C \cdot V_s \qquad \text{(Equation I.3)}$$

where:

Mass 1 = initial mass of chemical in source zone (µg);

S-GW2 = soil to groundwater to indoor air component (µg/g);

ρ_b = dry bulk density of the soil (g/cm^3);

V_s = volume of source zone (m^3); and,

C = unit conversion (10^6) from cubic centimeter (cm^3) to cubic meter (m^3).

I.3.2.2. Determination of Mass Remaining after One Week of Volatilization to Atmosphere and Leaching to Water Table

As explained in the MOE (2011) rationale document, one week was arbitrarily chosen to be sufficiently short to be approximated by using a constant removal rate of the exposure concentration rather than one that declines with time. Mass of a chemical in soil theoretically remaining after one week of mass loss due to volatilization to atmosphere and leaching to water table at a constant rate is calculated as follows:

$$Mass\ 2 \ = \ Mass\ 1 - \left(\frac{C_{leachate} \cdot C_1 \cdot A_{s} \cdot q_{surface}}{52\left(\frac{week}{year}\right)} \right) - \left(J \cdot A_s \cdot C_2 \cdot \frac{365.25 - frozen\ days}{365.25} \right)$$

(Equation I.4)

where:

Mass 2 = chemical mass remaining after one week of mass loss due to volatilization to atmosphere and leaching to water table (µg);

$C_{leachate}$ = allowable concentration in leachate at source (µg/L);

$q_{surface}$ = recharge rate through soil to water table (m/year);

A_s = area of contaminated soil (m^2);

C_1 = unit conversion (1000) from litre (L) to cubic meter (m^3);

J = chemical flux at the ground surface ($g/cm^2/s$), determine using the Finite Source Jury model (refer to Section 7.3.6 of the MOE (2011) rationale document);

C_2 = unit conversion ($60 \cdot 60 \cdot 24 \cdot 7$) from second (s) to week (week); and,

Frozen day = number of “frost” days.

I.3.2.3. Determination of Half-life due to Mass Loss from Volatilization to Atmosphere and Leaching to Water Table

As discussed in the MOE (2011) rationale document, the initial mass (Mass 1) and the mass remaining after one week (Mass 2) are entered into the re-arranged decay equation to generate the effective half-life for this mode of source depletion for each chemical.

$$t_{1/2} \ = \ \frac{-\ln(2) \cdot 1 week}{ln\frac{Mass\ 2}{Mass\ 1} \cdot \frac{365.25}{7}}$$

(Equation I.5)

where:

$t_{1/2}$ = half-life for vapour intrusion into building (years).

I.3.2.4. Determination of Source Depletion Multipliers (SDM)

The SDM is determined as a function of the soil half-life as below:

$$SDM = \frac{1}{exp\left(\frac{-ln2 \cdot t}{t_{1/2}}\right)} \qquad \text{(Equation I.6)}$$

As with the development of the S-IA component value, the S-GW2 component value incorporates a time lag (t) between the start of substance depletion and the attainment of the health-based indoor air concentration (HBIAC). The S-GW2 component values are based on initial indoor air concentrations (IAC) that are up to 100-fold greater than the HBIAC. As discussed in MOE (2011) rationale document, a list of constraints on the potential initial IAC were used, including the following key considerations:

- An initial IAC is expected to continuously decrease to the HBIAC within the allotted 3 or 5 years, resulting in an SDM of up to 100-fold;
- Incremental lifetime cancer risk from S-IA exposure pathway does not exceed 1 x 10^{-6}; and,
- A further protection is built in such that the SDM doesn't result in an exceedance of short-term effects concentrations (e.g., sub-chronic, developmental), where available.

I.4. IDENTIFICATION OF CHEMICAL OF CONCERN FOR VAPOUR INTRUSION

Vapour intrusion component values (S-IA, S-GW2) are derived only for chemicals that are sufficiently volatile to cause vapour concentrations above HBIACs. The screening steps to identify these chemicals are provided below:

Step 1: A chemical is first evaluated with a comparison of Henry's Law constant or vapour pressure for assessing its volatility. A chemical is generally considered sufficiently volatile and screened in, to be further assessed as part of Step 2, if it has a:

- Henry's Law constant greater than $1x10^{-5}$ atm-m^3/mol; or,
- Vapour pressure greater than 1.0 millimeter of mercury (equivalent to 1.0 Torr).

Step 2: If the chemical is considered “volatile”, its theoretical predicted indoor air concentration based on conservative assumptions (C_{air}) is then compared to the HBIAC and odour thresholds (if available) to determine if the volatile chemical can reach indoor air concentrations of concern for vapour intrusion, as follows:

- If C_{air} > HBIAC (or odour thresholds), then the chemical is retained for the development of S-IA and S-GW2 component values; and,
- If C_{air} ≤ HBIAC (or odour thresholds), then the chemical is not retained for the development of S-IA and S-GW2 component values.

I.5 REFERENCES

Ministry of the Environment (MOE, currently known as Ministry of the Environment, Conservation and Parks). 2011. Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario. Available upon request at https://www.ontario.ca/page/brownfields-redevelopment.

APPENDIX II: Use of Leachate Analysis in Development of Excess Soil Quality Standards

Use of Leachate Analysis in Development of Excess Soil Quality Standards

II.1. INTRODUCTION

Groundwater sampling may not be completed at excess soil source or reuse sites and therefore may not be available as a potential line of evidence to assess whether the soil to groundwater pathways are protected. In addition, since soil to groundwater (S-GW) component values generally decrease with increasing source size and analytical reporting limits (RLs as set in O.Reg. 153/04) remain constant, the ability of bulk soil analysis to evaluate target risk levels (TRLs; as defined in Section II.2) decreases. To address these issues, leachate analysis is incorporated into the development of excess soil quality standards.

If a chemical is identified as a chemical of potential concern (COPC), there are two situations when leachate analysis is considered a required element of an excess soil quality standard and a leachate screening level (LSL) must be met, as follows:

1. **Situation 1 – Chemicals with Analytical limitations:** If the potential risk level associated with a soil standard is greater than the upper risk threshold (URT, as defined in Section II.2), due to the final soil standard being adjusted upwards to the analytical RL from a S-GW pathway component value (i.e., S-GW1, S-GW2, S-GW3) and leachate analysis can identify a lower level of potential risk; and,
2. **Situation 2 – metals and hydride-forming metals** (referred to herein as “metals”): If the COPC is a metal substance for which S-GW component values are not derived (i.e., all metals except mercury and methylmercury).

When leachate analysis is required and the LSL can achieve the TRL, a multiplier of 1000x is applied to the S-GW component values used in the development of the final excess soil quality standard. Leachate analysis in Situation 1 is mandatory even if no multiplier is provided, as long as the potential risk associated with the LSL is less than half that associated with the soil standard. Conversely, if leachate analysis cannot reduce the level of potential risk by at least half, then a LSL is not shown on the generic tables and leachate analysis is not required. Leachate analysis for the second situation is also mandatory, even though there are no S-GW component values on which to apply a multiplier, except if the soil standard is based on measured background concentrations or if the soil standard is low enough that it could not result in an exceedance of the LSL.

The decision sequences to identify and assess each of these situations are detailed below and the methods for determining LSLs follow in the final sections of this appendix.

Voluntary use of leachate analysis is also provided as a pathway modifier within the Beneficial Reuse Assessment Tool (BRAT) and can be used to generate site specific soil standards. Under this situation, the BRAT will provide a LSL only if conditions for applying the 1000x multiplier to the soil to groundwater component values are met (i.e. LSL is not provided if it will not result in any relief for the soil to groundwater pathways). In some situations, even if a 1000x multiplier is applied to the S-GW pathway component values, the final standard may not change.

II.2 CHEMICALS WITH ANALYTICAL LIMITATIONS

Excess soil quality standards were developed using the same models and assumptions used to develop the brownfield site condition standards, with some modifications (see Sections 2 and 3 of this rationale document). TRLs were kept similar to brownfields; an incremental cancer risk level (ICRL) of 1 in 1,000,000 for human health carcinogens, a hazard quotient (HQ) of between 0.2 and 0.8 for human health non-carcinogens, and an HQ of 1 for aesthetic objectives and ecological standards. However, as in brownfields, if a calculated risk-based component value is lower than either the background concentration or the RL of a chemical, the final standard for that chemical is adjusted upwards to the higher of background or the RL. This final adjustment results in a soil standard with a greater level of potential risk than the TRL. As described below, an URT is also calculated and a chemical with a standard (1) that is adjusted upwards to the RL and (2) that results in a potential risk exceeding the URT is considered a chemical with analytical limitations. Under this situation, leachate analysis may be required to better evaluate the overall potential risk level.

A review of the potential risk associated with excess soil quality standards that have been adjusted upwards to RLs was completed to assess the extent to which the proposed excess soil quality standards were meeting TRLs. As noted in Section 2.4.2 of the MOE (2011) rationale document, TRLs were not applied to established drinking water standards selected as human health GW1 component values. However, for the purposes of assessing whether leachate analysis is required, the potential risk level associated with these values was assessed using oral TRVs that were reviewed and selected for inclusion in the development of excess soil quality standards. The potential risk associated with standards that were adjusted up to background concentrations in soil were not evaluated, as these risks are naturally occurring and not considered contamination.

When evaluating the potential risk level associated with soil meeting a standard set at a RL, the actual concentration of a chemical in the soil volume was assumed to be 0.5x the RL. Prior to assessing the potential risk level, a biodegradation factor of 3x was applied to chemicals which are anticipated to undergo aerobic biodegradation during excess soil activities. The chemicals to which this factor is applied include: benzene, toluene, ethylbenzene and xylenes, petroleum hydrocarbon fractions (F1 and F2), naphthalene and hexane (the same chemicals to which a bioattenuation factor is applied in the soil/groundwater to indoor air pathways for derivation of the brownfield soil standards).

This review identified that for some chemicals, the risk-based S-GW component values for one or more of the soil to groundwater pathways were lower than the RLs such that the potential risk associated with the soil standard exceeded the URT. The URT for an ICRL is 1 in 10,000 and for non-cancer risk, aesthetic objectives and chemicals with developmental effects the URT is an HQ of 1. (Drinking water standards that are based on aesthetic objectives, which result in the S-GW1 value being based on an aesthetic objective, are listed in Section II.8.) A URT of an HQ of 10 for ecological exposure pathways is considered acceptable, unless the chemical bio-magnifies, in which case the URT is set at an HQ of 1. As noted above, chemicals with excess soil quality standards that may result in an exceedance of the URT are considered to be chemicals with analytical limitations.

The decision sequence detailed below was developed to identify chemicals with analytical limitations and determine whether leachate analysis could reduce the potential risk level associated with the soil to groundwater pathways by at least a factor of 2:

- **Step 1:** Is the excess soil quality standard set at RL?
  No – no leachate required
  Yes – move to Step 2

- **Step 2:** Is the potential risk associated with one or more S-GW pathways above the URT?
  No – no leachate required
  Yes – move to Step 3

- **Step 3:** Is the potential risk level associated with the LSL less than half the risk level associated with the excess soil quality standard? (This can be assessed by comparing the ratio of the effect-based LSL to the higher of the effect-based LSL and the water RL to 2x the ratio of the lowest of the S-GW component values and the final soil standard).
  No – no leachate required
  Yes – leachate required, move to Step 4

- **Step 4:** Does the final LSL meet the TRL? (This is assessed by evaluating if the final LSL was adjusted to a RL).
  No – no multiplier applied to soil to groundwater component values
  Yes – 1000x multiplier applied to the soil to groundwater component values

II.3. SITUATION 2 – METALS

Leaching of metals from soil to groundwater was not considered in the development of the brownfield soil standards due to the uncertainty of modelling the partitioning of metals between soil and groundwater in a generic setting, but groundwater sampling was available as a direct line of evidence to confirm that groundwater was protected. The movement of excess soil may not require groundwater sampling, therefore leachate analysis is required to be completed as an additional line of evidence to demonstrate that the soil to groundwater pathways for metals are protected.

The process described below was developed to determine whether leachate analysis can be used to assess whether the soil to groundwater pathways are protected for metals:

- **Step 1:** Is excess soil quality standard set at background?
  Yes – no leachate required
  No – move to Step 2

- **Step 2:** Does soil at the soil standard have the potential to result in exceedance of the LSL using the selected leachate analysis? (This can be assessed by comparing the final soil standard to the minimum soil concentration that could result in the LSL being met to determine if it is greater).
  Yes – leachate required
  No – no leachate required

II.4. CALCULATION OF LEACHATE SCREENING LEVELS

LSLs were calculated for all chemicals (with the exception of metals, which are described in Section II.5) using the soil concentration that corresponds to the lowest of the applicable S-GW component values (C_T), coupled with the partitioning equation (shown in Equation 1, also provided in Section 7.3.1 of the MOE (2011) rationale document). The LSL is the concentration of the chemical expected to be present in the leachate eluate, at the liquid/solid ratio of the leachate test (which is 20:1 for the proposed leachate method, with no headspace for volatile chemicals), when the concentration of the chemical in soil is equal to C_T.

