Rationale Document for
Development of Excess Soil Standards

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1. Introduction

The Ministry of the Environment and Climate Change (MOECC) has developed generic tables of Excess Soil Standards (“the standards”) along with associated rules for the use of the standards at excess soil reuse sites (“the reuse sites”). The 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. The standards do not replace the determination of hazardous and non-hazardous waste, or what is appropriate for shore infilling. The standards are intended to provide users the ability to look-up a table of generic standards to enable the terrestrial reuse of excess soil at a reuse site. This document provides an overview of the derivation process, the associated assumptions and placement requirements as well as recommendations for applying these standards, and the actual numerical standards in table format. The MOECC has also developed a technical tool to facilitate the generation of site-specific excess soil standards that is based on the same approach used to develop the generic tables of standards and this tool is discussed in Section 5 of this document.

While a number of assumptions and exposure pathways used in the development of the existing O.Reg 153/04 brownfields site condition standards (SCSs) are applicable in an excess soil reuse context, certain differences were identified, including consideration of larger volumes of impacted soil. Consideration of these differences was incorporated into the development of the excess soil reuse standards, and the final standards and associated requirements for application are intended to address these differences. The standards have been developed and organized specific to site condition categories, including land use, groundwater potability, overburden thickness, distance to the nearest water body and soil placement volume and are presented in a series of tables, similar to the brownfields tables of site condition standards (Table 2 to 9). Users can determine appropriate soil quality by matching reuse site conditions with the appropriate table of standards. This is intended to enable greater utilization of soil as a resource, while maintaining the protection of human health and the environment. The standards were developed using generic assumptions to account for the potential exposure risks that one may encounter at any number of different properties in Ontario so as to enable their broad application. Utilization of site specific standard setting approaches is also considered and discussed in this document.

2. Overview of Excess Soil Standard Development

Similar to the brownfield soil standards, excess soil standards were derived through the consideration of a number of component values developed to provide a human or ecological receptor with an acceptable level of protection from a substance via a specific exposure pathway. Both the brownfield and excess soil standards assume a contaminated soil “source” located above the water table. Eleven (11) soil component values were considered when deriving the excess soil standards. The lowest of the component values becomes the risk-based standard for a substance. As with the brownfield soil standards, the final excess soil standard is not permitted to be numerically higher than the free phase product formation threshold, or lower than either the analytical reporting limit (RL) or the typical background concentration found in Ontario.

2.1. Components Considered for the Development of Excess Soil Standards

The contaminant pathways considered for the development of excess soil 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 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)
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 S-GW2, descriptions of the soil component values and pathways can be found in Section 1.3.2 of the MOECC (2011) *Rationale for the development of soil and ground water standards for use at contaminated sites in Ontario* (the "MOECC (2011) rationale document"). The S-GW2 pathway 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. Some modifications were made to the methods used to develop component values for brownfields, to make them more applicable to an excess soil context, these are detailed in Section 3.4.

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

Some of the pathways not considered in the development of brownfield or excess soil standards include the following:

1) Consumption of garden products cultivated at a reuse site;
2) Agricultural land use specific exposure scenarios; and,
    - 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
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 MOECC (2011) rationale document. Part IV of the MOECC document on *"Rules for On-Site and Excess Soil Management"*" outlines additional protections for certain reuse sites e.g., where soil is used as a growing medium for crops, also presented in Section 6 of this this document.

3. Deviations from Brownfield Standard Development

Consideration of the potential differences between a brownfield redevelopment scenario and an excess soil reuse scenario identified the need for some deviations from the assumptions and inputs used in the development of the brownfield soil standards and in the associated requirements for application of the numerical standards. In addition, some key inputs have been updated based on a review of new science. These differences are discussed in the following sections.

3.1. Volume of Excess Soil

Under a brownfield context, a typical "spill" scenario was modelled as a contaminated soil volume of 13 m by 13 m by 2 m depth (approximately 350 m^3). This source size assumption influences exposure pathways which assume a finite contamination volume which depletes over time (source depletion), and/or employ groundwater transport. When a volume of soil is larger than the volume used to derive a soil standard, there may be increased potential exposure via some pathways, due to lower levels of source depletion, dilution and attenuation. The sensitivity of the component value for each transport pathway to soil volume is summarized in the following table.

Attenuation Mechanisms		**Source Dimension**		
		Source Length	*Source Width*	*Source Thickness*
S-GW1	*Wellbore Dilution*	✓✓✓ (no further impact once source area reaches 14,000 m^2)		
	Source Depletion			✓✓* (minimal impact to most of substances once source thickness reaches approximately 10-30 m)
S-GW2	*Aquifer Mixing Cell*	Minimal		
	Source Depletion			✓✓✓* (minimal impact to most of substances when source thickness is approximately 30 m or higher)
S-GW3	*Aquifer Mixing Cell*	Minimal		
	Lateral mixing	Minimal		
	Surface Water Mixing		✓ (no further impact once source width reaches 65 m)	

S-IA	*Source Depletion*	✓✓✓* (minimal impact to most of substances when source volume is appx. 5,000 - 20,000 m^3)		
S-Nose	*Source Depletion*			✓✓* (minimal impact to most of substances when source depth is 10 - 30 m)
S-OA	*Atmospheric Mixing Cell*	✓✓✓*		
	Finite Source Jury Vapour Flux			✓✓* (minimal impact to most of substances when source depth is 10 - 30 m)

Notes: √√√: Potential reduction factor of 50x or greater (as compared to generic setting) when source size increases
√√: Potential reduction factor of 10x to 50x (as compared to generic setting) when source size increases
√: Potential reduction factor of 2x to 10x (as compared to generic setting) when source size increases
*: Chemical specific

As noted in the table above, the impact of source area on the S-GW1 pathway does not increase once the source reaches an area of 14,000 m^3. A source area of this size reduces the wellbore dilution factor (WBD) applied to the S-GW1 pathway to 1, as the source area covers the theoretical extent of the capture zone caused by pumping a domestic well in the generic setting. The WBD concept is explained in Section 7.3.2 of the MOECC (2011) rationale document.

Source width (measured perpendicular to groundwater flow direction) has no further impact on the S-GW3 pathway once a width of 65 m is reached. Under the generic brownfield scenario, which assumes a source width of 13 m, a Surface Water Dilution Factor (SWDF) of 10 is applied to the Aquatic Protection Value (APV). The SWDF decreases in proportion to the source width, until it is capped at 2, when the source width reaches 65 m. This was considered appropriate as the contaminant source is assumed to be located on only one side of the water body. The SWDF concept is discussed in Section 7.8.1 of the MOECC (2011) rationale document.

For small volume sites, those with excess soil volumes up to 350 m^3, or up to 1000 m^3 with rationale provided by a Qualified Person (QP), the brownfield soil standards from O.Reg 153/04 can be applied, as these standards were developed based on the assumption of an approximate contamination volume of 350 m^3.

However, within an excess soil scenario, soil volumes much larger than 350 m^3 may be reused at reuse sites and therefore standards are derived assuming larger soil volumes. To facilitate movement of excess soil to a wide range of different reuse sites, excess soil standards were derived for a volume independent scenario. These standards are applicable to any volume of soil being reused at a reuse site. To effectively eliminate the impact of soil volume on component values which employ groundwater transport or assume a finite contamination volume, assumptions were modified to represent an infinite contaminant volume.

While a range of factors were considered in the derivation of the standards related to both volume and dimension of the impacted soils to ensure the standards are protective of human health and the environment, some assumptions regarding the layout of the source had to be made. If the source configuration deviates from that used to create the small volume tables, the QP should assess whether use of the selected generic standards is appropriate. The volume independent tables of standards are suitable for use with any source dimensions.

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

The S-GW2 component value is included to protect receptors from exposure to a substance that has leached from soil to groundwater, moved with groundwater, then migrated as a vapour from groundwater to indoor air. Under a brownfield context, the S-GW2 pathway is not included as the S-IA component value is generally numerically lower, therefore it would be protective of both exposure pathways. The S-GW2 component value is usually numerically higher, partly because there is potential for additional vapour attenuation through contaminant leaching and mixing with groundwater before vapours migrate back up to overlying buildings. In addition, the groundwater to indoor air pathway (GW2) can be more directly evaluated through groundwater sampling in a brownfield scenario. However, groundwater sampling may not be required at reuse sites and therefore may not be available as a line of evidence to assess whether this pathway is protected.

Since impacted soil volumes may be much larger under an excess soil scenario than that assumed in a brownfield scenario, and could result in greater leaching, the S-GW2 pathway is considered a check value to ensure that the soil standard is protective of the vapour intrusion pathway for off-site buildings. Consideration of the S-GW2 pathway is also necessary for scenarios where the S-IA pathway is eliminated (e.g. no buildings on-site) and groundwater monitoring is not completed to confirm that concentrations of contaminants in groundwater that may flow off site will be protective of vapour intrusion risks at adjacent properties.

Similar to the brownfield assumption for GW2 component values, it is necessary to prevent a potential scenario wherein groundwater from an I/C/C site at the I/C/C S-GW2 standard flows onto an adjacent R/P/I property and does not meet the R/P/I standard. To protect for this situation, the I/C/C S-GW2 component value defaults to the R/P/I S-GW2 component value.

The S-GW2 component value is calculated 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 considered in the derivation of this component value. A detailed S-GW2 calculation process is presented in Appendix I.