The S-GW component values considered to determine $C_{T,}$ are as follows:

- For potable sites, C_T is the lowest of S-GW1, S-GW1 Odour, S-GW2, S-GW2 Odour and S-GW3 component values. The final C_T is adjusted up to background soil concentration, if lower.

- For non-potable sites, C_T is the lowest of S-GW2, S-GW2 Odour and S-GW3 component values. The final C_T is adjusted up to background soil concentration, if lower.

$$LSL = \frac{C_T}{K_d + \frac{\eta_w + \eta_a H'}{\rho_b}} \qquad \text{(Equation II.1)}$$

Where:

LSL = leachate screening level in (mg/L)

C_T = soil concentration that corresponds to lowest of applicable S-GW component values, adjusted up to soil background concentration if required (mg/g)

K_d = distribution coefficient (cm^3/g)

K_{oc} = organic carbon-water partition coefficient (cm^3/g)

f_{oc} = fraction of organic carbon of the soil (dimensionless)

η_w = fractional water content (ml/ml)

η_a = fractional volumetric air content (ml/ml), assuming zero for leachate test

H' = Henry's Law constant (dimensionless)

P_b = mass of soil per unit volume (dry soil bulk density, g/ml)

At the liquid to solid ratio considered in the leachate test (which is 20:1),

$$\frac{\eta_w + \eta_a H'}{\rho_b} = 20 \ (cm^3/g)$$

Also, the final LSL is not permitted to be numerically higher than the solubility or lower than the analytical RL set for groundwater under O. Reg. 153/04.

II.5. CALCULATION OF LEACHATE SCREENING LEVELS - METALS

Due to the uncertainty associated with identifying distribution coefficient (K_d) values for metals (with the exception of mercury and methylmercury) that would be representative of the expected range of site conditions, calculation of LSLs using the partitioning equation method was not completed. Instead, for metals, LSL are based on the lowest of the GW1, GW1-Odour and GW3 values component values, as applicable depending on groundwater use, adjusted with respect to reporting limits, as required. No metals are considered sufficiently volatile/toxic for the GW2 or GW2-Odour pathway to be of concern except for mercury and methylmercury, for which organic carbon-water partition coefficients (Koc) have been selected and LSL are calculated using the method presented in Section II.4.

If the soil standard for a metal cannot result in the exceedance of the LSL at the liquid to solid ratio of the selected leachate analysis (i.e. a liquid to solid ratio of 20:1), even if the entire mass of the chemical present in soil were to dissolve into the aqueous phase, then leachate analysis is not required. Also, the final LSL is not permitted to be numerically higher than the solubility or lower than the analytical RL or the background concentration set for groundwater under O. Reg. 153/04.

II.6. USE OF LEACHATE ANALYSIS AS A PATHWAY MODIFIER

Leachate analysis can be used to assess site specific soil to water partitioning; therefore, it can provide a more direct line of evidence to assess potential impacts to groundwater. If the results of leachate analysis indicate no potential threat to groundwater quality, soil to groundwater component values can be modified using a multiplier and/or ruled out from the development of excess soil quality standards.

Use of leachate analysis as a “pathway modifier” is facilitated within the BRAT. For chemicals for which the LSL can achieve the TRL, a 1000x multiplier is applied to the soil to groundwater component values and the final soil standard is adjusted accordingly.

II.7. CHEMICALS WITH THE POTENTIAL TO BIOMAGNIFY

Based on a review of the United Nations Environmental Programme (UNEP) Stockholm Convention on Persistent Organic Pollutants (POPs), the following chemicals were identified as having the potential to biomagnify. The Canadian Environmental Protection Act – Designated Substances List was also consulted, but it did not identify any chemicals that were not already included on the Stockholm Convention List. Special consideration was given to mercury, which can be methylated in the environment. While inorganic mercury is unlikely to biomagnify, it is included on the list due to its potential to be methylated in the environment, and to subsequently biomagnify as methylmercury.

Table II.1. Chemicals with the Potential to Biomagnify

Chemical	Reference
Aldrin, Chlordane, DDD, DCE, DDT, Dieldrin, Dioxan/Furan, Endosulfan, Endrin, Heptachlor, Hexachlorobenzene, Hexachlorobutadiene, Hexachlorocyclohexane Gamma-, Pentachlorophenol, and Polychlorinated biphenyls	UNEP, POP listed in the Stockholm Convention
Mercury and Methylmercury	CCME (2000)

II.8. COMPONENT VALUES BASED ON AESTHETIC OBJECTIVES

The S-GW1 odour and S-GW2 odour component values are based on aesthetic objectives. In addition, some of the drinking water quality standards or guidelines used to derive the S-GW1 component value are based on aesthetic objectives. There are eleven (11) chemicals for which this is the case, all are based on an Ontario Drinking Water Quality Standard (ODWQS) aesthetic objective and are listed below:

- Chlorobenzene;
- Copper;
- Dichlorobenzene, 1,2-;
- Dichlorobenzene, 1,4-;
- Dichlorophenol 2,4-;
- Ethylbenzene;
- Methyl tert-Butyl ether (MTBE);
- Pentachlorophenol;
- Trichlorophenol 2,4,6-;
- Xylenes; and
- Zinc.

II.9. REFERENCES

Canadian Council of Ministers of the Environment. 2000. Canadian Tissue Residue Guidelines for the Protection of Wildlife Consumers of Aquatic Biota: Methylmercury. Canadian Environmental Quality Guidelines Canadian Council of Ministers of the Environment.

Ministry of the Environment (MOE, currently known as Ministry of the Environment, Conservation and Parks). 2011. Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario. Available upon request at https://www.ontario.ca/page/brownfields-redevelopment.

United Nations Environmental Programme (UNEP), Stockholm Convention on Persistent Organic Pollutants.

APPENDIX III: Development of Ceiling Values to Support the Statistical Compliance Approach for Excess Soil Quality Standards

Development of Ceiling Values to Support the Statistical Compliance Approach for Excess Soil Quality Standards

III.1. BACKGROUND

As indicated in Section 3.6 of this rationale document, the excess soil quality standards incorporate both a single-point-compliance approach and a statistical compliance approach. The statistical approach is developed to allow for the use of a statistical assessment of the soil quality, provided that a number of requirements are met. Key requirements include that the soil analytical results are from a single population and that both the 90th percentile and the 95% upper confidence level of the mean (95% UCLM) of the data set meet the applicable excess soil quality standard. While this approach allows a small portion of the soil analytical results (10% or less) to exceed the applicable soil standard, every single sample must meet the applicable ceiling value. This requirement helps confirm that the soil data is representative of a single population (the presence of two populations may indicate areas of impact) and that any volume of soil does not pose significant risks to human health and the environment (i.e. maximum concentrations are below upper risk thresholds and acute risks). Details on the development of ceiling values for the attainment approach are presented in the following sections.

III.2. OVERVIEW OF CEILING VALUE DEVELOPMENT PROCESS

Figure III.1 outlines the steps used to develop ceiling values for the attainment approach. Three (3) key inputs are considered to determine a ceiling value, as follows

- 2x the applicable excess soil quality standard;
- Effect-based Cap (see Section III.3 for details); and,
- Acute Cap (see Section III.4 for details).

The lowest of these components becomes the ceiling value for a chemical. The final ceiling value is not permitted to be numerically lower than either the analytical reporting limit (RL) or typical background soil concentration found in Ontario.

For Table 1 standards, two additional considerations are applied to ensure that soils which are determined to meet Table 1 using this approach could reasonably be considered naturally occurring in Ontario. For Table 1, the ceiling value remains the same as the Table 1 standard if either of the following situations is identified:

- Ontario Typical Range (OTR) was not developed (Table 1 set at RL); or,
- OTR was set at the RL as the OTR samples were non-detects or target chemical was detected at concentrations lower that the RL (Table 1 set at RL).

Final ceiling values with respect to generic excess soil quality standards are provided in Appendix 3 of Part II of the MECP (2020) Soil Rules and Excess Soil Standards.

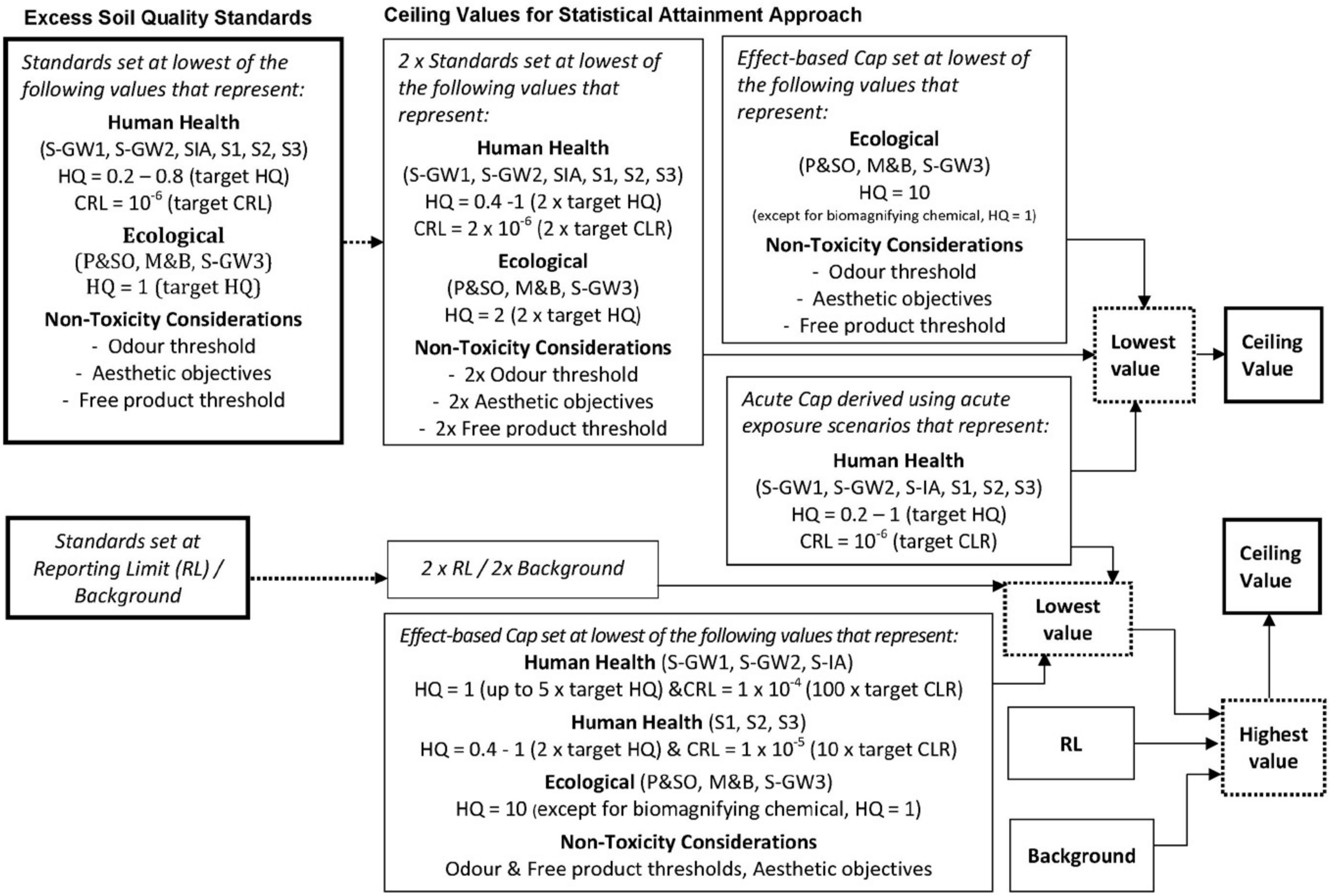

Figure III.1. Overview of Ceiling Value Development Process

III.3. DERIVATION OF EFFECT-BASED CAPS

The derivation approaches and inputs used for developing effect-based caps are the same as those used in the development of generic excess soil quality standards. The final cap is the lowest of the risk-based and other non-toxicity values that are derived using the following approach:

1. Calculation of a human health-based cap is based on;
    - A hazard quotient (HQ) of 1 per component value based on non-cancer effects, unless noted below;
    - A cancer risk level (CRL) of $1\text{x}10^{-4}$ per component value based on cancer effects, unless noted below;
    - For direct exposure to soil via soil ingestion and dermal contact (S1, S2, and S3), an HQ of 2x of target HQ and a CRL of 10^{-5} are considered for each component value with the exception of the following:
        - S1-S3 component values for lead are not calculated and are set at 120 µg/g (residential/parkland/institutional [R/P/I], based on Table 1 value) and 1000 µg/g (industrial/commercial/community [I/C/C], based on the criteria published in 1996, refer to the MOE (2011) rationale document for further details); and,
        - S1-S3 component values for uranium are not calculated and are set at 23 µg/g (for R/P/I) and 300 µg/g (for I/C/C), based on CCME (2007) values.
2. Calculation of an eco-protection cap is based on a HQ of 10 per eco-protection component value with the exception of biomagnifying substances, for which an HQ of 1 is retained.
3. Calculation of other caps is based on odour thresholds (for vapours), aesthetic objectives (e.g., for drinking water), or free-product thresholds; thus, no adjustment from target component values is made.

III.4. DERIVATION OF ACUTE CAPS

The calculation of health-based acute caps is completed using acute toxicity reference values (TRVs) and acute exposure scenarios. The derivation approaches and inputs used for developing acute caps are the same as those used in the development of generic excess soil quality standards with the exception of the following:

III.4.1. Selection of Acute TRVs

Toxicity reference values (TRVs) for acute effects were selected from several agencies using a hierarchy approach. A jurisdictional review was completed and internally reviewed to identify available acute TRVs. A complete list of selected TRVs is presented in Table III.1 of this appendix.

For several chemicals, acute TRVs could not be identified or selected. In these cases, a surrogate acute TRV was extrapolated from the chronic TRV; the chronic TRV was multiplied by a factor of five (5) with the exception of TRVs that are based on developmental effects. The factor of 5 was based on an internal review of various studies (Batke *et al*., 2011; Bokkers & Slob, 2005; Escher *et al*., 2016; Fay & Chou, 2007; Kalberlah *et al*., 2002; Malkiewicz *et al*., 2009; RIVM, 2001; Schneider *et al*., 2005; Schneider *et al*., 2006) identifying ratios between TRVs or effect levels for various chemicals across a range of exposure durations. The weighted mean acute-to-chronic ratio was larger than five, indicating that an extrapolation factor of five would account for the majority of chemicals.

In addition, when acute TRVs that are reported in selected references are numerically lower than existing chronic TRVs, acute TRVs will be set at chronic TRVs. This situation is identified for bis(2-ethylhexyl)phthalate, endrin, mercury, nickel, styrene, 1,1,1-trichloroethane, and vanadium.

III.4.2. Acute Incidental Soil Ingestion Rate

The toddler is the receptor used for R/P/I sites; recommendations of acute soil ingestion rates (SIRs) are higher than chronic SIRs. Some children have been observed to ingest up to 25 to 60 g of soil during a single day (Calabrese et al., 1997), whereas chronic ingestion rates are averaged over long periods of time. Acute SIRs used by various agencies vary from 400 mg/day to 10,000 mg/day, but data have not been recently compiled in the literature in support of an accurate SIR that is suitable for acute durations. Therefore, the selection of an acute SIR is based on professional judgement. An SIR of 1000 mg/day for toddlers is recommended by the United States Environmental Protection Agency (US EPA) in the Exposure Factors Handbook (US EPA, 2011a, pp. 5-4 & 5-5) for acute scenarios and for pica. Given the range of acute SIRs used by various agencies, 1000 mg/day for toddlers is reasonable.

On I/C/C sites, a toddler would not reasonably be expected for chronic durations. However, acute durations for toddlers on I/C/C sites are possible and likely. Therefore, the acute toddler exposure calculations used for R/P/I sites are also used for I/C/C sites.

III.4.3. Acute Exposure Duration, Averaging Time, and Exposure Frequency

The human health component values for acute exposure which are used in the excess soils program are calculated using the following acute exposure parameters:

- **Exposure Duration (ED) and Averaging Time (AT):** Various agencies consider an acute ED to be anywhere between 1 day to 14 days, but generally up to a few days. For the purposes of the calculations, an ED of "1 to 3 days" has been selected.

  For acute exposure assessment, the AT is considered to be equal to the ED (US EPA, 2003). It is noted that if the ED and AT were changed to "1 day" or "3 days", this would not affect the selected acute parameters or the calculations.

- **Exposure Frequency (EF):** There are three EF parameters used in the calculations of component values for chronic exposure: weeks/year, days/ week, and hours/day. For acute exposure durations of only 2 or 3 days, some of these EF parameters might not be relevant:
  - **EF (weeks/year):** Since the exposure duration is only 1 to 3 days, an EF (weeks/year) parameter is not needed. This parameter could either be left out of the calculation or be set to 52 weeks/year.
  - **EF (days/week):** Since the exposure duration is only 1 to 3 days, the EF (days/week) parameter is not needed. There should be no prorating to account for days of no exposure within a week because the entire exposure duration is already less than a week. This parameter could either be left out of the calculation or be set to 7 days/week.
  - **EF (hours/day):** The EF (hours/day) parameter is only used in calculations involving inhalation. Since the exposure duration considered is 1 to 3 days, the value for the EF (hours/day) parameter can remain the same as that for the corresponding calculations of chronic exposure.

Table III.1. Acute Toxicity Reference Values

CHEMICAL NAME	Final Oral (Acute) TRV (mg/kg-day)	Is Oral Acute TRV based on reproductive or developmental effects?	Reference	Final Inhalation (Acute) TRV (mg/m^3)	Is Inhalation Acute TRV based on reproductive or developmental effects?	Reference
Acenaphthene	0.3		Extrapolated from Chronic TRV			
Acenaphthylene	0.3		Extrapolated from Chronic TRV			
Acetone	4.5		Extrapolated from Chronic TRV	62		ATSDR 1994a
Aldrin	0.002	YES	ATSDR 2002a			
Anthracene	1.5		Extrapolated from Chronic TRV			
Antimony	0.002		Extrapolated from Chronic TRV	0.001		Extrapolated from Chronic TRV
Arsenic	0.0015		MOE 2005	0.000015	YES	Cal EPA 2016 (8h)
Barium	0.3		NYS DOH 2006	0.005		Extrapolated from Chronic TRV

CHEMICAL NAME	**Final Oral (Acute) TRV (mg/kg-day)**	**Is Oral Acute TRV based on reproductive or developmental effects?**	**Reference**	**Final Inhalation (Acute) TRV (mg/m^3)**	**Is Inhalation Acute TRV based on reproductive or developmental effects?**	**Reference**
Benzene	0.015	YES	MDH 2009	0.03		ATSDR 2007a
Benz[a]anthracene						
Benzo[a]pyrene	0.0013		MDH 2012			
Benzo[b]fluoranthene						
Benzo[ghi]perylene						
Benzo[k]fluoranthene						
Beryllium	0.01		Extrapolated from Chronic TRV	0.000035		Extrapolated from Chronic TRV
Biphenyl 1,1'-	0.19		Extrapolated from Chronic TRV	28		US EPA 2007 (8h AEGL 2)
Bis(2-chloroethyl)ether						
Bis(2-chloro-1-methylethyl) ether, *erroneously known as Bis(2-chloroisopropyl)ether*	0.2		Extrapolated from Chronic TRV			

CHEMICAL NAME	Final Oral (Acute) TRV (mg/kg-day)	Is Oral Acute TRV based on reproductive or developmental effects?	Reference	Final Inhalation (Acute) TRV (mg/m^3)	Is Inhalation Acute TRV based on reproductive or developmental effects?	Reference
Bis(2-ethylhexyl)phthalate	0.06		Set at chronic TRV. Acute TRV of 0.029 mg/kg/d (MDH 2015) not used.			
Boron (Hot Water Soluble)						
Boron (total)	0.2	YES	ATSDR 2010a	0.3		ATSDR 2010a
Bromodichloromethane	0.04		ATSDR 1989a			
Bromoform	0.7		ATSDR 2005a			
Bromomethane	0.003		EFSA 2011	0.2		ATSDR 1992
Cadmium	0.007		NYS DOH 2006	0.00003		ATSDR 2012a
Carbon Tetrachloride	0.02		ATSDR 2005b	36		US EPA 2014 (8h AEGL 2)
Chlordane	0.001	YES	ATSDR 1994b	0.0035		Extrapolated from Chronic TRV
Chloroaniline p-	0.01		Extrapolated from Chronic TRV			

CHEMICAL NAME	Final Oral (Acute) TRV (mg/kg-day)	Is Oral Acute TRV based on reproductive or developmental effects?	Reference	Final Inhalation (Acute) TRV (mg/m^3)	Is Inhalation Acute TRV based on reproductive or developmental effects?	Reference
Chlorobenzene	0.3		Extrapolated from Chronic TRV	47		US EPA 2012 (8h AEGL 1)
Chloroform	0.3		ATSDR 1997a	0.5		ATSDR 1997a
Chlorophenol, 2-	0.015		Extrapolated from Chronic TRV			
Chromium Total	7.5		Extrapolated from Chronic TRV	0.3		Extrapolated from Chronic TRV
Chromium VI	0.0415		Extrapolated from Chronic TRV	0.0005		Extrapolated from Chronic TRV
Chrysene						
Cobalt	0.005		Extrapolated from Chronic TRV	0.0025		Extrapolated from Chronic TRV
Copper	0.01		ATSDR 2004	0.25		Extrapolated from Chronic TRV
Cyanide (CN-)	0.11		HSWMR 1999	1.1		US EPA 2002 (8h AEGL 1)

CHEMICAL NAME	Final Oral (Acute) TRV (mg/kg-day)	Is Oral Acute TRV based on reproductive or developmental effects?	Reference	Final Inhalation (Acute) TRV (mg/m^3)	Is Inhalation Acute TRV based on reproductive or developmental effects?	Reference
Dibenz[a h]anthracene						
Dibromochloromethane	0.1		ATSDR 2005c			
Dichlorobenzene, 1,2-	0.7		ATSDR 2006a	3		Extrapolated from Chronic TRV
Dichlorobenzene, 1,3-	0.4		ATSDR 2006a			
Dichlorobenzene, 1,4-	0.4		(proxy)	12		ATSDR 2006a
Dichlorobenzidine, 3,3’-						
Dichlorodifluoromethane	1		Extrapolated from Chronic TRV			
DDD	0.0005	YES (proxy)	(proxy)			
DDE	0.0005	YES (proxy)	(proxy)			
DDT	0.0005	YES	ATSDR 2002b			
Dichloroethane, 1,1-	0.6		MDH 2016	0.825		Extrapolated from Chronic TRV
Dichloroethane, 1,2-	0.23		MDH 2013a	2		Extrapolated from Chronic TRV
Dichloroethylene, 1,1-	1		(proxy)	0.8		proxy

CHEMICAL NAME	Final Oral (Acute) TRV (mg/kg-day)	Is Oral Acute TRV based on reproductive or developmental effects?	Reference	Final Inhalation (Acute) TRV (mg/m^3)	Is Inhalation Acute TRV based on reproductive or developmental effects?	Reference
Dichloroethylene, 1,2-cis-	1		ATSDR 1996a	554		US EPA 2010 (8h AEGL 1)
Dichloroethylene, 1,2-trans-	1		(proxy)	0.8		ATSDR 1996a
Dichlorophenol, 2,4-	0.015		Extrapolated from Chronic TRV			
Dichloropropane, 1,2-	0.1		ATSDR 1989b	0.23		ATSDR 1989b
Dichloropropene,1,3-	0.2		EFSA 2009	0.1		Extrapolated from Chronic TRV
Dieldrin	0.00011	YES	MDH 2017			
Diethyl Phthalate	7		ATSDR 1995a			
Dimethylphthalate	25		Extrapolated from Chronic TRV			
Dimethylphenol, 2,4-	0.1		Extrapolated from Chronic TRV			
Dinitrophenol, 2,4-	0.01		ATSDR 1995b			
Dinitrotoluene, 2,4 & 2,6-	0.05		ATSDR 2016			

CHEMICAL NAME	Final Oral (Acute) TRV (mg/kg-day)	Is Oral Acute TRV based on reproductive or developmental effects?	Reference	Final Inhalation (Acute) TRV (mg/m^3)	Is Inhalation Acute TRV based on reproductive or developmental effects?	Reference
Dioxane, 1,4-	5	YES	ATSDR 2012b	7.2		ATSDR 2012b
Dioxin/Furan (TEQ)	0.0000002		ATSDR 1998	0.0000002		Extrapolated from Chronic TRV
Endosulfan	0.007		ATSDR 2015a			
Endrin	0.00025		Set at chronic TRV. Acute TRV of 0.0001 mg/kg/d (proxy) not used.			
Ethylbenzene	0.5		Extrapolated from Chronic TRV	22		ATSDR 2010b
Ethylene dibromide	0.045		Extrapolated from Chronic TRV	0.004		Extrapolated from Chronic TRV
Fluoranthene	0.2		Extrapolated from Chronic TRV			
Fluorene	0.2		Extrapolated from Chronic TRV			