3.3. Soil Texture

The generic brownfield SCSs are derived for two soil textures, coarse and medium-fine. Coarse textured soil is considered to be a soil with greater than 50% by mass of particles that are greater than 75 μm or larger in mean diameter. While most direct soil contact human health component values (S1, S2, S3) and ecological component values are independent of soil texture, the remaining component values are sensitive to the soil type in both the vadose zone and saturated zone (capillary fringe).

The following table presents the effect of soil type (coarse-textured vs fine/medium textured) on each component value. 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 grained soil due to the faster degradation rate for coarse textured soils. Sensitivity analyses indicated that soil standards driven by vapour transport component values (e.g. S-IA, S-OA) are the most sensitive to soil texture.

Pathway\Tier2 Input Parameters	**S-IA**	**S- Odour**	**S-Nose**	**S-OA**	**S-GW1**	**S-GW2**	**S-GW3**	**S1-S3**	**Plants & Organisms**	**Birds & Mammals**
Soil Type – vadose zone - (bulk density: 1.70 coarse, 1.40 medium-fine - total porosity: 0.36 coarse, 0.47 medium-fine - water filled porosity: 0.119 coarse, 0.170 medium-fine - soil vapour permeability:1.63E-07/1.78E-07 coarse, 2.30E-09/2.50E-09 medium-fine for RPI/ICC respectively - foc: 0.010 coarse, 0.035 medium-fine	✓✓	✓✓	✓✓	✓✓	✓	✓✓	✓	NA	✓	NA
Vertical recharge rate: - vertical recharge rate: 0.28 m/year for coarse, 0.20 m/year for medium-fine	NA	NA	NA	NA	✓	✓	✓	NA	NA	NA
Soil Type – capillary fringe - porosity: 0.375 coarse, 0.399 medium-fine - residual moisture content: 0.053 for coarse and 0.061 for medium-fine	NA	NA	NA	NA	NA	✓✓	NA	NA	NA	NA

Notes: √√: Strong influence, component values are significantly lower for coarse–textured soil, where is applicable

√: Minimal influence, component values are marginally lower (less than 1.2 - 1.5 for most compounds) for coarse-textured soil, where is applicable

Under an excess soil scenario, soil disturbance during excavation, transport and deposition may change soil structures, including soil porosity, hydraulic conductivity and vapour permeability. Medium-fine grained excess 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. Therefore, the generic tables of excess soil standards are developed using coarse-textured soil inputs and as such may be applied at a reuse site with either coarse-textured or a medium/fine textured soils. The soil texture of a reuse site can be evaluated and may be accounted for as part of site specific standard development.

3.4. Modifications to Derivation of Component Values and Selection of Final Standards

Some adjustments were made to some component values due to differences between a brownfields scenario and an excess soil reuse scenario as detailed in the following sections.

3.4.1. Odour Based Component Values

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

3.4.2. S-GW3 Shallow Component Value

For development of the brownfield soil standards, the S-GW3 component value for the shallow soil scenario was not calculated as the anticipated difference in using the component value calculated for the greater than 2 m of overburden scenario was considered to be within the anticipated range of sampling error and the error in partitioning assumptions, and the groundwater standard remained as a final check that the pathway was protected. Since groundwater sampling may not be a part of the evaluation of excess soils, the S-GW3 shallow value was calculated to reduce the potential difference associated with using the S-GW3 value for more than 2 m of overburden. The S-GW3 shallow value is used in Tables 6 and 7 and Table 8 and 9, as both these situations assume no dilution in the aquifer (i.e. the same assumption made for the GW3 (shallow) component value in development of the brownfields groundwater standards).

3.4.3. Consideration for Standards within 30 m of Surface Water

Under O.Reg 153/04, Table 8 and 9 generic SCS are derived for one soil texture (coarse) and two land uses (Agriculture and other and R/P/I/I/C/C). For the generic excess soil reuse standards, Table 8 and 9 are derived for one soil texture (coarse) and three land uses (Agriculture and other, R/P/I and I/C/C). And, as noted in the previous section, the S-GW3 shallow component value was used in place of the S-GW3 component value.

3.4.4. Standards for Electrical Conductivity and Sodium Adsorption Ratio

Under O.Reg 153/04, the component values for electrical conductivity (EC) and Sodium Adsorption Ratio (SAR) are for the protection of plants and soil organisms. As such, in the brownfields scenario, they are removed from the soil standards for sub-surface soil (below 1.5 m depth). However, in an excess soil scenario, since there are no standards for sodium or chloride in soil to protect the soil to groundwater pathways and groundwater sampling may not be required, EC and SAR act as “surrogates” for S-GW1 and S-GW3 values for these chemicals. Therefore, the component values for EC and SAR are retained when developing soil standards for sub-surface soil, in order to maintain protection of the soil to groundwater pathways for sodium and chloride.

3.5. Changes to Key Inputs

Changes and updates were made to some key input parameters for the derivation of excess soil standards. The changes are detailed in the sections below.

3.5.1. Toxicity Reference Values (TRVs)

The following TRVs have been recently updated in the MOECC 2016 (MGRA) *Approved Model* and as such are used in development of the excess soil reuse standards:

- The chronic inhalation TRV for TCE was updated from 0.04 mg/m^3 to 0.002 mg/m^3. The new TCE TRV is based on developmental effects, the previous TRV was not. The inhalation unit risk for TCE was changed from 0.002 (mg/m^3)$^{-1}$ to 0.0041 (mg/m^3)$^{-1}$.
- The chronic inhalation TRV for tetrachloroethylene (PCE) was updated from 0.25 mg/m^3 to 0.004 mg/m^3, and the inhalation unit risk for PCE was changed from “none selected” to 0.00026 (mg/m^3)$^{-1}$.
- The chronic inhalation TRVs for ethylbenzene and bromomethane were identified as non-developmental toxicants and have been updated.
- The oral slope factor for bromoform was changed from 0.0079 to 0.011 (mg/kg-day)$^{-1}$. And, the inhalation unit risk for bromoform was changed to “none selected” from 0.0011 (mg/m^3)$^{-1}$.
- The oral chronic TRV for chloroform was changed from 0.01 to 0.015 (mg/kg-day). And, the inhalation unit risk for chloroform was changed to “none selected” from 0.0053 (mg/m^3)$^{-1}$.

The MOECC also recently reviewed and updated its selections for the following TRVs; the following values were used in the excess soil reuse standards:

Chemicals		**Oral Chronic TRV (mg/kg-day)**	**Oral Sub-chronic TRV (mg/kg-day)**	**Inhalation Chronic TRV (mg/m^3)**	**Oral Slope Factor (mg/kg-day)$^{-1}$**	**Inhalation Unit Risk (mg/m^3)$^{-1}$**
Copper	Old	0.03	none selected	none selected	no change	no change
	New	**0.01**	**0.01**	**0.05**		
Cyanide (CN-)	Old	0.02	0.05	0.008	no change	no change
	New	**0.002**	**0.006**	**0.0025**		
Dichloroethylene, 1,1-	Old	no change	no change	0.07	no change	no change
	New			**0.2**		
Dichloroethylene, 1,2-cis-	Old	0.03	0.3	0.15	no change	no change
	New	**0.002**	**0.017**	**none selected**		
Dichloroethylene, 1,2-trans-	Old	no change	0.2	no change	no change	no change
	New		**0.065**			
Ethylbenzene	Old	no change	none selected	1	no change	no change
	New		**0.4**	**2**		
Vinyl Chloride	Old	no change	no change	no change	1.4	0.0088
	New				**0.72**	**0.0044**

A brief description of the TRV selection process and an expanded table with references is provided in Appendix II.

3.5.2. *Ecotoxicity Values*

The Canadian Council of Ministers of the Environment (CCME) Soil Quality Guidelines (SQG) include an environmental health guideline for soil contact that was used in the derivation of the plants and soil organisms component value for generic brownfield soil standards. The same component value derivation method was used for the excess soil reuse standards. CCME SQG have been finalized or updated since the brownfield soil standards were developed and the following table details the values that were updated for the derivation of the excess soil reuse standards.

Chemical	Toxicity to Soil Invertebrates and plants[a]					
	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

[a] Canadian environmental quality guidelines, 1999 (as updated), Canadian Council of Ministers of the Environment, Winnipeg.

3.5.3. *Soil Allocation Factors for Inhalation Exposure Pathways*

A review of source allocation factors (SAFs) for the inhalation pathway was completed for selected chemicals by the MOECC. The review identified revised SAFs for the following chemicals. Details are presented in Appendix III.

Chemicals	**Revised Source Allocation Factor for Inhalation Pathways (S-IA and S-GW2)**
Bromomethane (a.k.a. methyl bromide)	0.5
Chloroform	0.5
Dichloroethane 1,1-	0.8
Dichloroethane 1,2-	0.8
Dichloroethylene 1,1-	0.8
Dichloroethylene trans-1,2-	0.8
Dichloropropane 1,2-	0.8
Dichloropropene 1,3-	0.8
Ethylene dibromide	0.8
Hexane	0.8
Tetrachloroethylene	0.5
Trichloroethylene	0.5
Vinyl chloride	0.8

3.5.4. *Updates to Drinking Water Quality Standards*

Several new and revised Ontario Drinking Water Quality Standards (ODWQS) and aesthetic objectives (AO), for chemicals which have excess soil reuse standards, will come into effect in 2017 and 2018. The new/updated values, shown in the following table, have been incorporated into the development of the volume independent excess soil standards.

CHEMICAL	NEW ODWQS (mg/L)	OLD ODWQS (mg/L)	NEW ODWQS EFFECTIVE DATE	Comments
Arsenic	0.01	0.025	January 1, 2018	
Benzene	0.001	0.005	January 1, 2017	
Carbon Tetrachloride	0.002	0.005	January 1, 2017	
Ethylbenzene	0.14	NV	July 1, 2017	
Ethylbenzene-AO	0.0016	0.0024	July 1, 2017	
Methyl-t-butyl ether - AO	0.015	0.015	July 1, 2017	Already used as AO based on Canadian DWQS
Selenium	0.05	0.01	July 1, 2017	
Tetrachloroethylene	0.01	0.03	July 1, 2017	
Toluene	0.06	NV	July 1, 2017	Current AO is lower, therefore no change.
Xylenes	0.09	NV	July 1, 2017	
Xylenes -AO	0.02	0.3	July 1, 2017	
Vinyl Chloride	0.001	0.002	January 1, 2017	

As detailed in the MOECC (2011) rationale document, when an ODWQS is not available, a review of other selected jurisdictions is completed, using a specific order of preference, to identify acceptable drinking water quality standards (DWQS). A review of the DWQS and toxic equivalency factors (TEFs) previously selected using this process was completed, and several updates were identified, as shown in the table below. (TEFs are used to derive DWQS for polycyclic aromatic hydrocarbons based on their toxicity relative to that of benzo(a)pyrene).

Chemical	Standard (mg/L)	Toxicity	Reference

		Equivalency Factor	
Anthracene	0.001	0.01	WHO EHC 1998
Bromodichloromethane	0.025	NA	CDWQS
Chromium VI	0.01	NA	Cal EPA
Methylnaphthalene, 2-(1-)	0.01	.001	WHO EHC 1998
Molybdenum	standard removed	NA	(previously WHO)
Naphthalene	0.01	.001	WHO EHC 1998
Pyrene	0.01	.001	WHO EHC 1998

WHO World Health Organization, Environmental Health Criteria 2. CDWQS Canadian Drinking Water Quality Standard 3. California Environmental Protection Act, Drinking Water Health Goal

3.6. Leachate Analysis

Leachate analysis has been incorporated as a mandatory component, in limited situations, of the excess soil standards to provide a more direct line of evidence to assess whether excess soil placed at a reuse site could result in unacceptable conditions in groundwater, which may then migrate to drinking water wells, under buildings or to surface water bodies. Within the brownfields redevelopment scenario (under O.Reg 153/04), there is the ability to use groundwater sampling as an additional line of evidence to confirm (or rule out) the presence of groundwater impacts. However, groundwater sampling may not be required as part of an excess soil relocation project.

Leachate analysis is required if the soil originates from an area of potential environmental concern (APEC) and if a chemical identified as a contaminant of potential concern (COPC) meets one of the following conditions: 1) soil to groundwater component values are not derived within the soil standards development process (i.e. the chemical is an inorganic compound); or, 2) the soil standard for a chemical is identified as having analytical limitations. These situations and how to identify them are described in Appendix IV. If soil does not originate from an APEC, then leachate analysis is not a required element of meeting the excess soil standards (e.g. leachate analysis is not required as part of the mandatory minimum sampling of soil from non-APEC areas of I/C/C properties). Leachate analysis is not required if the small volume standards (Table 1 or brownfields Tables 2 to 9) are applied to an excess soil volume of less than or equal to 350 m^3. Note that the small volume standards can be applied to an excess soil volume of greater than 350 m^3, but less than 1000 m^3, and the QP should consider whether leachate analysis is warranted to assess potential increased risk.

Chemicals which require leachate analysis are denoted with an “^{a}” on the excess soil standard stables and a Leachate Screening Level (LSL) is provided on the corresponding LSL table. The derivation of LSLs is described in Appendix IV.

This additional line of evidence will help to identify potential risks to groundwater and ensure the protection of human health and the environment. It also, under some conditions, results in the application of a 1000x multiplier to the soil to groundwater component values (e.g. S-GW1, S-GW2, S-GW3) prior to determination of the final soil standard, sometimes resulting in a numerically higher soil standard. Conditions for applying the multiplier to the soil to groundwater component values are detailed in Appendix IV.

3.7. Attainment of Standards

The current O.Reg 153/04 approach to meeting site condition standards is based on single sampling point compliance, in which every soil sample must be numerically equal to or lower than the applicable SCSs. However, it is recognized that this approach does not account for the variability in soil sampling and analysis. It is also important to understand how soil standards are derived and to take that into account when demonstrating the attainment of applicable soil standards. For example, if soil standards represent not-to-exceed values, the use of single sampling point is considered appropriate. However, if the standard is derived to represent an average limit, the use of an appropriate statistical test (e.g. an upper confidence limit of the mean) is deemed acceptable. In addition to the existing single sampling point compliance approach, the MOECC has developed a new attainment approach for excess soil reuse standards, which allows more flexibility and provides a better representation of the soil quality when there is a sufficient soil data set for use of the statistical tests.

3.7.1. Statistical Compliance Approach

In this new attainment approach, excess soil is deemed to meet applicable standards if the following requirements are met:

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

Requirement 1 is intended to, through the use of a statistical approach, account for the potential variability in soil sampling and analysis yet ensure that the overall soil quality meets the applicable excess soil standard. It permits some soil (up to 10% of samples) to be higher than the standard. Requirement 2 is intended to both help identify unique populations (which may indicate areas of impact), and to ensure that any volume of soil does not pose unacceptable risks to human health and the environment (as discussed in Appendix V). Requirement 3 is intended to provide some certainty that the overall soil quality is meeting the standard, and that the statistics used to demonstrate this are supported with a comparable data set – i.e. do not indicate a large variance in the data illustrating the possibility of poor representation of true soil quality, or unique populations.

The use of this attainment approach requires that any mandatory leachate analysis results meet the applicable LSLs. The attainment approach also requires at least 20 soil sample results, which should be collected from excess soil that has similar soil characteristics and may be impacted by similar processes. This requirement is independent of the number of soil samples required by sampling frequencies detailed in the regulation, 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 should be used for each sample.

3.7.2. Other Considerations for Using the Statistical Compliance Approach

The user should be familiar with statistical methods and/or consult with someone having this expertise when evaluating the excess soils data set. The QP 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. This is an example of an area where software such as ProUCL can be an excellent resource as it takes into consideration the data distribution, sample size, skewedness 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 it can identify valuable information in terms of soil quality, as well as informing the best approach for developing the statistics used when evaluating whether the Attainment Requirements have been met. An examination of the data set may indicate that it is either normally distributed or non-normally distributed, which each compel different statistical tests in order to be representative of the excess soil. This may be because there is an area of the property containing impacted soil which has significantly different concentrations than the rest of the property. Varying concentrations may also be found when sampling at different soil depths – e.g. some samples are taken at the soil surface (e.g. top 1.5m) and other samples from depth (e.g. below 1.5m), and soil types. Where these situations occur, an evaluation of the data set by someone with the necessary statistical expertise and using statistical software (such as ProUCL) will lead to more defensible conclusions and may help to drive better excess soil management decisions. For example, the segregation and removal/disposal of a particular volume of soil that may be impacted, as represented by a few data points (e.g. an area or "hot spot" on the site where a spill occurred that comes across statistically as a unique population), may permit the remaining volume of soil to meet the Attainment Requirements (less variability in the UCLM, and elimination of measurements above the applicable ceiling value). Alternatively, the data may be separated in to two distinct populations and managed differently, e.g., as soil that is deemed to be Table 1 quality and soil that is some other quality (e.g. Tables 2 or 3).

4. Using the Excess Soil Standards

A key objective of the Excess Soil Reuse Regulation is to ensure that excess soil quality is characterized and only deposited at reuse sites that are appropriate and to achieve this, rules for using the excess soil standards are provided in the regulation. Otherwise, selection of the appropriate table of standards would be made by a QP, with consideration of how the excess soil standards were derived and using any associated rules for application of the standards at reuse sites in environmentally sensitive areas and on agricultural land as detailed in Section 6.

When the excess soil standards are used it is important that the QP is familiar with the limitations of the standards, that the correct table be selected based on the conditions at the reuse site and that the key assumptions used to develop the excess soil standards remain applicable, as determined by a QP. The following sections detail some of the main limitations to be considered by QPs when assessing whether use of the excess soil standards is appropriate, and if it is, provides key site conditions that should be considered to inform selection of the most appropriate table of excess soil standards for a particular reuse site.

4.1. Limitations of Excess Soil Reuse Standards

Conditions can exist at a site which are not consistent with the assumptions used to develop the generic excess soil standards and which may result in the standards not being appropriate for excess soil reuse at a particular site. The opposite is also true in that site specific conditions may offer greater protection due to a particular combination of site characteristics.

The presence of any of the conditions listed below does not necessarily indicate that the excess soil standards are not valid for a given site. This is also true for the brownfields generic site condition standards. The MOECC (2011) *Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario* (Page 16) 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 MOECC (2011) rationale document and provides a brief discussion on this.

> *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 QP should consider these types of factors in assessing appropriateness of the use of the Generic Site Condition Standards.*

Impacted Soil Volume and Dimension: The volume specific standards (e.g. small volume) rely on assumptions of a finite volume and source depletion. The total impacted area at the reuse site, including both excess soil and any existing impacted soil, is estimated and used to select the applicable excess soil standards. It is important to note that if the total impacted zone has a volume or dimensions that are greater than what are assumed in the development of selected excess soil standards, pathways which employ source depletion or groundwater transport (e.g., Soil Odour, S-GW1, S-GW2, S-IA, S-GW3 components of the standards) may not be appropriately protected. Of particular note is the assumption of a 2m thickness of impacted soil, as a greater thickness may impact the amount of vapour which migrates to indoor air. Should the reuse site be known to already contain impacted soil, consideration should be given to whether or not the addition of additional impacted soils may invalidate some of the assumptions within the small volume excess soils standards. Without such knowledge and consideration, it may be more appropriate to use the Volume Independent standards.