CHEMICAL NAME	Final Oral (Acute) TRV (mg/kg-day)	Is Oral Acute TRV based on reproductive or developmental effects?	Reference	Final Inhalation (Acute) TRV (mg/m^3)	Is Inhalation Acute TRV based on reproductive or developmental effects?	Reference
Heptachlor	0.0006		ATSDR 2007b			
Heptachlor Epoxide	0.0006		(proxy)			
Hexachlorobenzene	0.008	YES	ATSDR 2015b			
Hexachlorobutadiene	0.0017		Extrapolated from Chronic TRV			
Hexachlorocyclohexane Gamma-	0.003		ATSDR 2005d			
Hexachloroethane	1		ATSSR 1997b	58		ATSDR 1997b
Hexane (n)				10,000		US EPA 2013 (8h AEGL 2)
Indeno[1 2 3-cd]pyrene						
Lead						
Mercury	0.0015		Extrapolated from Chronic TRV	0.00009		Set at chronic TRV. Acute TRV of 6 x 10^{-5} mg/kg/d (Cal EPA 2016 (8h)) not used

CHEMICAL NAME	Final Oral (Acute) TRV (mg/kg-day)	Is Oral Acute TRV based on reproductive or developmental effects?	Reference	Final Inhalation (Acute) TRV (mg/m^3)	Is Inhalation Acute TRV based on reproductive or developmental effects?	Reference
Methoxychlor	0.00002		Extrapolated from Chronic TRV			
Methyl Ethyl Ketone	0.6		Extrapolated from Chronic TRV	586		US EPA 2011 (8h AEGL 1)
Methyl Isobutyl Ketone	1		Extrapolated from Chronic TRV	3		Extrapolated from Chronic TRV
Methyl Mercury	0.0001		Extrapolated from Chronic TRV			
Methyl tert-Butyl Ether (MTBE)	0.4		ATSDR 1996b	7.2		ATSDR 1996b
Methylene Chloride	0.2		ATSDR 2000	2		ATSDR 2000
Methlynaphthalene, 2-(1-)	0.02		Extrapolated from Chronic TRV			
Molybdenum	0.025		Extrapolated from Chronic TRV	0.06		Extrapolated from Chronic TRV
Naphthalene	0.6		ATSDR 2005e	0.0185		Extrapolated from Chronic TRV

CHEMICAL NAME	Final Oral (Acute) TRV (mg/kg-day)	Is Oral Acute TRV based on reproductive or developmental effects?	Reference	Final Inhalation (Acute) TRV (mg/m^3)	Is Inhalation Acute TRV based on reproductive or developmental effects?	Reference
Nickel	0.012		WHO DW, 2005	0.0011		TCEQ 2011
Pentachlorophenol	0.005	YES	ATSDR 2001			
Petroleum Hydrocarbons F1						
Aliphatic C6-C8	25		Extrapolated from Chronic TRV	92		Extrapolated from Chronic TRV
Aliphatic C>8-C10	0.5		Extrapolated from Chronic TRV	5		Extrapolated from Chronic TRV
Aromatic C>8-C10	0.2		Extrapolated from Chronic TRV	1		Extrapolated from Chronic TRV
Petroleum Hydrocarbons F2						
Aliphatic C>10-C12	0.5		Extrapolated from Chronic TRV	5		Extrapolated from Chronic TRV
Aliphatic C>12-C16	0.5		Extrapolated from Chronic TRV	5		Extrapolated from Chronic TRV
Aromatic C>10-C12	0.2		Extrapolated from Chronic TRV	1		Extrapolated from Chronic TRV

CHEMICAL NAME	Final Oral (Acute) TRV (mg/kg-day)	Is Oral Acute TRV based on reproductive or developmental effects?	Reference	Final Inhalation (Acute) TRV (mg/m^3)	Is Inhalation Acute TRV based on reproductive or developmental effects?	Reference
Aromatic C>12-C16	0.2		Extrapolated from Chronic TRV	1		Extrapolated from Chronic TRV
Petroleum Hydrocarbons F3						
Aliphatic C>16-C21	10		Extrapolated from Chronic TRV			
Aliphatic C>21-C34	10		Extrapolated from Chronic TRV			
Aromatic C>16-C21	0.15		Extrapolated from Chronic TRV			
Aromatic C>21-C34	0.15		Extrapolated from Chronic TRV			
Petroleum Hydrocarbons F4						
Aliphatic C>34	100		Extrapolated from Chronic TRV			
Aromatic C>34	0.15		Extrapolated from Chronic TRV			

CHEMICAL NAME	Final Oral (Acute) TRV (mg/kg-day)	Is Oral Acute TRV based on reproductive or developmental effects?	Reference	Final Inhalation (Acute) TRV (mg/m^3)	Is Inhalation Acute TRV based on reproductive or developmental effects?	Reference
Phenanthrene						
Phenol	1		ATSDR 2008	24		US EPA (2009) 8h AEGL 1
Polychlorinated Biphenyls	0.0001		Extrapolated from Chronic TRV	0.0025		Extrapolated from Chronic TRV
Pyrene	0.15		Extrapolated from Chronic TRV			
Selenium	0.025		Extrapolated from Chronic TRV			
Silver	0.025		Extrapolated from Chronic TRV			
Styrene	0.12		Set at chronic TRV. Acute TRV of 0.1 mg/kg/d (ATSDR 2010c) not used.	21		ATSDR 2010c

CHEMICAL NAME	Final Oral (Acute) TRV (mg/kg-day)	Is Oral Acute TRV based on reproductive or developmental effects?	Reference	Final Inhalation (Acute) TRV (mg/m^3)	Is Inhalation Acute TRV based on reproductive or developmental effects?	Reference
Tetrachloroethane, 1,1,1,2-	0.15		Extrapolated from Chronic TRV			
Tetrachloroethane, 1,1,2,2-	0.05		Extrapolated from Chronic TRV			
Tetrachloroethylene	0.008		ATSDR 2014 draft	0.04		ATSDR 2014 draft
Thallium	0.0000675		Extrapolated from Chronic TRV			
Toluene	0.8		ATSDR 2017	7.5		ATSDR 2017
Trichlorobenzene, 1,2,4-	0.17		MDH 2013b	0.04		Extrapolated from Chronic TRV
Trichloroethane, 1,1,1-	2		Set at chronic TRV. Acute TRV of 0.3 mg/kg/d (proxy, ATSDR 1989c) not used.	11		ATSDR 2006b
Trichloroethane, 1,1,2-	0.3		ATSDR 1989c	11		(proxy)

CHEMICAL NAME	Final Oral (Acute) TRV (mg/kg-day)	Is Oral Acute TRV based on reproductive or developmental effects?	Reference	Final Inhalation (Acute) TRV (mg/m^3)	Is Inhalation Acute TRV based on reproductive or developmental effects?	Reference
Trichloroethylene	0.0005		Extrapolated from Chronic TRV	0.002		Extrapolated from Chronic TRV
Trichlorofluoromethane	1.5		Extrapolated from Chronic TRV			
Trichlorophenol, 2,4,5-	0.015		Extrapolated from Chronic TRV			
Trichlorophenol, 2,4,6-	0.015		Extrapolated from Chronic TRV			
Uranium	0.002	YES	ATSDR 2013	0.0015		Extrapolated from Chronic TRV
Vanadium	0.04		FDEP 2005	0.001		Set at chronic TRV. Acute TRV of 8 x 10^{-4} mg/m^3 (ATSDR 2012c) not used
Vinyl Chloride	0.015		Extrapolated from Chronic TRV	1.3	YES	ATSDR 2006c

CHEMICAL NAME	Final Oral (Acute) TRV (mg/kg-day)	Is Oral Acute TRV based on reproductive or developmental effects?	Reference	Final Inhalation (Acute) TRV (mg/m^3)	Is Inhalation Acute TRV based on reproductive or developmental effects?	Reference
Xylene Mixture	1		ATSDR 2007c	8.7		ATSDR 2007c
Zinc	1.5		Extrapolated from Chronic TRV			

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APPENDIX IV: Updates to Human Health Toxicity Reference Values

Updates to Human Health Toxicity Reference Values

In order to keep up-to-date with recent science, on an ongoing basis, the Ministry of the Environment, Conservation and Parks (the “Ministry”) identifies and reviews toxicity reference values (TRVs) derived by various government agencies. The most scientifically sound TRVs are then selected for use in some Ministry programs. In cases where more than one TRV is considered acceptable, they may be selected together and the TRV that results in less stringent component values will be used for the purpose of developing generic excess soil quality standards. On occasion, the Ministry may modify an agency’s TRV if the modification can be sufficiently supported with scientific evidence or is otherwise straightforward. Table IV.1 presents the updated TRVs for selected chemicals.

As part of the TRV selection process, confidence ratings are assigned to TRVs that are assessed. In some cases, as with the inhalation chronic non-cancer TRV for *cis*-1,2-dichloroethylene (cis-DCE), an available TRV that may be assigned a rating of low confidence will not be selected. In the development of generic excess soil quality standards for cis-DCE, no inhalation TRV is selected and therefore the soil to indoor air (S-IA) component value is not derived. However, the soil to groundwater to indoor air (S-GW2) component value is derived based on 10 times the value for vinyl chloride. This is done to account for the potential anaerobic biodegradation of cis-DCE to vinyl chloride. And the derived S-GW2 value is considered to be an appropriate line of evidence to evaluate the vapour intrusion pathway.

For a site specific assessment, if the qualified person is of the opinion that an inhalation TRV for cis-DCE is required to develop a vapour intrusion component value (e.g., S-IA), one may be obtained or selected from a surrogate compound (*e.g.*, the inhalation chronic non-cancer TRV for *trans*-1,2-dichloroethylene), from route-to-route extrapolation (e.g., extrapolation from the oral chronic non-cancer TRV for *cis*-1,2-dichloroethylene), or from an alternative approach.

In addition, for some chemicals (i.e., 1,1- dichloroethylene, ethylbenzene), the update of TRVs results in a situation that sub-chronic inhalation TRVs are numerically lower than the updated chronic TRVs. In these cases, sub-chronic inhalation TRVs will be set at chronic inhalation TRVs.

Table IV.1: Updated Human Health Toxicity Reference Values

Chemical		Oral Chronic TRV (mg/kg-day)	Ref.	Oral Sub-chronic TRV (mg/kg-day)	Ref.	Inhal. Chronic TRV (mg/m^3)	Ref	Oral Slope Factor (mg/kg-day)$^{-1}$	Ref.	Inhal. Unit Risk (mg/m^3)$^{-1}$	Ref.
Acenaphthene	Old	NR		NR		NR		0.0073	US EPA IRIS 1992; (TEF= 10^{-3})*	0.0011	CalEPA ATH 2005/1993; (TEF= 10^{-3})*
	New							**0.001**	**US EPA IRIS 2017; (TEF= 10^{-3})***	**6x10^{-4}**	**US EPA IRIS 2017; (TEF= 10^{-3})***
Acenaphthylene	Old	NR		NR		NR		0.073	US EPA IRIS 1992; (TEF= 10^{-2})*	0.011	Cal EPA ATH 2005/ 1993; (TEF= 10^{-2})*
	New							**0.01**	**US EPA IRIS 2017; (TEF= 10^{-2})***	**0.006**	**US EPA IRIS 2017; (TEF= 10^{-2})***
Anthracene	Old	NR		NR		NR		none		none	
	New							**0.01**	**US EPA IRIS 2017; (TEF= 10^{-2})***	**0.006**	**US EPA IRIS 2017; (TEF= 10^{-2})***

Chemical		Oral Chronic TRV (mg/kg-day)	Ref.	Oral Sub-chronic TRV (mg/kg-day)	Ref.	Inhal. Chronic TRV (mg/m^3)	Ref	Oral Slope Factor (mg/kg-day)$^{-1}$	Ref.	Inhal. Unit Risk (mg/m^3)$^{-1}$	Ref.
Arsenic	Old	NC	USEPA IRIS 1993; CalEPA ChREL 2000; ATSDR 2005D	none		3 x10^{-5}	Cal EPA ChREL 2000	1.5	Cal EPA ATH 2005)	1.5	WHO Air 2000
	New		**USEPA IRIS 1991; ATSDR 2007**			**none**		**1.8**	**HC DW2006; HC CSD2010**	**0.15**	**TCEQ 2012**
Benz[a] anthracene	Old	NR		NR		NR		0.73	US EPA IRIS 1992; (TEF= 10^{-1})*	0.11	Cal EPA ATH 2005/1993; (TEF= 10^{-1})*
	New							**0.1**	**US EPA IRIS 2017; (TEF= 10^{-1})***	**0.06**	**USEPA IRIS 2017; (TEF= 10^{-1})***