Presence of Exposure Pathway Not Considered for the Development of Excess Soil Standard: If any exposure pathways listed in Section 2.2 is applicable for a given site, or if another exposure pathway not considered in the development of the standards is present, then the use of the excess soil standards presented may not be protective of that exposure.

Presence of a Chemical for Which Excess Soil Standards are Not Derived: If a chemical is known or suspected to be present in excess soil and has the potential to negatively impact human health or the environment and an excess soil standard is not derived for that chemical, use of the excess soil standards will not protect for that potential exposure.

Soil with high permeability: If a high permeability zone is present in the vadose zone which provides a direct preferential pathway to a building then the soil properties assumed in the generic Johnson & Ettinger (J&E) modelling to determine the S-IA and S-GW2 components of the standard may not be appropriate.

High building susceptibility to soil vapour entry: If site buildings have characteristics that vary significantly from the generic assumptions (e.g. commercial building with a basement) this could result in enhanced transport of vapour into a building and the S-IA and S-GW2 component values may be non-conservative.

Significant preferential pathways: The development of excess soil standards assumes that preferential pathways (e.g. which may be caused by shallow bed rock, gas under pressure, utility conduits that directly connect the contamination source to the enclosed space of the building, etc.) are not present. If preferential pathways are identified, the S-IA and the soil to groundwater pathways may be non-conservative.

Organic carbon content: If the average organic carbon content (foc) of soil above the water table is <0.002 then more contaminant may be in the water and gas phases than assumed in the excess soil standards.

Continuous source: If there is a continuous source of contamination then the pathways which assume a depleting source (i.e., S-IA, S-GW1, S-GW2, S-GW3, and S-Odour) in the development of volume specific standards may be non-conservative.

4.2. Selection of Appropriate Table of Standards

Once it is established that use of the generic tables of excess soil standards is appropriate, it is important that the correct table be selected based on conditions at the reuse site. The key site conditions that QPs should assess to inform selection of the most appropriate table of excess soil standards for a particular reuse site are the same as those used to select an applicable site condition under O.Reg 153/04 and are documented in the Excess Soil Reuse Regulation. In summary, the key 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. The requirements for assessing each of these conditions are generally the same as under O.Reg 153/04 and documented in the Excess Soil Reuse Regulation. As generic excess soil reuse standard tables are only derived for one grain size (coarse), assessment of soil texture is not required.

The following table provides a screening matrix of key site conditions and how they impact table selection.

Site Condition Table / Conditions of Use	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, or is adjacent to or within 30 m of, an Environmentally Sensitive Area.	x	x	x	x	x	x	x	x
Use of non-potable standards has not been approved by Municipality	✓	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	✓	✓	✓
Sub-surface soil (soil > 1.5 m below ground surface) will be maintained at > 1.5 m below ground surface.	✓	✓	✓	✓	✓	✓	✓	✓

X This Table should not be used without further assessment.

✓ This Table may be acceptable, see Section 4.1 for other considerations.

For ease of reference, the tables of excess soil standards have been labeled in the same order as the brownfields tables, (i.e. 2 through 9), with an extension of ".1" for the volume independent tables. The corresponding tables of LSLs and ceiling values are numbered in a similar manner.

Table Description	Small Volume (up to 350 m^3) (or up to 1000 m^3 with rationale provided by a QP)	Volume Independent
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

* or shallow groundwater (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)

As with the brownfields tables, for R/P/I and I/C/C property use all tables are available, but for "Agricultural and other property use", non-potable and stratified tables are not available.

Each table of volume independent standards and Table 1 have two (2) corresponding tables, one containing LSLs and the other Ceiling Values. For example, chemicals marked with a superscript "a" in the Table 3.1 – Excess Soil Reuse Standards, if they are a contaminant of potential concern, must meet the LSLs provided in Table 3.1 – Leachate Screening Levels. If the attainment approach detailed in Section 7 will be used, the ceiling values that apply to the Table 3.1 – Excess Soil Standards are those in Table 3.1 – Ceiling Values. All tables of excess soil standards and corresponding leachate screening levels and ceiling values are provided in Part IV of the MOECC document on *"Rules for On-Site and Excess Soil Management"*.

5. Site Specific Excess Soils Standards Development

Determining acceptable soil quality for a given reuse site may also be achieved through the development of site-specific excess soil standards that better reflect the conditions of that particular reuse site. This kind of site specific assessment may identify site conditions which may provide for greater protection than what is assumed generically in the tables of generic excess soils standards; accounting for these site-specific conditions could lead to the development of site-specific standards which can in turn result in greater reuse options for excess soils.

The MOECC has developed a spreadsheet based tool (the "Beneficial Reuse Assessment Tool" (BRAT)) that will allow for the convenient development of site specific excess soils standards, when certain conditions are met. The BRAT allows for modification of the generic excess soils standards using site specific information. This approach relies on more detailed knowledge of the excess soil reuse site than is required to apply the generic standards, which can significantly change what is deemed to be acceptable soil quality. BRAT also has the ability to reflect more site specific land use characteristics, such as no building development or soil placed at depth.

The tool was developed to guide the user through a series of questions, first to determine if the use of BRAT is permitted and then to identify properties of the excess soil and physical and site use characteristics of the reuse site, to generate a site-specifc table of standards. This approach has the benefit of permitting a number of different combinations, permutations and modifications of generic assumptions, as opposed to having each of the site conditions preselected by the MOECC as is done in Tables 2-9 in O.Reg 153/04 and in the excess soil volume independent tables.

The information required to provide a suitable rationale to support modification of soil and site characteristics is similar to that required under O.Reg 153/04 to use Modified Generic Risk Assessment (MGRA), and at a minimum, would include the requirements of Table 4, Schedule E of that regulation.

The use of BRAT requires a QP ESA or QP RA and is not permitted within environmentally sensitive areas (ESAs). Other site specific standard development options which may rely in part on BRAT include risk assessment if permitted through a site specific instrument. Refer to the Excess Soil Reuse Regulation regarding requirements for risk assessment.

6. Additional Considerations When Using Generic Excess Soils Standards

The following sections describe where limitations associated with specific excess soils standards may warrant additional consideration and/or requirements to ensure they are applied appropriately.

6.1. Special Rules When Applying Excess Soil Reuse Standards

The Regulation includes “special rules” that apply to the Excess Soil Standards and the placement of excess soil at reuse sites. These rules are intended to help protect agricultural land and *Environmentally Sensitive Areas* from potential impacts. These types of properties may have unique circumstances or receptors which are not accounted for in the derivation of the Excess Soils Standards and so these 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 anticipated such as when naturally occurring local background conditions may be elevated relative to the excess soil reuse standards. Part IV of the MOECC document on *“Rules for On-Site and Excess Soil Management”* lays out these rules in greater detail.

6.2. Application of Agricultural Standards

The Agricultural site condition standards do not include consideration of plant uptake of contaminants and the subsequent ingestion by people or livestock. The information available at the time of developing brownfields standards was not sufficient to develop adequate component values for this exposure scenario. Redeveloping brownfields to an agricultural land use is not as likely or as common as the reuse of excess soils at Agricultural properties and so the absence of this exposure scenario becomes more relevant and important for excess soils 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 that will be consumed, the excess soil must meet Table 1 of O.Reg 153/04 and if from an area of potential contamination, must also meet the applicable LSLs as outlined in Part IV of the MOECC document on *"Rules for On-Site and Excess Soil Management"* regarding Soil Originating from areas of potential environmental concern (APEC). Refer to the Excess Soil Reuse Regulation regarding this requirement.

In addition, Agricultural standards do not include consideration of soil fertility. Soil fertility is considered as part of good farm practices and general guidance to farmers on importation of excess soil to agricultural properties is available in the Ontario Ministry of Agriculture Food and Rural Affairs (OMAFRA) fact sheet available here: http://www.omafra.gov.on.ca/english/engineer/facts/16-055.htm.

7. References

Ministry of the Environment and Climate Change (MOECC, formerly known as Ministry of the Environment), 2011. Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario. (https://www.ontario.ca/document/rationale-development-soil-and-ground-water-standards-use-contaminated-sites-ontario)

MOECC, 2016a. Modified Generic Risk Assessment. (https://files.ontario.ca/2016_modified_generic_risk_assessment_model.xlsx)

MOECC, 2016b. A Guide to Using the "Approved Model" (November, 2016) When Submitting A Modified Generic Risk Assessment. (https://www.ontario.ca/page/guide-using-approved-model-when-submitting-modified-generic-risk-assessment

APPENDIX I

Consideration of Vapour Intrusion Assessment in the Development of Excess Soil Reuse Standards

Consideration of Vapour Intrusion Assessment in the Development of Excess Soil Standards

I.1. Background

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

The MOECC reviewed key assumptions and modelling approaches used to develop the brownfield SCSs in conjunction with consultation with external stakeholders and jurisdictional review. This work identified two vapour intrusion components (S-IA and soil to groundwater to indoor air (S-GW2)) as applicable checks to ensure that building occupants are conservatively protected when excess soils are being placed at a reuse site. Note that the soil to groundwater to indoor air (S-GW2) pathway is not included in the development of the SCSs as this component generally does not drive a soil value to below an S-IA value under brownfield generic settings. However, the inclusion of the S-GW2 component in excess soil standards is considered a necessary check as there is no groundwater monitoring may not be required to confirm an acceptable protection of groundwater.