Chemical		Oral Chronic TRV (mg/kg-day)	Ref.	Oral Sub-chronic TRV (mg/kg-day)	Ref.	Inhal. Chronic TRV (mg/m^3)	Ref	Oral Slope Factor (mg/kg-day)$^{-1}$	Ref.	Inhal. Unit Risk (mg/m^3)$^{-1}$	Ref.
Benzo[a] pyrene	Old	none		none		none		7.3	USEPA IRIS 1992; (TEF=1)*	1.1	CalEPA ATH 2005/1993; (TEF=1)*
	New	**3 x10^{-4}**	**US EPA IRIS 2017**	**0.005**	**mod Cal EPA DW 2010**	**2x10^{-6}**	**US EPA IRIS 2017**	**1**	**US EPA IRIS 2017; (TEF=1)***	**0.6**	**US EPA IRIS 2017; (TEF=1)***
Benzo[b] fluoranthene	Old	NR		NR		NR		0.73	US EPA IRIS 1992; (TEF= 10^{-1})*	0.11	CalEPA ATH 2005/1993; (TEF= 10^{-1})*
	New							**0.1**	**US EPA IRIS 2017; (TEF= 10^{-1})***	**0.06**	**US EPA IRIS 2017; (TEF= 10^{-1})***
Benzo[ghi] perylene	Old	NR		NR		NR		0.073	US EPA IRIS 1992; (TEF= 10^{-2})*	0.011	CalEPA ATH 2005/1993; (TEF= 10^{-2})*
	New							**0.01**	**US EPA IRIS 2017; (TEF= 10^{-2})***	**0.006**	**US EPA IRIS 2017; (TEF= 10^{-2})***

Chemical		Oral Chronic TRV (mg/kg-day)	Ref.	Oral Sub-chronic TRV (mg/kg-day)	Ref.	Inhal. Chronic TRV (mg/m^3)	Ref	Oral Slope Factor (mg/kg-day)$^{-1}$	Ref.	Inhal. Unit Risk (mg/m^3)$^{-1}$	Ref.
Benzo[k] fluoranthene	Old	NR		NR		NR		0.73	US EPA IRIS 1992; (TEF= 10^{-1})*	0.11	Cal EPA ATH 2005/ 1993; (TEF= 10^{-1})*
	New							**0.1**	**US EPA IRIS 2017; (TEF= 10^{-1})***	**0.06**	**US EPA IRIS 2017; (TEF= 10^{-1})***
Bromoform	Old	NC		NC		none		0.0079	US EPA IRIS 1991	0.0011	US EPA IRIS 1991
	New							**0.01**	**Cal EPA 2003**	**none**	
Chrysene	Old	NR		NR		NR		0.073	US EPA IRIS 1992; (TEF= 10^{-2})*	0.011	Cal EPA ATH 2005/ 1993; (TEF= 10^{-2})*
	New							**0.01**	**US EPA IRIS 2017; (TEF= 10^{-2})***	**0.006**	**US EPA IRIS 2017; (TEF= 10^{-2})***

Chemical		Oral Chronic TRV (mg/kg-day)	Ref.	Oral Sub-chronic TRV (mg/kg-day)	Ref.	Inhal. Chronic TRV (mg/m^3)	Ref	Oral Slope Factor (mg/kg-day)$^{-1}$	Ref.	Inhal. Unit Risk (mg/m^3)$^{-1}$	Ref.
Chloroform	Old	0.01	US EPA IRIS 2001	NC		NC		0.031	Cal EPA ARB 1990	0.0053	Cal EPA ATH 2005
	New	**0.015**	**WHO CICAD 2004**					**none**		**none**	
Copper	Old	0.03	HC DW 1992	none		none		none		none	
	New	**0.01**	**ATSDR 2004**	**0.01**	**ATSDR 2004**	**0.05**	**MOE Air 1974**				
Cyanide (CN-)	Old	0.02	Cal EPA DW 1997; US EPA IRIS 1993	0.05	ATSDR 2006	0.008	MOE Air 2005	none		none	
	New	**0.002**	**mod US EPA IRIS 2010a**	**0.006**	**mod US EPA IRIS 2010a**	**0.0025**	**mod USEPA IRIS 2010a**				
Dibenz[a,h] anthracene	Old	NR		NR		NR		7.3	US EPA IRIS 1992; (TEF= 1)*	1.1	Cal EPA ATH 2005/ 1993; (TEF= 1)*
	New							**1**	**US EPA IRIS 2017; (TEF= 1)***	**0.6**	**US EPA IRIS 2017; (TEF= 1)***

Chemical		Oral Chronic TRV (mg/kg-day)	Ref.	Oral Sub-chronic TRV (mg/kg-day)	Ref.	Inhal. Chronic TRV (mg/m^3)	Ref	Oral Slope Factor (mg/kg-day)$^{-1}$	Ref.	Inhal. Unit Risk (mg/m^3)$^{-1}$	Ref.
Dichloro-ethylene, 1,1-	Old	NC	US EPA IRIS 2002	none		0.07	Cal EPA chREL 2000	none		none	
	New		**US EPA IRIS 2002; WHO CICAD 2003**			**0.2**	**US EPA IRIS 2002; WHO CICAD 2003**				
Dichloro-ethylene, *cis*-1,2	Old	0.03	mod RIVM 2001	0.3	ATSDR 1996; mod RIVM 2001	0.15	mod RIVM 2001	none		none	
	New	**0.002**	**US EPA IRIS 2010b**	**0.017**	**US EPA PPRTV 2011**	**none**					
Dichloro-ethylene, *trans*-1,2	Old	NC		0.2	ATSDR 1996; mod USEPA IRIS 1989	NC	RIVM 2001	none		none	
	New			**0.065**	**Mod USEPA IRIS 2010b**		**RIVM 2001; 2009**				

Chemical		Oral Chronic TRV (mg/kg-day)	Ref.	Oral Sub-chronic TRV (mg/kg-day)	Ref.	Inhal. Chronic TRV (mg/m^3)	Ref	Oral Slope Factor (mg/kg-day)$^{-1}$	Ref.	Inhal. Unit Risk (mg/m^3)$^{-1}$	Ref.
2,4-Dinitrophenol	Old	NC	US EPA IRIS 1987	NC	USEPA IRIS 1987	none		none		none	
	New		**US EPA IRIS 1987; US EPA PPRTV 2007**		**US EPA PPRTV 2007**						
Ethylbenzene	Old	NC		none		1	**US EPA IRIS 1991**	none		none	
	New			**0.4**	**ATSDR 2010**	**2**	**Cal EPA chREL 2000**				
Fluoranthene	Old	NR		NR		NR		0.073	US EPA IRIS 1992; (TEF= 10^{-2})*	0.011	Cal EPA ATH 2005/ 1993; (TEF= 10^{-2})*
	New							**0.01**	**US EPA IRIS 2017; (TEF= 10^{-2})***	**0.006**	**US EPA IRIS 2017; (TEF= 10^{-2})***

Chemical		Oral Chronic TRV (mg/kg-day)	Ref.	Oral Sub-chronic TRV (mg/kg-day)	Ref.	Inhal. Chronic TRV (mg/m^3)	Ref	Oral Slope Factor $(mg/kg\text{-}day)^{-1}$	Ref.	Inhal. Unit Risk $(mg/m^3)^{-1}$	Ref.
Indeno[1,2,3-cd]pyrene	Old	NR		NR		NR		0.73	US EPA IRIS 1992; (TEF= 10^{-1})*	0.11	Cal EPA ATH 2005/ 1993; (TEF= 10^{-1})*
	New							**0.1**	**US EPA IRIS 2017; (TEF= 10^{-1})***	**0.06**	**US EPA IRIS 2017; (TEF= 10^{-1})***
Nickel	Old	0.02	IRIS 1996	NR		NR		NR		NR	
	New	**0.011**	**Cal EPA chRD (2005); HC CSD (2010); Cal EPA chREL (2012)**								
Pyrene	Old	NR		NR		NR		0.0073	US EPA IRIS 1992; (TEF= 10^{-3})*	0.0011	Cal EPA ATH 2005/ 1993; (TEF= 10^{-3})*
	New							**0.001**	**US EPA IRIS 2017; (TEF= 10^{-3})***	**6 x10^{-4}**	**US EPA IRIS 2017; (TEF= 10^{-3})***

Chemical		**Oral Chronic TRV (mg/kg-day)**	**Ref.**	**Oral Sub-chronic TRV (mg/kg-day)**	**Ref.**	**Inhal. Chronic TRV (mg/m^3)**	**Ref**	**Oral Slope Factor (mg/kg-day)$^{-1}$**	**Ref.**	**Inhal. Unit Risk (mg/m^3)$^{-1}$**	**Ref.**
Silver	Old	NC		none		none		none		none	
	New										
Tetrachloro-ethylene	Old	0.014	HC 1996; WHO DW 2003	NC	Mod HC 1996	0.25	WHO Air 2000	none		none	
	New	**0.006**	**US EPA IRIS 2012**		**Mod HC DW 1996; Mod HC CSD 2010**	**0.04**	**US EPA IRIS 2012**	**0.002**	**US EPA IRIS 2012**	**2.6 x10^{-4}**	**US EPA IRIS 2012**
Trichloro-ethylene	Old	0.0015	HC DW 2005	none		0.04	USEPA NCEA 2001	0.013	Cal EPA DW 1999	0.002	Cal EPA ATH 2005
	New	**5 x10^{-4}**	**US EPA IRIS 2011; ATSDR 2013**			**0.002**	**US EPA IRIS 2011; ATSDR 2013**	**0.046**	**US EPA IRIS 2011**	**0.0041**	**US EPA IRIS 2011**
Vinyl Chloride	Old	NC		none		NC		1.4	US EPA IRIS 2000	NC	
	New							**1.5**	**WHO DW 2004/2011**		

Notes: NR: not re-evaluated ; NC: no change in TRV; none: none selected; *: Kalberlah et al. 1995

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(Note that references for Old TRVs are not listed here)

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APPENDIX V: Updates to Source Allocation Factors for Inhalation Exposure Pathways

Updates to Source Allocation Factors for Inhalation Exposure Pathways

V.1. BACKGROUND

Source allocation factors (SAFs), sometimes also referred to as soil allocation factors (CCME, 2006), are used by several jurisdictions when deriving soil and groundwater standards. SAFs are used in an effort to account for exposures from other media, in addition to the medium (soil or groundwater) for which a standard is being developed. Jurisdictions typically assume that there are four or five media which may contribute to total exposure; these media typically include: air, soil, food, water and consumer products. In cases where five media are retained, generally a default of 20% of the total exposure will be allocated to soil and another 20% to groundwater when developing generic standards for use at contaminated sites.

The Ministry of the Environment, Conservation and Parks (the “Ministry”) uses this approach and applies a default SAF of 0.2 when deriving human health component values for non-cancer effects. For the inhalation pathway, SAFs are used in the inhalation exposure modelling to calculate non-cancer health based indoor air concentrations, which are then used to calculate the S-IA and S-GW2 component values. For additional details regarding the Ministry’s use of SAFs and the development of generic standards for the brownfields program, the reader is referred to the MOE (2011) rationale document.

As part of the standards development process for excess soils, it was noticed that for some volatile organic chemicals, estimated vapour intrusion component values (i.e. S-IA, S-GW2) could be, in some cases, well below analytical reporting limits. In an effort to better understand and more accurately quantify risks for these chemicals, a decision was made to re-examine the use of a default SAF of 0.2 for the inhalation pathway and to develop an alternative approach to determine SAFs.

V.2. UPDATED APPROACH TO DETERMINE SAFS FOR USE WITH INHALATION NON-CANCER TOXICITY REFERENCE VALUES

The following discussion explains the updated approach developed by the Ministry for determining SAFs to be applied in conjunction with inhalation non-cancer toxicity reference values (TRVs) to derive component values or standards for the chemicals listed below in Table V.1.

One of the important assumptions of this updated approach is that a SAF is not only chemical specific, but it is also specific to the TRV and the use of that TRV in deriving a component value or standard. Therefore, if a new TRV is selected for use, a new SAF must be determined.

Typically, a default SAF of 20% is used when developing soil standards as described in the MOE (2011) rationale document. For the updated approach, departing from the default SAF of 20% was based on a comparison between estimated background intakes and the TRV. In general, if background exposures are estimated to be low relative to the selected TRV, then more of the TRV can be allocated to the derivation of a component value or standard. If background exposures are high relative to the selected TRV, then additional exposures should be minimized by allocating only 20% of the TRV to the component value or standard being derived.

The following stepwise procedure describes the updated approach for determining a SAF. Figure V.1 shows the process for determining SAFs as a decision tree.

1) The critical effect of the inhalation non-cancer TRV was identified as being either a route-of-entry effect (*i.e.*, portal-of-entry effect) or a systemic effect.

2) If the critical effect of the TRV was a route-of-entry effect, only background air exposures (from indoor and/or outdoor air) were considered to contribute to the body burden of exposure. Background air concentrations were estimated using the following methodology:

    - Upper estimate air concentrations (95th percentiles if available or 90th percentiles) were obtained from available published literature or government reports.

    - Air concentrations were preferred from the following jurisdictions as follows: Ontario or Canada, United States (U.S.), and finally Western Europe, Australia, and New Zealand. Although data from Ontario or Canada were preferred, data from the U.S. and other countries were sometimes also considered based on the quality of the Ontarian/Canadian data and on the variability of the data.

    - The higher of the indoor or outdoor air concentrations was used.

3) If the critical effect of the TRV was a systemic effect, background exposures from all media (air, drinking water, food, soil/dust, and consumer products) were considered to contribute to the body burden of exposure, and were estimated using the methodology described below:

    - Background air concentrations were estimated as described in Step 2.

    - Central tendency estimates of background intake rates from other media (food, drinking water, soil/dust, and consumer products) were identified from published literature or government reports. As with the air data, although data from Ontario or Canada were preferred, data from the U.S. and other countries were sometimes also considered based on the quality of the Ontarian/Canadian data and on the variability of the data. Also, although central tendency values were preferred for media other than air, other estimates were sometimes considered if central tendency estimates were not available.

- Media concentrations were converted to estimated intake rates using the following exposure parameters: toddler drinking water ingestion rate of 0.8 L/day (Richardson & O'Connor, 1997), toddler soil ingestion rate of 100 mg/day (central tendency, professional judgement), and toddler body weight of 15.3 kg (Richardson & Stantec, 2013). Note that the use of central tendency estimates (e.g., soil ingestion rate) may not be appropriate for the purpose of undertaking a site specific risk assessment.
- To obtain total background intakes, upper estimates of intake from air were converted to µg/kg/day using standard route-to-route extrapolation parameters (70 kg body weight and 20 m^3/day inhalation rate). Estimates of relative absorption were assumed to be 100%. Upper estimate intakes from air (expressed in µg/kg/day) were then summed with central tendency estimates of intakes from all other media for an estimate of total background intake. Estimates of total background intake available from the scientific literature and from government reports were also considered.

4) If the critical effect of the inhalation TRV was a route-of-entry effect, the upper estimate of background air concentration was directly compared to the inhalation TRV. If the critical effect of the TRV was a systemic effect, the total background intake (in µg/kg/day) was compared to the inhalation cancer TRV (converted to a corresponding value in µg/kg/day). Estimates of total background intake available from the published literature or government reports were also considered.

5) Determining the SAF value: Ideally, the sum of background exposure and any additional exposure via inhalation should not exceed 100% of the selected TRV. In an effort to achieve this goal, the selected approach uses 3 possible default values for the SAF: 20% (which is equivalent to the current default), 50%, or 80%.

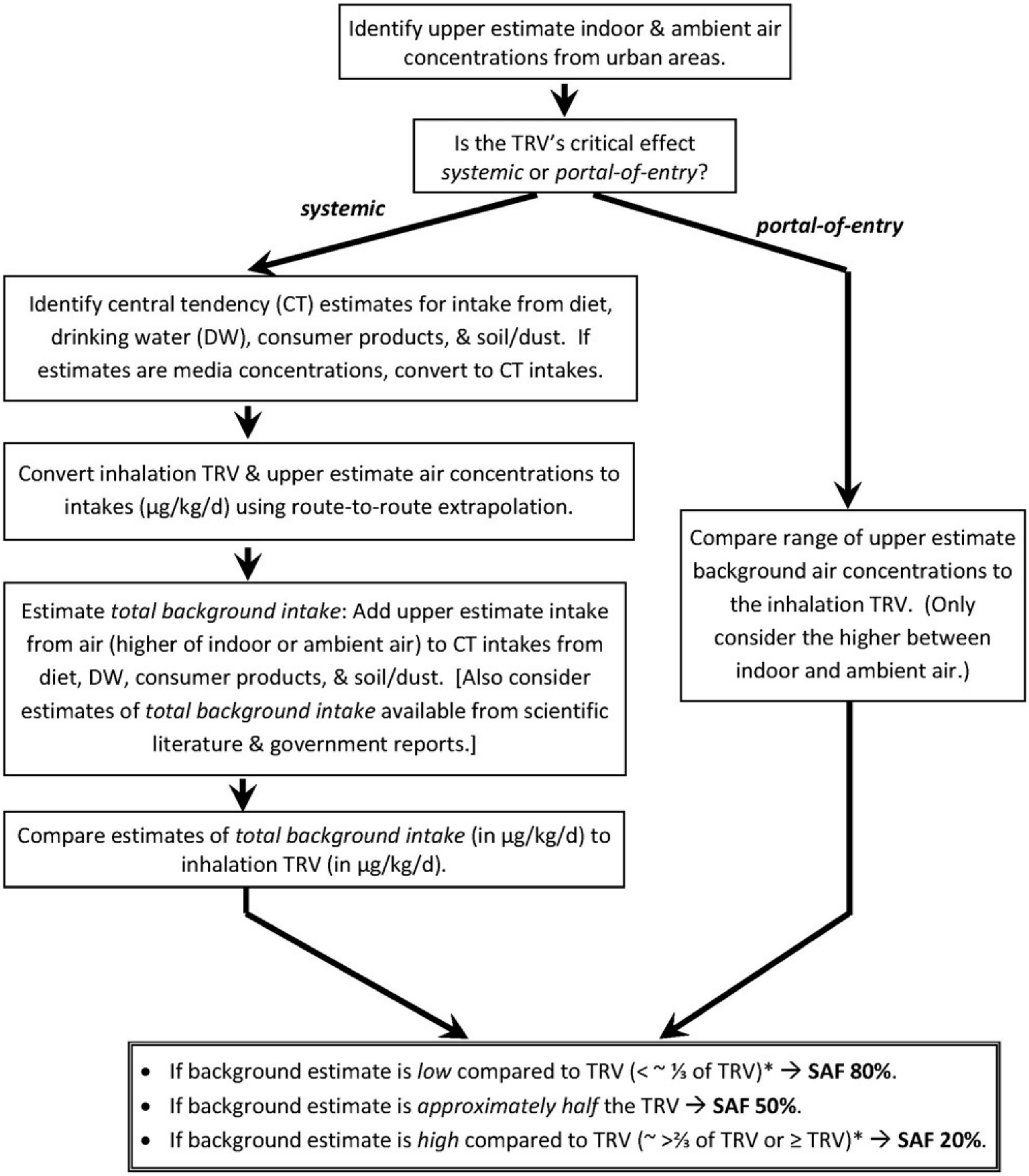
   - A SAF of 20% was selected when the background estimate is relatively high compared to the TRV or exceeding the TRV. A factor of 20% is the current default used by the Ministry (and many other jurisdictions, e.g., CCME) when developing soil and groundwater standards and it is considered to be a reasonable low-end SAF. A SAF of 20% would not contribute significantly to existing background exposures and it would not excessively restrict a medium that is not responsible for the majority of exposures to a substance.

- A SAF of 50% was selected when the background estimate was approximately half of the TRV.
- A SAF of 80% was selected when the background estimate was low compared to the TRV.

Also, it is noted that to obtain a conservative estimate of total background intake that was not excessive, central tendency estimates for intakes from diet, drinking water, soil/dust, and consumer products were used in combination with upper estimates for intakes from air.

V.3. UPDATED SAFS FOR SELECTED CHEMICALS

The above approach was used to determine SAFs for 15 selected volatile organic chemicals for which the presence in subsurface media (e.g., impacted soil) has the potential to pose unacceptable human health risks due to vapour intrusion. The inhalation TRVs, background exposure estimates and selected inhalation SAFs (including supporting rationales) are presented in the Table V.1.



* These are not intended to be precise boundaries. Some judgement and interpretation may be required.

Figure V.1: Decision Tree for Determining a Source Allocation Factor

Table V.1: Chemical-Specific Source Allocation Factors (SAFs) for Inhalation Exposure Pathways for Selected Chemicals

Chemical	Inhalation Non-Cancer TRV (mg/m^3) Agency / Year	Systemic or Route-of-Entry? / Critical Effect	Background Indoor & Outdoor Air Levels (μg/m^3)	Comparison of Background/Baseline Intake Rates from Various Media (μg/kg/d)	Recommended SAF (20%, 50%, or 80%) for Inhalation Exposure Pathways
benzene	3 x 10^{-2} mg/m^3 = 30 μg/m^3 [≈ 9 μg/kg/d] (US EPA IRIS 2003)	Systemic effect: decreased lymphocyte count	- Canada indoor: 90/95th percentile (%iles) 3.643 - **21.010 μg/m^3** (HC IAQ studies) - United States (US) indoor: 95th %iles 9.9 - 29 μg/m^3 (US EPA 2011) - Canada outdoor: 90/95th %iles 0.740 - 2.704 μg/m^3 (HC IAQ studies) - US outdoor: means 0.45 - 2.29 μg/m^3	**Air** - 21.010 μg/m^3 → ~6 μg/kg/d **Drinking water (DW)** - Treated water across Ontario (MOECC 2017): med 0.32 μg/L (~0.02 μg/kg/d), 95th %ile 0.50 μg/L (~0.03 μg/kg/d) **Food** - 0.12-1.4 μg/d (FAO/WHO 2009) → ~0.002-0.02 μg/kg/d - 0.42-180 μg/d (FAO/WHO 2009) → ~0.006-2.6 μg/kg/d **Soil/dust** - 0.065 (mean), 0.10 (95% upper confidence limit of the mean) 0.52 ppm (97.5th %iles) Sydney, NS urban reference area with no major industrial activity (JDAC 2001) - <0.002 - 0.16 ppm: vicinity of petroleum plant & refinery in Oakville (CCME, 2004) - 0.1 ppm → ~6.5 x 10^{-4} μg/kg/d **Consumer products** - cigarette smoking 1800-7900 μg/d (FAO/WHO 2009) → ~26-110 μg/kg/d. - passive smoking 6-63μg/d(FAO/WHO 2009) → 0.09-0.9 μg/kg/d	Indoor air levels are typically higher than outdoor air. 95th %ile indoor air levels in Canada are up to 21 μg/m^3 which is > 2/3 of the inhalation TRV of 30 μg/m^3. (Inhaling 21 μg/m^3 is roughly equivalent to an intake of 6 μg/kg/d.) Intakes from DW ingestion & soil ingestion are likely negligible in comparison to air. Intakes from diet (& from active or passive smoking) may add considerably more to total intakes. Since background intakes amount to a high proportion of the TRV, a SAF of **20%** is recommended.

Chemical	Inhalation Non-Cancer TRV (mg/m^3) Agency / Year	Systemic or Route-of-Entry? / Critical Effect	Background Indoor & Outdoor Air Levels (µg/m^3)	Comparison of Background/Baseline Intake Rates from Various Media (µg/kg/d)	Recommended SAF (20%, 50%, or 80%) for Inhalation Exposure Pathways
bromomethane (methyl bromide)	0.005 mg/m^3 = 5 µg/m^3 (US EPA IRIS 1992; Cal EPA chREL 2000)	**Route-of-entry** effect: Lesions of olfactory epithelium of nasal cavity	- Canada indoor: range <0.043 - 0.805, 90/95th %iles 0.067 - 0.097 (HC IAQ studies) - US indoor: NJ all samples <detection limit (DL); NY state median <0.25, 95th %ile 0.9, maximum (max) 23 (US EPA, 2011) - Canada outdoor: range <0.043 - 0.614, 90/95th %iles 0.062 - 0.075 (HC IAQ studies) - US outdoor: Highest urban mean 2.2 (ATSDR, 1992a)	- Non-air sources are not relevant because critical effect is via route-of-entry.	Since the TRV's critical effect is a route-of-entry effect, only background air exposures factor into estimating a SAF. The inhalation 95th percentile air concentrations (conc) tend to be <1 µg/m^3, but US outdoor urban means are up to 2.2 µg/m^3. Although Canadian data appear low, US data are considered here as a conservative measure. Since 2.2 µg/m^3 is approximately 50% of the TRV, a SAF of **20%** is recommended.

Chemical	Inhalation Non-Cancer TRV (mg/m^3) Agency / Year	Systemic or Route-of-Entry? / Critical Effect	Background Indoor & Outdoor Air Levels (µg/m^3)	Comparison of Background/Baseline Intake Rates from Various Media (µg/kg/d)	Recommended SAF (20%, 50%, or 80%) for Inhalation Exposure Pathways
carbon tetrachloride (CCl4)	2 µg/m^3 [≈ 0.6 µg/kg/d] (US EPA Region III, 2004)	Systemic effect: Hepatic effects (increased liver weight and liver lipid content).	- indoor concs usually > outdoor - Canada indoor: range 0.035 - 7.22, 90/95th %iles 0.65 - **1.225** µg/m^3 (HC IAQ studies) - US indoor: 95th %iles <DL - 1.1 (US EPA 2011); avg **2.6** µg/m^3 (from n=2120) (ATSDR 2005) - Canada outdoor: range <DL - 0.961, 90/95th %iles 0.577 - 0.717 (HC IAQ studies) - US outdoor: range of medians in several urban areas 0.7 - 1.0 (ATSDR 2005)	**Air** - 1.225 µg/m^3 → ~0.35 µg/kg/d - 2.6 µg/m^3 → ~0.7 µg/kg/d. **Drinking Water** - Ontario DW rarely > 0.5 µg/L → 0.03 µg/kg/d (HC DW 2010) - USA typical: 0.01 µg/kg/d, range 0.003-0.9 µg/kg/d (ATSDR 2005) - 99% of groundwater (GW) samples were <DL, but some may be up to 29 or 720 µg/L (ATSDR 2005) - If at DW standard 5 µg/L, then 0.3 µg/kg/d **Food** - Levels in most foods: <DL (ATSDR 2005) **Soil/dust** - Only 0.8% of 361 soil/sediment samples contained CCl$_4$; the conc was reported to be <5.0 ppm (WHO EHC 1999) → ~0.03 µg/kg/d **Consumer products** - Banned from consumer products (ATSDR 2005)	Intake from DW (Ontario usually < 0.03 µg/kg/d, US typical 0.01 µg/kg/d) & soil (~0.03 µg/kg/d) are negligible compared to intake from air at 1.225 µg/m^3 (~0.35 µg/kg/d). Indoor air concentrations typically exceed outdoor air. 95th percentile indoor air concentrations in Canada are up to 1.225 µg/m^3. In the US, an indoor mean of 2.6 µg/m^3 has been reported. Comparison of the US mean of 2.6 µg/m^3 to the TRV (2 µg/m^3) suggests that a minimum SAF of **20%** is left to be allocated.