This appendix presents 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 value, 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 MOECC (2011) *Rationale for the development of soil and ground water 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 will be protective of indoor air toxicity reference values (TRVs) and odour; and,
- Source depletion due to mass loss from volatilization into buildings is also considered to reflect the potential 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 a VOC, 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 (refer herein 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 herein as zone of vapour intrusion influence); therefore mass loss due to volatilization and transport of VOC into indoor air can be assumed to occur within this zone and is incorporated in the development of source depletion multipliers (SDMs). It is 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 on how to determine the extent of 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 and (2) PHC compounds.

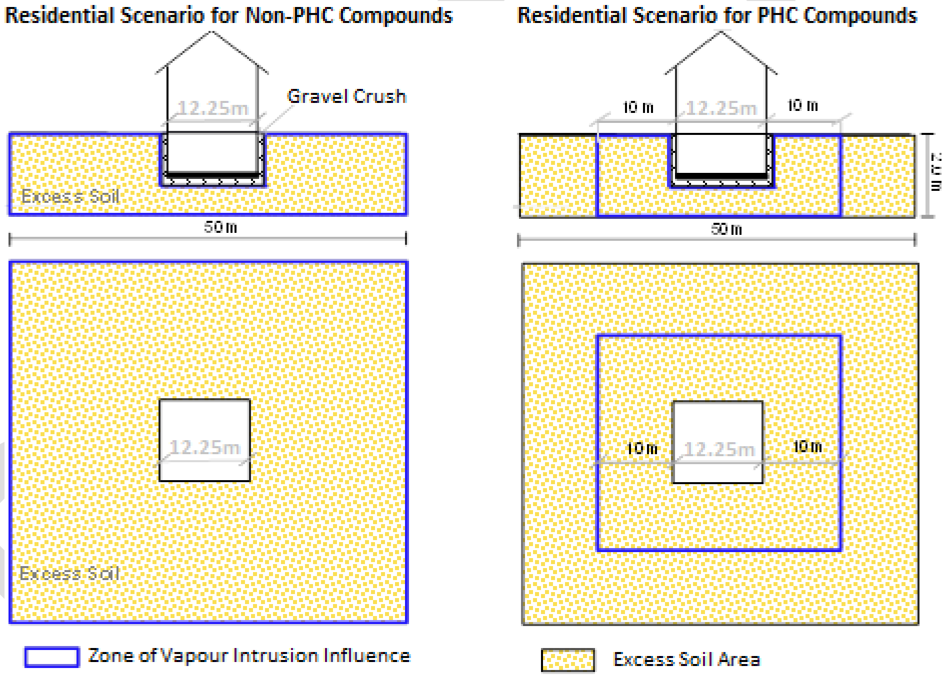

Figure I. 1. Site Plan (Lower) and Cross Sectional (Upper) View of Excess Soil Area and Zone of Vapour Intrusion Influence

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 substance that leaches from soil to groundwater, migrates down-gradient and potentially moves upward to overlying buildings (either on- or off-site). The conceptual model for the S-GW2 pathway is illustrated in Figure I.2

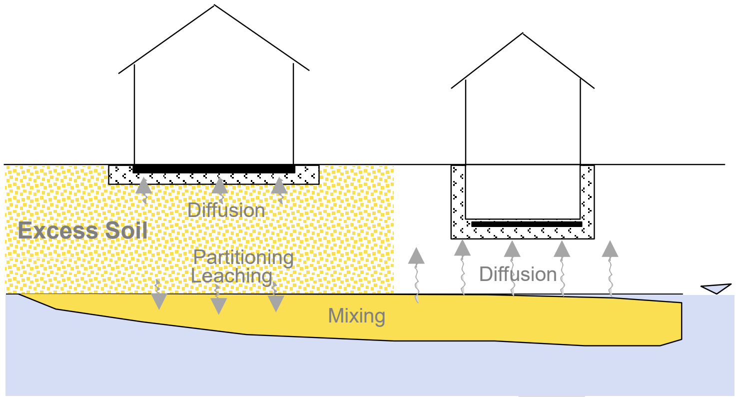

Figure I.2. Conceptual Model for the Soil to Groundwater to Indoor Air (S-GW2) pathway

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 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 MOECC (2011) rationale document.
- A soil to soil leachate partitioning component coupled with a vertical transport model of leachate to the groundwater 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 the atmosphere considered to reflect the potential reduction of soil contamination over time.

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

Recharge through the contaminated soil area leaches dissolved substances to an underlying aquifer via a mixing cell and transport downgradient in groundwater. Volatile substances in the impacted groundwater may then migrate upward to the 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

$$S - GW2 = C_{leachate} \cdot \left(K_{oc} \cdot f_{oc} + \frac{\eta_w + H' \cdot \eta_a}{\rho_b} \right)$$ (Equation 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, shown as below. Please refer to Section 7.6 of the MOECC (2011) rationale document for the derivation approach of GW2 component values.

$$C_{leachate} = GW2 \left\{ 1 + \left(\frac{K_h \cdot C \cdot i_h \cdot B}{q_{surface} \cdot L} \right) \right\}$$ (Equation 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;
$q_{surface}$ = Recharge rate through soil to water table (m/year);
L = Length of source of contaminated soil in direction of groundwater flow (m);
C = Unit conversion ($60 \cdot 60 \cdot 24 \cdot 365.25$) from meter per second (m/s) to meter per year (m/year).

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 thus 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 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 Contaminant in Excess Soil

Initial mass of contaminant in excess soil is determined as below

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

where:

Mass 1 = Initial mass of contaminant 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 Contaminant Mass Remaining after One Week of Volatilization to Atmosphere and Leaching to Water Table

As explained in the MOECC (2011) rationale document, one week was arbitrarily chosen to be sufficiently short to be approximated by using a a constant removal rate of the exposure concentration rather than one that declines with time. Mass of contaminant 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:

$$Mass\ 2 = Mass\ 1 - \left(\frac{C_{leachate} \cdot C_1 \cdot A_s \cdot q_{surface}}{52\left(\frac{week}{year}\right)}\right) - \left(J \cdot A_s \cdot C_2 \cdot \frac{365.25 - frozen\ days}{365.25}\right) \qquad \text{(Equation 4)}$$

where:

Mass 2 = contaminant 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); and,

C_1 = Unit conversion (1000) from litter (L) to cubic meter (m^3).

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

C_1 = Unit conversion (60·60·24·7) 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 MOECC (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 contaminant.

$$t_{1/2} = \frac{-\ln(2) \cdot 1 week}{ln\frac{Mass\ 2}{Mass\ 1} \cdot \frac{365.25}{7}} \qquad \text{(Equation 5)}$$

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:

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

Similar to 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 criteria (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 MOECC (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 health-based IAC within the allotted 3 or 5 years, resulting in a 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.3. 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 toxicologically-derived indoor air concentrations. 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 is considered to be "volatile", 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 health-based indoor air concentration (HBIAC) to determine if the volatile chemical can reach indoor air concentrations that be of concern for vapour intrusion, as follows:

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

I.4 References

Ministry of the Environment and Climate Change (MOECC, formerly known as the Ministry of the Environment), 2011. Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario.

APPENDIX II

Updates to Human Health Toxicity References Values (TRVs)

Updates to Human Health Toxicity References Values (TRVs)

In order to keep up-to-date with recent science, on an ongoing basis Technical Assessment and Standards Development Branch (TASDB) identifies and reviews TRVs derived by various government agencies. The most scientifically sound TRVs are then selected for use in some TASDB programs. In cases where more than one TRV is considered acceptable, they may be selected together. On occasion, TASDB may modify an agency's TRV if the modification can be sufficiently supported with scientific evidence or is otherwise straightforward. Table II.1 present the updated TRVs for 12 chemicals.

As part of the TRV selection process, a confidence rating is assigned to TRVs that are assessed. In some cases, as with the inhalation chronic non-cancer TRV for *cis*-1,2-dichloroethylene, an available TRV that may be assigned a rating of low confidence will not be selected for the derivation of generic soil standards. However, if a TRV is required in such a case (e.g. site-specific risk assessment), 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 other means.