Chemical	Inhalation Non-Cancer TRV (mg/m^3) Agency / Year	Systemic or Route-of-Entry? / Critical Effect	Background Indoor & Outdoor Air Levels (µg/m^3)	Comparison of Background/Baseline Intake Rates from Various Media (µg/kg/d)	Recommended SAF (20%, 50%, or 80%) for Inhalation Exposure Pathways
chloroform	0.1 mg/m^3 = 100 µg/m^3 [≈ 30 µg/kg/d] (ATSDR 1997)	Systemic effect: Liver toxicity	- Canada indoor: 90/95th %iles 3.267 - **11.480** µg/m^3 (HC IAQ studies) - US indoor: 95th %iles 4.1 - 7.5 µg/m^3 (US EPA 2011) - Canada outdoor: 90/95th %iles 0.099 - 1.121 µg/m^3 (HC IAQ studies) - US outdoor: means <0.10 - 0.12 µg/m^3	**Air** - 11.480 µg/m^3 → ~ 3.3 µg/kg/d **Drinking water** - mean intakes ~ 0.7 µg/kg/d and up to 10 µg/kg/d for some (WHO DW 2004). **Food** - mean intake ~1 µg/kg/d (WHO DW 2004) **Soil/dust** - Soil monitoring data could not be identified perhaps due to rapid leaching and/or volatilization. Sediment: 30-80 ng/kg in samples exposed to chlorinated electrical power plant cooling water & also in control samples (ATSDR 1997) - Detected in 8% of 425 sediment samples: median <5.0 µg/kg (ATSDR 1997) - 5 µg/kg → ~3 x 10^{-5} µg/kg/d **Consumer products** - swimming pools: 65 µg/kg/d from a 1-h swim (WHO DW 2004); 95th %ile time spent in freshwater swimming pool (doers only) is 181 min/month (US EPA EFH 2011) ≈ 6 min/d. Thus for a 6-min/d swim, 6.5 µg/kg/d is expected.	Estimated intakes in µg/kg/d: ~3.3 (95th %ile) from air, 0.7-10 from DW, ~1 (mean) from diet, + ~6.5 from swimming (for those who swim) for total of 11.5 - 20.8 µg/kg/d, which ≈ 50% of TRV. (Intake from soil is comparatively negligible). Thus, **50%** SAF is recommended. [Additional support: Canadian background intakes are ~1-10 & max of 100 µg/kg/d (HC PSL 2001). From US biomonitoring Tan et al. (2007) estimated total background intakes of ~0.5 (central tendency) & >5 µg/kg/d (upper estimate).]

Chemical	Inhalation Non-Cancer TRV (mg/m^3) Agency / Year	Systemic or Route-of-Entry? / Critical Effect	Background Indoor & Outdoor Air Levels (µg/m^3)	Comparison of Background/Baseline Intake Rates from Various Media (µg/kg/d)	Recommended SAF (20%, 50%, or 80%) for Inhalation Exposure Pathways
1,1-dichloroethane (1,1-DCA)	0.17 mg/m^3 = 170 µg/m^3 [≈ 50 µg/kg/d] (modified from US EPA HEAST 1984)	Systemic effect: kidney toxicity	- Canada indoor: 95th %iles <0.013 - **0.040** µg/m^3 (HC IAQ studies) - US indoor: 95th %iles <DL µg/m^3 (US EPA 2011) - Canada outdoor: 95th %iles <DL µg/m^3 (HC IAQ studies) - US outdoor: means <DL µg/m^3	**Air** - 0.040 µg/m^3 → 0.01 µg/kg/d **Drinking water** - U.S. DW usually <10 µg/L (WHO DW 2003a) → ~0.5 µg/kg/d - (Max U.S. well water 60 µg/L (ATSDR 2015) → ~3 µg/kg/d) **Food** - Low bioaccumulation potential (ATSDR 2015). - Not found in most foods (ATSDR 2015). **Soil/dust** - Max Ontario Typical Range (OTR) soil background conc: 0.05 ng/g (MOEE 1993) → ~3 x 10^{-7} µg/kg/d **Consumer product** - No Information identified	Biomonitoring studies in the U.S. found 1,1-DCA in blood to be <DL in all age categories (ATSDR 2015), therefore background exposures are likely to be low. This is corroborated by the low concentrations found in air, DW, food, and soil. Upper estimates of background exposures are a minor fraction of the TRV. Thus a SAF of **80%** is recommended.

Chemical	Inhalation Non-Cancer TRV (mg/m^3) Agency / Year	Systemic or Route-of-Entry? / Critical Effect	Background Indoor & Outdoor Air Levels (µg/m^3)	Comparison of Background/Baseline Intake Rates from Various Media (µg/kg/d)	Recommended SAF (20%, 50%, or 80%) for Inhalation Exposure Pathways
1,2-dichloroethane (1,2-DCA)	0.4 mg/m^3 = 400 µg/m^3 [≈ 100 µg/kg/d] (Cal EPA chREL 2000)	Systemic effect: Significant elevation in liver enzymes	- Canada indoor: range <DL - 23, medians <DL - 0.292, 90/95th %iles <DL - **5.492** µg/m^3 (HC IAQ studies) - US indoor: 95th %iles <DL - 1.1 µg/m^3 (US EPA 2011) - Canada outdoor: range: <DL - 1.033, 90/95th %iles <DL - 0.1 µg/m^3 (HC IAQ studies) - US outdoor: means 0.405 - 6.07 µg/m^3 (ATSDR 2001)	**Air** - 5.492 µg/m^3 → ~1.6 µg/kg/d **Drinking water** - Canada: most DW supply samples: <DL – 1 µg/L (HC DW 2014) → <0.05 µg/kg/d - Ontario DW (MOECC 2017): median/95th %ile 0.2/0.5 µg/L (~0.01/0.03 **µg/kg/d)** **Food** - In market basket surveys US, Canada & Japan, mostly <DL; reported in some foods ≤ ng/g levels (WHO DW 2003b). - Intakes ~ 0.06 µg/kg/d (ATSDR 2001). **Soil/dust** - Max OTR soil background conc: 0.18 ng/g (MOEE 1993) → ~1 x 10^{-6} µg/kg/d - Means in Netherlands soils: 11 ppm near homes, <5 ppm near a garage, 30 ppm near waste site (ATSDR 2001) - Soil near industrial facilities in Claire, MI, USA had 6–19 µg/kg (ATSDR 2001) - 11 ppm → ~0.07 **µg/kg/d** **Consumer products** - Discontinued in adhesives/cleaners (HC DW 2014). It may be in cigarette smoke.	Intakes from DW and soil are very low compared to air. Canadian indoor 95th percentile of 5.492 µg/m^3 (or even the indoor max of 23 µg/m^3) is considerably lower than the TRV of 400 µg/m^3. A SAF of **80%** is recommended.

Chemical	Inhalation Non-Cancer TRV (mg/m^3) Agency / Year	Systemic or Route-of-Entry? / Critical Effect	Background Indoor & Outdoor Air Levels (μg/m^3)	Comparison of Background/Baseline Intake Rates from Various Media (μg/kg/d)	Recommended SAF (20%, 50%, or 80%) for Inhalation Exposure Pathways
1,1-dichloroethylene (1,1-DCE)	0.2 mg/m^3 = 200 μg/m^3 [≈ 60 μg/kg/d] (US EPA IRIS 2002; WHO CICAD 2003)	Systemic effect: Fatty changes in female liver	- Canada indoor: range <0.01 - 4.05 μg/m^3, 90/95th %iles <0.018 - **0.83** μg/m^3 (HC IAQ studies) - US indoor: 95th %ile 0.7 μg/m^3 (US EPA 2011) - Canada outdoor: range <0.01 - 0.83, 90/95th %iles <0.018 - 0.12 μg/m^3 (HC IAQ studies) - Canada annual outdoor means: 0.011 - 0.016 μg/m^3 (EC/HC 2013b)	**Air** - 90th %ile 0.83 μg/m^3 → ~ **0.24 μg/kg/d** **Drinking water** - Treated water across Ontario (MOECC 2017): median 0.3 μg/L (~0.02 μg/kg/d), 95th %ile 0.5 μg/L (**~0.03 μg/kg/d**). - Canadian upper bound intake: 0.003 - 0.01 μg/kg/d (EC/HC 2013b) - US medians: Public wells 0.20 μg/L (~0.01 μg/kg/d), Domestic wells 0.026 μg/L (~0.001 μg/kg/d) [EC/HC 2013b] **Food** - Upper bound intake **0.2 - 1.3 μg/kg/d** (EC/HC 2013b) **Soil/dust** - Evaps to air very quickly from soil (ATSDR 1994). Upper bound intake <0.001 μg/kg/d (EC/HC 2013b) **Consumer products** - Used mainly as an industrial solvent (EC/HC 2013b).	Intakes from air and food are comparable, while intakes from DW and soil/dust are much lower. Upper estimate intakes from air (~0.24 μg/kg/d) and food (0.2 - 1.3 μg/kg/d) are considerably lower than the TRV of 200 μg/m^3 (~60 μg/kg/d). A SAF of **80%** is therefore recommended.

Chemical	Inhalation Non-Cancer TRV (mg/m^3) Agency / Year	Systemic or Route-of-Entry? / Critical Effect	Background Indoor & Outdoor Air Levels (µg/m^3)	Comparison of Background/Baseline Intake Rates from Various Media (µg/kg/d)	Recommended SAF (20%, 50%, or 80%) for Inhalation Exposure Pathways
***trans*-1,2-dichloroethylene (trans-1,2-DCE)**	0.06 mg/m^3 = 60 µg/m^3 [≈20 µg/kg/d] (RIVM 2001; 2009)	Systemic effect: Liver toxicity & lung toxicity	- Canada indoor: range <0.018 - 5.084, 95th %iles <0.018 - **0.255 µg/m^3** (HC IAQ studies) - Canada outdoor: range <0.018 - 0.055, 95th %iles <0.018 - **0.314 µg/m^3** (HC IAQ studies) - US outdoor mean range: 0.052 - 0.03 µg/m^3 (ATSDR 1996)	**Air** - 95th %ile 0.3 µg/m^3 → **~0.09 µg/kg/d** **Drinking water** - DW standard 20 µg/L → ~1 µg/kg/d. Avg DW concs: 0.23 to 2.7 µg/L (ATSDR 1996) → ~0.01 to ~0.1 µg/kg/d **Food** - Because of high volatility of 1,2-DCE, no significant retention would be expected in foodstuffs (Cal EPA DW 2006). **Soil/dust** - Volatilizes rapidly from moist soil surfaces & leaches through subsurface soil, & could become a GW contaminant (ATSDR 1996). - Max OTR soil background conc: 0.018 ng/g (MOEE 1993) → ~1 x 10^{-7} µg/kg/d **Consumer products** No information identified.	95th %ile of air (0.3 µg/m^3) is considerably < TRV of 60 µg/m^3. DW upper estimates not available, but even if DW were consumed at concentration of Ontario. DW standard (20 µg/L), resultant intake of ~1 µg/kg/d is still considerably < TRV of 60 µg/m^3 (≈ 20 µg/kg/d). Intakes from other media are expected to be minimal/negligible. Thus, a SAF of **80%** is recommended.