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

Table II.1: Updated Human Health Toxicity Reference Values

Chemicals		Oral Chronic TRV (mg/kg-day)	Ref.	Oral Sub-chronic TRV (mg/kg-day)	Ref.	Inhalation Chronic TRV (mg/m^3)	Ref.	Oral Slope Factor (mg/kg-day)$^{-1}$	Ref.	Inhalation Unit Risk (mg/m^3)$^{-1}$	Ref.
Bromoform*	Old	no change in TRV		no change in TRV		none selected		0.0079	US EPA IRIS 1991**	0.0011	US EPA IRIS 1991**
	New							**0.01**	**Cal EPA 2003**	**none selected**	
Chloroform*	Old	0.01	US EPA IRIS 1991**	no change in TRV		no change in TRV		0.031	Cal EPA ARB 1990**	0.0053	Cal EPA ATH 2005**
	New	**0.015**	**WHO CICAD 2004**					**none selected**		**none selected**	
Copper	Old	0.03	HC DW 1992**	none selected		none selected		none selected		none selected	
	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; CCME 1997**	0.05	ATSDR 2006**	0.008	MOE Air 2005**	none selected		none selected	
	New	**0.002**	**mod US EPA IRIS 2010**	**0.006**	**mod US EPA IRIS 2010**	**0.0025**	**mod US EPA IRIS 2010**				
Dichloroethylene, 1,1-	Old	no change in TRV		none selected		0.07	Cal EPA chREL 2000**	none selected		none selected	
	New					**0.2**	**US EPA IRIS 2002; WHO CICAD 2003**				
Dichloroethylene, *cis*-1,2-	Old	0.03	mod RIVM 2001**	0.3	ATSDR 1996; mod RIVM 2001**	0.15	mod RIVM 2001**	none selected		none selected	
	New	**0.002**	**US EPA IRIS 2010**	**0.017**	**US EPA PPRTV 2011**	**none selected**					
Dichloroethylene, *trans*-1,2-	Old	no change in TRV		0.2	ATSDR 1996; mod US EPA IRIS 1989**	no change in TRV		none selected		none selected	
	New			**0.065**	mod US EPA IRIS 2010						

Chemicals		**Oral Chronic TRV** (mg/kg-day)	**Ref.**	**Oral Sub-chronic TRV** (mg/kg-day)	**Ref.**	**Inhalation Chronic TRV** (mg/m^3)	**Ref.**	**Oral Slope Factor** (mg/kg-day)$^{-1}$	**Ref.**	**Inhalation Unit Risk** (mg/m^3)$^{-1}$	**Ref.**
Ethylbenzene	Old	no change in TRV		none selected		1	US EPA IRIS 1991**	none selected		none selected	
	New			**0.4**	**ATSDR 2010**	**2**	**Cal EPA chREL 2000**				
Tetrachloroethylene*	Old	0.014	HC 1996; WHO DW 2003**	no change in TRV		0.25	WHO Air 2000**	none selected		none selected	
	New	**0.006**	**US EPA IRIS 2012**			**0.04**	**US EPA IRIS 2012**	**0.002**	**US EPA IRIS 2012**	**0.00026**	**US EPA IRIS 2012**
Trichloroethylene*	Old	0.0015	HC DW 2005**	none selected		0.04	USEPA NCEA 2001D**	0.013	Cal EPA DW 1999**	0.002	Cal EPA ATH 2005**
	New	**0.0005**	**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	no change in TRV		no change in TRV		no change in TRV		1.4	US EPA IRIS 2000**	0.0088	US EPA IRIS 2000**
	New							**0.72**	WHO DW 2004/ 2011	**0.0044**	US EPA IRIS 2000; MOE Air 2005

* Updated in MOECC (2016) Modified Generic Risk Assessment (MGRA) Approved Model

** References listed in MOECC (2016) Modified Generic Risk Assessment (MGRA) Approved Model and MOECC (2011) Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario

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APPENDIX III

Updates to Soil Allocation Factors for Inhalation Exposure Pathways

Updates to Soil Allocation Factors for Inhalation Exposure Pathways

The following discussion explains the approach used for estimating and recommending Source Allocation Factors (SAFs) to be applied in conjunction with inhalation non-cancer toxicity reference values (TRVs) to derive component values or standards.

It is important to note that a SAF is not only contaminant-specific, but it is also specific to the TRV and the use of that TRV in deriving a component value or standard. Thus, if a new TRV is selected for use, a new SAF must be estimated.

Departing from the default SAF of 20% is based on a comparison between estimated intakes and the TRV. Basically, if estimated background exposures are relatively low, then more of the TRV can be allocated to the derivation of a component value or standard. If background exposures are relatively high, then additional exposures should be minimized by allocating only 20% of the TRV to the component value or standard being derived. The following procedure was used to estimate a SAF:

1) The critical effect of the TRV was identified as being either a route-of-entry effect or a systemic effect.

2) If the critical effect of the TRV is 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:
    a. A 95th percentile (if available) or 90th percentile air concentration was obtained from available literature.
    b. Canadian air concentrations were preferred to air concentrations measured in the U.S. or other countries.
    c. The higher of indoor and outdoor air measurements was used.
    d. The upper estimate (95th or 90th percentile) of the background air concentration was directly compared to the inhalation TRV.

3) If the critical effect of the TRV is a systemic effect, all background exposures (from all media) were considered to contribute to the body burden of exposure. Background exposures from all media were summed:
    a. Upper estimate air concentrations were estimated as described above.
    b. Central tendency estimates of background intake rates from other media were identified from the literature. Although Canadian data were preferred, data from the U.S. and other countries were sometimes considered. Also, although central tendency values were preferred for media other than air, other estimates were sometimes considered.
    c. Media concentrations were converted to estimated intake rates using the following exposure parameters: drinking water ingestion rate of 2 L/day, inhalation rate of 20 m^3/day, soil ingestion rate of 100 mg/day, and body weight of 70 kg. For the sake of simplicity, estimates of relative absorption were all assumed to be 100%.
    d. To obtain total background intakes, upper estimates of intake from air (in µg/kg/day) were summed with central tendency estimates of intakes (in µg/kg/day) in from other media.
    e. The background intake (in µg/kg/day) was then compared to the inhalation non-cancer TRV (converted to an equivalent in µg/kg/day).

4) This approach uses only 3 possible values for the SAF: 20% (which is equivalent to the current default), 50%, or 80%.
    a. A SAF of 20% was recommended when the estimated background exposures were near, at, or exceeding the TRV. A factor of 20% is a reasonable low end SAF that does not excessively restrict a medium that is not responsible for the majority of exposures to a substance. Also, 20% would not contribute significantly more to existing background exposures. For example, in a toxicological study, the effects noted in a group exposed to 10 µg/kg/d would likely be indistinguishable from effects in a group exposed to 12 µg/kg/d in the same study.
    b. A SAF of 50% was recommended when the estimated background exposures were approximately one-half of the TRV.
    c. A SAF of 80% was recommended when the estimated background exposures were near or below 20% of the TRV.

Please note also the following:

- The SAFs are generally determined using upper estimates of exposure. Therefore, in a scenario where a contaminant enters indoor air from both soil & groundwater at a particular site, it's unlikely that the actual combined concentrations would exceed the TRV.

- For volatile organic chemicals, intake from drinking water tends to be minimal compared to other media. Therefore, the SAF recommendations do not change for sites with potable or non-potable GW.

The above approach was used to estimate and recommend SAFs for 15 selected volatile organic chemicals for which the presence in subsurface sources (*e.g.*, impacted soil or groundwater) has the potential to pose unacceptable human health risks due to vapour intrusion. Rationales and the recommended SAFs are presented in the Table III.1.

Table III.1: Contaminant-Specific Source Allocation Factors (SAFs) for Soil-to-indoor-air (S-IA) and Groundwater-to-Indoor-Air (GW2) for Selected Chemicals

Chemicals	**Inhalation Non-Cancer TRV Most Recently Selected**		• **Background/Baseline Exposure Estimates**			**SAF Recommendations (20%, 50%, or 80%) for S-IA (soil to indoor air) on potable and non-potable GW conditions and for GW-2 (GW to indoor air)**
	Value (mg/m^3) Agency / Year	**Systemic or Route-of-Entry? / Critical Effect**	**Indoor & outdoor air concentrations (µg/m^3)**	**Comparison of Intake Rates from Various Media (µg/kg/d)**		
benzene	3 x 10^{-2} mg/m^3 = 30 µg/m^3 [≈ 9 µg/kg/d] (US EPA IRIS 2003)	Systemic effect: ↓ lymphocyte count	• Canada indoor: 90/95th %iles 3.643 - **21.010 µg/m^3** (HC IAQ studies) • 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	Indoor air concentrations are typically higher than outdoor air. 95th percentile indoor air concentrations in Canada are up to 21 µg/m^3 which is more than 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 are likely negligible in comparison to air. Intakes from diet (and 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% SAF** is recommended.
				DW	• Treated water across Ont (MOECC 2017): median 0.32 µg/L (~0.009 µg/kg/d), 95th %ile 0.50 µg/L (~0.014 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	• Very volatile, thus not expected in surface soil.	
				consumer products	• cigarette smoking 1800-7900 µg/d (FAO/WHO 2009) → ~26-110 µg/kg/d. • passive smoking 6-63 µg/d (FAO/WHO 2009) → 0.09-0.9 µg/kg/d	
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 <DL; NY state median <0.25, 95th %ile 0.9, 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)	air	• Not relevant since 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 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. 2.2 µg/m^3 is approximately 50% of the TRV, leaving the remaining **50% to be allocated to S-IA or GW-IA**.
				DW		
				food		
				soil/dust		
				consumer products		
carbon tetrachloride (CCl$_4$)	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.	Intake from DW (Ont usually < 0.014 µg/kg/d, US typical 0.01 µg/kg/d) is minimal compared to intake from 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.
				DW	• Ont DW rarely > 0.5 µg/L → 0.014 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 GW samples were <DL, but some may be up to 29 or 720 µg/L (ATSDR 2005) • If at DW standard 5µg/L, then 0.14 µg/kg/d	
				food	• Levels in most foods: <DL (ATSDR 2005)	
				soil/dust	• Expected to volatilize rapidly from soil due to high vapour pressure (ATSDR 2005)	
				consumer products	• Banned from consumer products (ATSDR 2005)	