Chemical	**Inhalation Non-Cancer TRV (mg/m^3) Agency / Year**	**Systemic or Route-of-Entry? / Critical Effect**	**Background Indoor & Outdoor Air Levels (µg/m^3)**	**Comparison of Background/Baseline Intake Rates from Various Media (µg/kg/d)**	**Recommended SAF (20%, 50%, or 80%) for Inhalation Exposure Pathways**
1,2-dichloropropane	0.004 mg/m^3 = 4 µg/m^3 (US EPA IRIS 1991)	**Route-of-entry** effect: Hyperplasia of nasal mucosa	- Canada indoor: range <0.022 - 4.487, 90/95th %iles <0.04 - **0.427 µg**/m^3 (HC IAQ studies) - US indoor: 90th %iles <DL in NJ, Mass, & NYS (NJDEP 2013) - Canada outdoor: range <0.022 - 0.23, 90/95th %iles <DL (HC IAQ studies) - US outdoor: Penn state max <DL (Penn DEP 2007)	Non-air sources are not relevant because critical effect is via route-of-entry.	Since the TRV's critical effect is route-of-entry, only background air exposures factor into estimating a SAF. Indoor concentrations seem higher than outdoor. The highest 95th %ile for Canadian indoor air is 0.427 µg/m^3, while US concentrations were even lower. 0.427 µg/m^3 is very low compared to TRV of 4 µg/m^3. Thus, a SAF of **80%** is recommended.

Chemical	Inhalation Non-Cancer TRV (mg/m³) Agency / Year	Systemic or Route-of-Entry? / Critical Effect	Background Indoor & Outdoor Air Levels (µg/m³)	Comparison of Background/Baseline Intake Rates from Various Media (µg/kg/d)	Recommended SAF (20%, 50%, or 80%) for Inhalation Exposure Pathways
1,3-dichloropropene	2 x 10^{-2} mg/m^3 = 20 µg/m^3 (US EPA IRIS 2000a)	**Route-of-entry** effect: Hypertrophy & hyperplasia of nasal epithelium	- Canada indoor: 95th %iles <0.011 - **<0.031** µg/m^3 (HC IAQ studies) - US indoor: 95th %iles <DL (US EPA 2011) - Canada outdoor: 95th %iles <0.011 - 0.026 µg/m^3 (HC IAQ studies)	Non-air sources are not relevant because critical effect is via route-of-entry.	TRV's critical effect is route-of-entry; thus, only background air exposures factor into deriving SAF. Canadian 95th percentile air concs are up to <0.031 µg/m^3 indoors & up to 0.026 µg/m^3 outdoors. US indoor 95th %ile are <DL. Upper estimates of background air are a fraction of the TRV; thus a SAF of **80%** of the TRV is recommended.

Chemical	Inhalation Non-Cancer TRV (mg/m^3) Agency / Year	Systemic or Route-of-Entry? / Critical Effect	Background Indoor & Outdoor Air Levels (μg/m^3)	Comparison of Background/Baseline Intake Rates from Various Media (μg/kg/d)	Recommended SAF (20%, 50%, or 80%) for Inhalation Exposure Pathways
ethylene dibromide (1,2-dibromoethane)	8 x 10^{-4} mg/m^3 = 0.8 μg/m^3 [≈ 0.2 μg/kg/d] (Cal EPA chREL 2001)	Systemic effect: Sperm abnormalities	- Canada indoor: range <0.02 - **0.208** μg/m^3, 90/95th %iles <DL (HC IAQ studies) - US New Jersey indoors: all data <DL (Weisel et al., 2008) - Canada outdoor: range <0.02 - 0.026 μg/m^3, 90/95th %iles <DL (HC IAQ studies) - US outdoor: Penn state max <DL (Penn DEP 2007)	**Air** - 95th %iles below DL, max 0.208 μg/m^3 → ~0.06 μg/kg/d **Drinking water** - <DL in Ontario & Canada (EC/HC 2013a) - US medians <0.1 μg/L (public wells) & <0.04 μg/L (domestic wells), EC/HC 2013a - Ontario standard 0.05 μg/L (~0.003 μg/kg/d) **Food** - Bans on use as pesticide has reduced exposure to Canadians via foods; cooking, baking, processing & market circulation decreases residual levels (EC/HC 2013a) **Soil/dust** - Rapidly volatilized from soils & leached to surface water & GW (ATSDR 1992b). - OTR soil background: 0.032 ng/g (MOEE 1993) - 0.08 μg/g in soil at depth (EC/HC 2013a) - ≤0.2 μg/g in tobacco field topsoil 19 y after last known applicn (Steinberg *et al*. 1987) - 0.2 μg/g → ~0.01 μg/kg/d **Consumer products** - No information identified	Concentrations in DW are <DL across Canada. Concentrations in food and soil are very low or negligible. 95th %iles concentrations in air are <DL and therefore only a fraction of the TRV of 0.8 μg/m^3. [Even the *max* Canadian indoor air concentration is very low (25% of the TRV).] Thus, a SAF of **80%** is recommended.

Chemical	Inhalation Non-Cancer TRV (mg/m^3) Agency / Year	Systemic or Route-of-Entry? / Critical Effect	Background Indoor & Outdoor Air Levels (µg/m^3)	Comparison of Background/Baseline Intake Rates from Various Media (µg/kg/d)	Recommended SAF (20%, 50%, or 80%) for Inhalation Exposure Pathways
hexane	2.5 mg/m^3 = 2500 µg/m^3 [≈ 700 µg/kg/d] (MOE AAQC 2005)	Systemic effect: neurological effects	- Canada indoor: 95th %iles 6.904 - **48.607** µg/m^3 (HC IAQ studies) - US indoor: 95th %iles 20 - 35 (US EPA 2011) - Canada outdoor: 95th %iles 0.702 - 3.572 µg/m^3 (HC IAQ studies)	**Air** - 48.607 µg/m^3 → ~14 µg/kg/d **Drinking water** - Highly volatile; for DW supplies in larger towns/cities typical treatment techniques likely volatilize hexane before it enters distribution systems, but it may be in some domestic wells. (ATSDR 1999) **Food** - Plants do not bioaccumulate hexane (CCME 2011). - Bioconcentration & bioaccumulation potential in aquatic & terrestrial food chains is low (CCME 2011). - Estimated dietary intake 2.21 µg/kg/d (CCME 2011). **Soil/dust** - Likely to volatilize rapidly from surface soils; at contaminated sites in USA, n-hexane was found in soil at 0.316 – 0.72 mg/kg (CCME 2011). - 0.72 ppm → ~0.005 µg/kg/d **Consumer products** - No information identified	Background concentrations in DW, food, air, and soil are very low or expected to be very low based on hexane's properties. Estimated intakes are a minor fraction of the TRV. Thus a SAF of **80%** is recommended.

Chemical	Inhalation Non-Cancer TRV (mg/m³) Agency / Year	Systemic or Route-of-Entry? / Critical Effect	Background Indoor & Outdoor Air Levels (µg/m³)	Comparison of Background/Baseline Intake Rates from Various Media (µg/kg/d)	Recommended SAF (20%, 50%, or 80%) for Inhalation Exposure Pathways
tetrachloroethylene (Perc)	0.04 mg/m³ = 40 µg/m³ [≈ 10 µg/kg/d] (US EPA IRIS 2012)	Systemic effect: Neurotoxicity	- Canada indoor: range 0.028 - 721.38, 90/95th %iles 2.448 - **10.87** µg/m³ (HC IAQ studies) - US indoor : 95th %iles 4.1 - 9.5 µg/m³ (US EPA 2011) - Canada outdoor: range <0.03 - 17.34, 90/95th %iles 0.126 - 1.016 µg/m³ (HC IAQ studies) - US outdoor medians: 0.3 - 1.7 µg/m³ (WHO IAQ 2010)	**Air** - 95th %ile: 10.87 µg/m³ → ~3 µg/kg/d. Average (avg) intakes: 1.22-2.25 µg/kg/d (HC PSL 1993) **Drinking water** - Treated water across Ontario (MOECC 2017): median 0.3 µg/L (~0.02 µg/kg/d), 95th %iles 0.5 µg/L (~0.03 µg/kg/d) - Mean intakes: 0.002 - 0.06 µg/kg/d (HC PSL 1993) **Food** - Switzerland ~ 2.3, Germany 1.2 µg/kg/d (ATSDR 2014D). - Mean intakes: 0.12 – 0.65 µg/kg/d (HC PSL 1993). **Soil/dust** - Rapidly volatilized from soils & can leach into GW & deeper soil (ATSDR 2014D) - ≤10 ppm in industrial soil in Vancouver (HC DW 2015) → ~0.014 µg/kg/d. **Consumer products** - Household products & clothes dry-cleaned recently add to indoor air (ATSDR 2014D).	Intake from industrial soil is negligible compared to air & to TRV. (Residential soil would be even lower.) Intakes from DW are also negligible compared to air & to TRV. Estimated daily intake from 95th %ile of air levels in Canada is ~ 3 µg/kg/d. Mean intake from diet may be in the range of 0.12 to 2.3 µg/kg/d. Upper intake from air + mean intake from diet is in range of about ½ of TRV. Accordingly, a **SAF of 50%** is recommended.

Chemical	Inhalation Non-Cancer TRV (mg/m^3) Agency / Year	Systemic or Route-of-Entry? / Critical Effect	Background Indoor & Outdoor Air Levels (µg/m^3)	Comparison of Background/Baseline Intake Rates from Various Media (µg/kg/d)	Recommended SAF (20%, 50%, or 80%) for Inhalation Exposure Pathways
Trichloroethylene (TCE)	2 µg/m^3 [≈ 0.6 µg/kg/d] (US EPA IRIS 2011; ATSDR 2013)	Systemic effect: Fetal heart malformations & decreased thymus weight	- Canada indoor: 90/95th %iles 0.19, 0.24, 0.298, 0.475, 0.52, 0.537, 0.96, 1.02, 1.668 µg/m^3 (HC IAQ studies) - US indoor: 90th %iles 0.18 - 5.2 µg/m^3 (Weisel et al., 2008), 95th %iles 0.56 - 15 µg/m^3 (US EPA 2011). - Canada outdoor: 90/95th %iles 0.04 - 0.538 µg/m^3 (HC IAQ studies) - US outdoor: 0.11 - 1.37 µg/m^3 (Penn DEP 2007)	**Air** - 1 µg/m^3 is a reasonable upper estimate of background indoor air concs → ~0.3 µg/kg/d **Drinking water** - Treated water across Ontario (MOECC 2017): median 0.3 µg/L (~0.02 µg/kg/d), 95th %iles 1.15 µg/L (~0.06 µg/kg/d) - Canada: 0.004 µg/kg/d (CCME 2007) **Food** - 0.004-0.01 µg/kg/d (CCME 2007) **Soil/dust** - Soil background is negligible (CCME 2007) - Max OTR soil background conc: ~1.4 ng/g (MOEE 1993) → ~9 x 10^{-6} µg/kg/d **Consumer products** - Adhesives & cleaning fluids (ATSDR 2007)	Intakes from air are considerably higher than intakes from other media. An upper estimate of background indoor air concentrations is ~ 1 µg/m^3, which is only 50% of the TRV (2 µg/m^3), while intakes from other media are negligible in comparison to air. Thus, a **SAF of 50%** is recommended.

Chemical	Inhalation Non-Cancer TRV (mg/m^3) Agency / Year	Systemic or Route-of-Entry? / Critical Effect	Background Indoor & Outdoor Air Levels (µg/m^3)	Comparison of Background/Baseline Intake Rates from Various Media (µg/kg/d)	Recommended SAF (20%, 50%, or 80%) for Inhalation Exposure Pathways
vinyl chloride (VC)	0.1 mg/m^3 = 100 µg/m^3 [≈ 30 µg/kg/d] (US EPA IRIS 2000b)	Systemic effect: Liver cell poly-morphism	- Canada indoor: range <0.015 - 0.964, 90/95th %iles 0.021 - 0.053 µg/m^3 (HC IAQ studies) - US indoor: medians <DL, 95th %iles <DL - 0.09 µg/m^3 (US EPA 2011) - Canada outdoor: <0.015 - 0.026, 95th %iles <DL (HC IAQ studies)	**Air** - 95th %ile up to 0.09 µg/m^3→ 0.03 µg/kg/d **Drinking water** - PVC pipes to convey potable DW; some VC monomers are retained in pipe matrix, may be released in DW (HC DW 2013). - Highly mobile in soil, thus occasionally detected in GW & DW in USA in µg/L range, but doesn't leach much into GW because of rapid volatilization (ATSDR 2006). - Treated water across Ontario (MOECC 2017): median 0.2 µg/L (~0.01 µg/kg/d), 95th %ile 0.2 µg/L (~0.01 µg/kg/d). **Food** - 0.1 µg/d (HC DW 2013) → ~0.014 µg/kg/d. **Soil/dust** - Max OTR soil background conc: ~0.4 ng/g (MOEE 1993) → ~3 x 10^{-7} µg/kg/d **Consumer products** No information identified	Indoor air is generally higher than outdoor air. The 95th %iles indoor air concentration of 0.09 µg/m^3 is considerably lower than the TRV of 100 µg/m^3. Intakes from other media are lower than intake from air - and total intakes are still considerably lower than the TRV. Thus, a **SAF of 80%** is recommended.

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