Chemicals	Inhalation Non-Cancer TRV Most Recently Selected		• Background/Baseline Exposure Estimates			SAF Recommendations (20%, 50%, or 80%) for S-IA (soil to indoor air) on potable and non-potable GW conditions and for GW-2 (GW to indoor air)
	Value (mg/m^3) Agency / Year	Systemic or Route-of-Entry? / Critical Effect	Indoor & outdoor air concentrations ($\mu g/m^3$)	Comparison of Intake Rates from Various Media (µg/kg/d)		
chloroform	0.1 mg/m^3 = 100 $\mu g/m^3$ [≈ 30 µg/kg/d] (ATSDR 1997)	Systemic effect: Liver toxicity	• Canada indoor: 90/95th %iles 3.267 - **11.480** $\mu g/m^3$ (HC IAQ studies) • US indoor: 95th %iles 4.1 -7.5 $\mu g/m^3$ (US EPA 2011) • Canada outdoor: 90/95th %iles 0.099 - 1.121 $\mu g/m^3$ (HC IAQ studies) • US outdoor: means <0.10 - 0.12 $\mu g/m^3$	air	• 11.480 $\mu g/m^3$ → ~ 3.3 µg/kg/d	Estimated intakes are ~3.3 µg/kg/d (95th %ile) from air, 0.7-10 µg/kg/d from DW, ~1 µg/kg/d (mean) from diet, + ~6.5 µg/kg/d from swimming (for those who swim) for a total of 11.5 - 20.8 µg/kg/d, which is approximately 50% of the TRV. Thus a **50% SAF** is recommended. [Additional support: For general Canadian population, estimates are ~1-10 µg/kg/d & max ~100 µg/kg/d (HC PSL 2001). Based on US biomonitoring data, Tan et al. (2007) estimated total background intakes of ~0.5 µg/kg/d (CT) & >5 µg/kg/d (upper estimate).]
				DW	• Mean intakes ~ 0.7 µg/kg/d (WHO DW 2004). Up to 10 µg/kg/d for some (WHO DW 2004).	
				food	• mean intakes ~ 1 µg/kg/d (WHO DW 2004)	
				soil/dust	• Very volatile, thus not expected in surface soil.	
				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.	
1,1-dichloroethane (1,1-DCA)	0.17 mg/m^3 = 170 $\mu g/m^3$ [≈ 50 µg/kg/d] (modified from US EPA HEAST 1984)	Systemic effect: Kidney toxicity	• Canada indoor: 95th %iles <0.013 - **0.040 $\mu g/m^3$** (HC IAQ studies) • US indoor: 95th %iles <DL $\mu g/m^3$ (US EPA 2011) • Canada outdoor: 95th %iles <DL $\mu g/m^3$ (HC IAQ studies) • US outdoor: means <DL $\mu g/m^3$	air	• 0.040 $\mu g/m^3$ → 0.01 µg/kg/d	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.
				DW	• U.S. DW usually <**10 µg/L** (WHO DW 2003a) → ~0.3 µg/kg/d • (Max U.S. well water 60 µg/L (ATSDR 2015) → 1.7 µg/kg/d)	
				food	• Low bioaccumulation potential (ATSDR 2015). • Not found in most foods (ATSDR 2015).	
				soil/dust	• High mobility in soil, thus rapid movement to other media (ATSDR 2015)	
				consumer products	• No information identified	
1,2-dichloroethane (1,2-DCA)	0.4 mg/m3 = 400 $\mu g/m^3$ [≈ 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** $\mu g/m^3$ (HC IAQ studies) • US indoor: 95th %iles <DL - 1.1 $\mu g/m^3$ (US EPA 2011) • Canada outdoor: range: <DL - 1.033, 90/95th %iles <DL - 0.1 $\mu g/m^3$ (HC IAQ studies) • US outdoor: means 0.405 - 6.07 $\mu g/m^3$ (ATSDR 2001)	air	• 5.492 $\mu g/m^3$ → **~1.6 µg/kg/d**	Intakes from DW and soil are very low compared to air. Canadian indoor 95th percentile of 5.492 $\mu g/m^3$ (or even the indoor max of 23 $\mu g/m^3$) is considerably lower than the TRV of 400 $\mu g/m^3$. A **SAF of 80%** is recommended.
				DW	• Canada: most DW supply samples range: <DL - 1 µg/L (HC DW 2014) → 0.03 µg/kg/d • Treated water across Ont (MOECC 2017): median 0.2 µg/L (~0.006 µg/kg/d), 95th %ile 0.5 µg/L (**~0.014 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	• Evaporates to air very quickly from soil (ATSDR 2001) thus not expected in surf soil.	
				consumer products	• In past was in adhesives & cleaners but discontinued for some time (HC DW 2014). 1,2-DCA may be in cigarette smoke.	

Chemicals	Inhalation Non-Cancer TRV Most Recently Selected		• Background/Baseline Exposure Estimates			SAF Recommendations (20%, 50%, or 80%) for S-IA (soil to indoor air) on potable and non-potable GW conditions and for GW-2 (GW to indoor air)
	Value (mg/m^3) Agency / Year	Systemic or Route-of-Entry? / Critical Effect	Indoor & outdoor air concentrations (µg/m^3)	Comparison of Intake Rates from Various Media (µg/kg/d)		
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 2013)	air	• 90th %ile 0.83 µg/m^3 → ~ **0.24 µg/kg/d**	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.
				DW	• - Treated water across Ont (MOECC 2017): median 0.3 µg/L (~0.009 µg/kg/d), 95th %ile 0.5 µg/L (**~0.014 µg/kg/d**). - Canadian upper bound intake: 0.003 - 0.01 µg/kg/d (EC/HC 2013) - US medians: Public wells 0.20 µg/L (~0.006 µg/kg/d), Domestic wells 0.026 µg/L (0.0007 µg/kg/d) [EC/HC 2013]	
				food	• Upper bound intake **0.2 - 1.3 µg/kg/d** (EC/HC 2013)	
				soil/dust	• Evaps to air very quickly from soil (ATSDR 1994). Upper bound intake <0.001 µg/kg/d (EC/HC 2013)	
				consumer products	• Used mainly as an industrial solvent (EC/HC 2013).	
***trans*-1,2-dichloroethylene (trans-1,2-DCE)**	0.06 mg/m3 = 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**	95th percentile of air (0.3 µg/m^3) is considerably lower than the TRV of 60 µg/m^3. DW upper estimates were not available, but even if DW were consumed at the concentration of the Ont. DW standard of 20 µg/L, the resultant intake of ~0.6 µg/kg/d is still considerably lower than the inhalation 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.
				DW	• DW standard 20 µg/L at 2 L/d → ~0.6 µg/kg/d. Avg DW concs: 0.23 to 2.7 µg/L → 0.007 to 0.08 µg/kg/d (ATSDR 1996).	
				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).	
				consumer products	• No information identified.	
1,2-dichloropropane	0.004 mg/m3 = 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)	air	• Not relevant since 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.
				DW		
				food		
				soil/dust		
				consumer products		

Chemicals	Inhalation Non-Cancer TRV Most Recently Selected		• Background/Baseline Exposure Estimates			SAF Recommendations (20%, 50%, or 80%) for S-IA (soil to indoor air) on potable and non-potable GW conditions and for GW-2 (GW to indoor air)
	Value (mg/m^3) Agency / Year	Systemic or Route-of-Entry? / Critical Effect	Indoor & outdoor air concentrations (µg/m^3)	Comparison of Intake Rates from Various Media (µg/kg/d)		
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)	air	• Not relevant since route-of-entry effect.	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 percentiles are <DL. Upper estimates of background air are a fraction of the TRV; thus a **SAF of 80%** of the TRV can be allocated to S-IA or GW-IA.
				DW		
				food		
				soil/dust		
				consumer products		
ethylene dibromide (EDB) (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)	indoor air	• 95th percentile below DL, max 0.208 µg/m^3 → ~0.06 µg/kg/d	95th percentile 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).] Concentrations in DW are <DL across Canada. Concentrations in food and soil are very low or negligible. Thus, a **SAF of 80%** is recommended.
				DW	• <DL in Ont & other Canadian studies (EC/HC 2013) • US DW medians <0.1 µg/L for public wells & <0.04 µg/L for domestic wells (EC/HC 2013) • DW standard 0.05 µg/L → ~ 0.0014 µg/kg/d	
				food	• Ban on use as pesticide has reduced likelihood of exposure of Canadian population in domestic & imported food; also, processing, cooking, baking, & market circulation of foods decrease the residual levels of EDB (EC/HC 2013)	
				soil/dust	• Rapidly lost from soils by volatilization to air or leaching to surf water & GW (ATSDR 1992b).	
				consumer products	• No information identified	
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	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.
				DW	• Highly volatile, thus typical treatment techniques for DW supplies in larger towns & cities would likely volatilize hexane before it could enter distribution systems, but it may be in some domestic DW 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 (CCME 2011).	
				consumer products	• No information identified	

Chemicals	Inhalation Non-Cancer TRV Most Recently Selected		• Background/Baseline Exposure Estimates			SAF Recommendations (20%, 50%, or 80%) for S-IA (soil to indoor air) on potable and non-potable GW conditions and for GW-2 (GW to indoor air)
	Value (mg/m^3) Agency / Year	Systemic or Route-of-Entry? / Critical Effect	Indoor & outdoor air concentrations (µg/m^3)	Comparison of Intake Rates from Various Media (µg/kg/d)		
tetrachloroethylene (Perc)	0.04 mg/m3 = 40 µg/m^3[≈ 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/m^3** (HC IAQ studies) - US indoor : 95th %iles 4.1 - 9.5 µg/m^3 (US EPA 2011) - Canada outdoor: range <0.03 - 17.34, 90/95th %iles 0.126 - 1.016 µg/m^3 (HC IAQ studies) - US outdoor medians: 0.3 - 1.7 µg/m^3 (WHO IAQ 2010)	air	- 95th %ile: 10.87 µg/m^3 → ~3 µg/kg/d.Mean intakes: 1.22-2.25 µg/kg/d (HC PSL 1993)	Although baseline soil concentrations would be lower than concentrations at industrial sites, even at industrial sites the intake from soil is negligible compared to air & compared to the TRV. Intakes from DW are also negligible compared to intakes from air and to the TRV.Estimated daily intake from the 95th percentile of air concentrations 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. Thus, upper intake from air + mean intake from diet is in the range of about half of the TRV. Accordingly, a **SAF of 50%** is recommended.
				DW	- Treated water across Ont (MOECC 2017): median 0.3 µg/L (~0.009 µg/kg/d), 95th %ile 0.5 µg/L (~0.014 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	- Volatilizes quickly from surface soil, but also mobile in soil & can leach into GW & deeper soil (ATSDR 2014D). - Found in soil up to 10 ppm at industrial site in Vancouver (HC DW 2015) → ~0.014 µg/kg/d.	
				consumer products	- Household products containing Perc & recently dry-cleaned clothes contribute to indoor air (ATSDR 2014D).	
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, 0.240, 0.298, 0.475, 0.520, 0.537, 0.960, 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	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**.**
				DW	- Treated water across Ont (MOECC 2017): median 0.3 µg/L (~0.009 µg/kg/d), 95th %ile 1.15 µg/L (~0.03 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)	
				consumer products	- adhesives & cleaning fluids (ATSDR 2007)	

Chemicals	Inhalation Non-Cancer TRV Most Recently Selected		• Background/Baseline Exposure Estimates			SAF Recommendations (20%, 50%, or 80%) for S-IA (soil to indoor air) on potable and non-potable GW conditions and for GW-2 (GW to indoor air)
	Value (mg/m^3) Agency / Year	**Systemic or Route-of-Entry? / Critical Effect**	**Indoor & outdoor air concentrations (µg/m^3)**	**Comparison of Intake Rates from Various Media (µg/kg/d)**		
vinyl chloride (VC)	0.1 mg/m3 = 100 µg/m^3 [≈ 30 µg/kg/d] (US EPA IRIS 2000b)	Systemic effect: Liver cell polymorphism	• 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	Indoor air is generally higher than outdoor air. The 95th percentile 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.
				DW	• 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 b/c of rapid volatilization (ATSDR 2006). • Treated water across Ont (MOECC 2017): median 0.2 µg/L (~0.006 µg/kg/d), 95th %ile **0.2 µg/L (~0.006 µg/kg/d).**	
				food	• 0.1 µg/d (HC DW 2013) → ~0.014 µg/kg/d.	
				soil/dust	• Highly mobile in soil, evaporates rapidly in water or soil if near surface (ATSDR 2006).	
				consumer products	• No information identified	

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APPENDIX IV

Use of Leachate Analysis in Development of Excess Soil Reuse Standards

Use of Leachate Analysis in Development of Excess Soil Reuse Standards

IV.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 the soil to groundwater component values generally decrease with increasing source size and analytical reporting limits (RLs) remain constant, the ability of bulk soil analysis to evaluate target risk levels (TRLs; as defined in Section IV.2) decreases. To address these issues, leachate analysis is incorporated into the excess soil reuse standards.

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

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 IV.2), due to the final soil standard being adjusted upwards to the analytical RL from a soil to groundwater pathway component value (e.g. S-GW1, S-GW2, S-GW3) and leachate analysis can identify a lower level of potential risk; and,

Situation 2 – Inorganics: If the chemical of concern is an inorganic substance for which soil to groundwater 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 soil 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. Leachate analysis for the second situation is also mandatory, even though there are no S-GW component values on which to apply a multiplier.

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. 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.

IV.2. Chemicals with Analytical Limitations

Excess soil standards were developed using the same models and assumptions used to develop the brownfield site condition standards, with some modifications (see Section 3). 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 that chemical, the final standard for that chemical is adjusted upwards to the higher of background and RL. This final adjustment results in a soil standard that does not meet the TRL.

A review of the potential risk associated with excess soil standards that have been adjusted upwards to RLs was completed to assess the extent to which the proposed excess soil standards were meeting TRLs. As noted in the MOECC 2011 rationale document in Section 2.4.2, 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 the inclusion in the Modified Generic Risk Assessment (MGRA) model and updated as detailed in Appendix II. 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 the contaminant 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 1 and 2, 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 standards).

The review identified that for some chemicals the risk based component values for one or more of the soil to groundwater exposure 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 IV.8). An 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. Chemicals with excess soil 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 reuse standard set at RL?
No – no leachate required
Yes – move to Step 2

Step 2: Is the potential risk associated with one or more soil to groundwater 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 reuse 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

IV.3. Situation 2 – Inorganic Chemicals

Leaching of inorganics from soil to groundwater was not considered in the development of the site condition soil standards for brownfields due to the uncertainty of modelling the partitioning of inorganics 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 inorganic chemicals 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 inorganic chemicals:

Step 1: Is excess soil reuse 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 minimum soil concentration that could results in the LSL being met to determine if it is greater).

Yes – leachate required
No – no leachate required

IV.4. Calculation of Leachate Screening Levels – Organic Chemicals

Leachate screening levels (LSL) were calculated for organic chemicals and for mercury and methylmercury 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 MOECC (2011) *Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario)*. 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.

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

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 (μg/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)

IV.5. Calculation of Leachate Screening Levels - Inorganic Contaminants

Due to the uncertainty associated with identifying Kd values for inorganics (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 inorganics, 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 inorganics are sufficiently volatile/toxic for the GW2 or GW2-Odour pathway to be of concern except for mercury and methylmercury, for which Kocs have been selected and LSL are calculated using the method for organic contaminants.

If the soil standard for an inorganic chemical 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.

IV.6. Use of Leachate Analysis as a Pathway Modifier

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

Use of leachate analysis as a "pathway modifier" is facilitated within 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.

IV.7. Compounds with the Potential to Biomagnify

Based on a review of the United Nations Environmental Programme (UNEP) Stockholm Convention on Persistent Organic Pollutants, 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 compounds 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.

Chemical	**Reference**
Aldrin	UNEP
Chlordane	UNEP
DDD	UNEP
DDE	UNEP
DDT	UNEP
Dieldrin	UNEP
Dioxan/Furan	UNEP
Endosulfan	UNEP
Endrin	UNEP
Heptachlor	UNEP
Hexachlorobenzene	UNEP
Hexachlorobutadiene	UNEP
Hexachlorocyclohexane Gamma-	UNEP
Mercury	CCME
Methylmercury	CCME
Pentachlorophenol	UNEP
Polychlorinated biphenyls	UNEP

United Nations Environmental Programme (UNEP) Stockholm Convention on Persistent Organic Pollutants, Canadian Council of Ministers of the Environment (CCME, 2000), Tissue Residue Guideline.

IV.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 2,3,6-
- Xylenes
- Zinc

IV.9. References

Canadian Council of Ministers of the Environment. 2000. Canadian tissue residue guidelines for the protection of wildlife consumers of aquatic biota: Methylmercury. http://ceqg-rcqe.ccme.ca/en/index.html#void

Canadian Environmental Protection Act, Domestic Substance List, Chemicals that are Persistent and Bio-accumulative.https://www.ec.gc.ca/lcpe-cepa/default.asp?lang=En&n=5F213FA8-1&wsdoc=D031CB30-B31B-D54C-0E46-37E32D526A1F

Ministry of the Environment (MOE, currently known as Ministry of the Environment and Climate Change), 2011. Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario.

United Nations Environmental Programme (UNEP), Stockholm Convention on Persistent Organic Pollutants http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx

APPENDIX V

Development of Ceiling Values to Support the Attainment Approach for Excess Soil Reuse Standards

Development of Ceiling Values to Support the Attainment Approach for Excess Soil Reuse Standards

V.1. Background

The MOECC has developed an alternative to the existing compliance requirement in O.Reg 153/04 for excess soil reuse standards. The new "Attainment Approach" was developed to allow more flexibility and to provide a better representation of the soil quality. The new approach uses a set of statistical tests to characterize a volume of soil and requires a data set of at least 20 soil sample results. The elements of the attainment approach were developed to ensure that the soil results are from a single population and require that the 90th percentile and the 95% upper confidence level of the mean (UCLM) of the data set meet the applicable excess soil reuse standard. But, while a small portion of the soil results (10% or less) may exceed the applicable excess soil reuse standard, every sample must met 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.

V.2. Overview of Ceiling Value Development Process

Figure V.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 reuse standard;
- Effect-based Cap (see Section V.3 for details); and,
- Acute Cap (see Section V.4 for details).

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

For Table 1 standards, two additional considerations are applied to ensure that the soils which are determined to meet Table 1 using this approach could reasonably be considered to be 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:

1. Ontario Typical Range (OTR) was not developed (Table 1 set at RL); or,
2. OTR was set at the RL as the OTR samples were undetected or detected at target values being less than RLs (Table 1 set at RL).

Final Ceiling Values with respect to generic excess soil reuse standards are provided in Part IV of the MOECC document on *"Rules for On-Site and Excess Soil Management"*

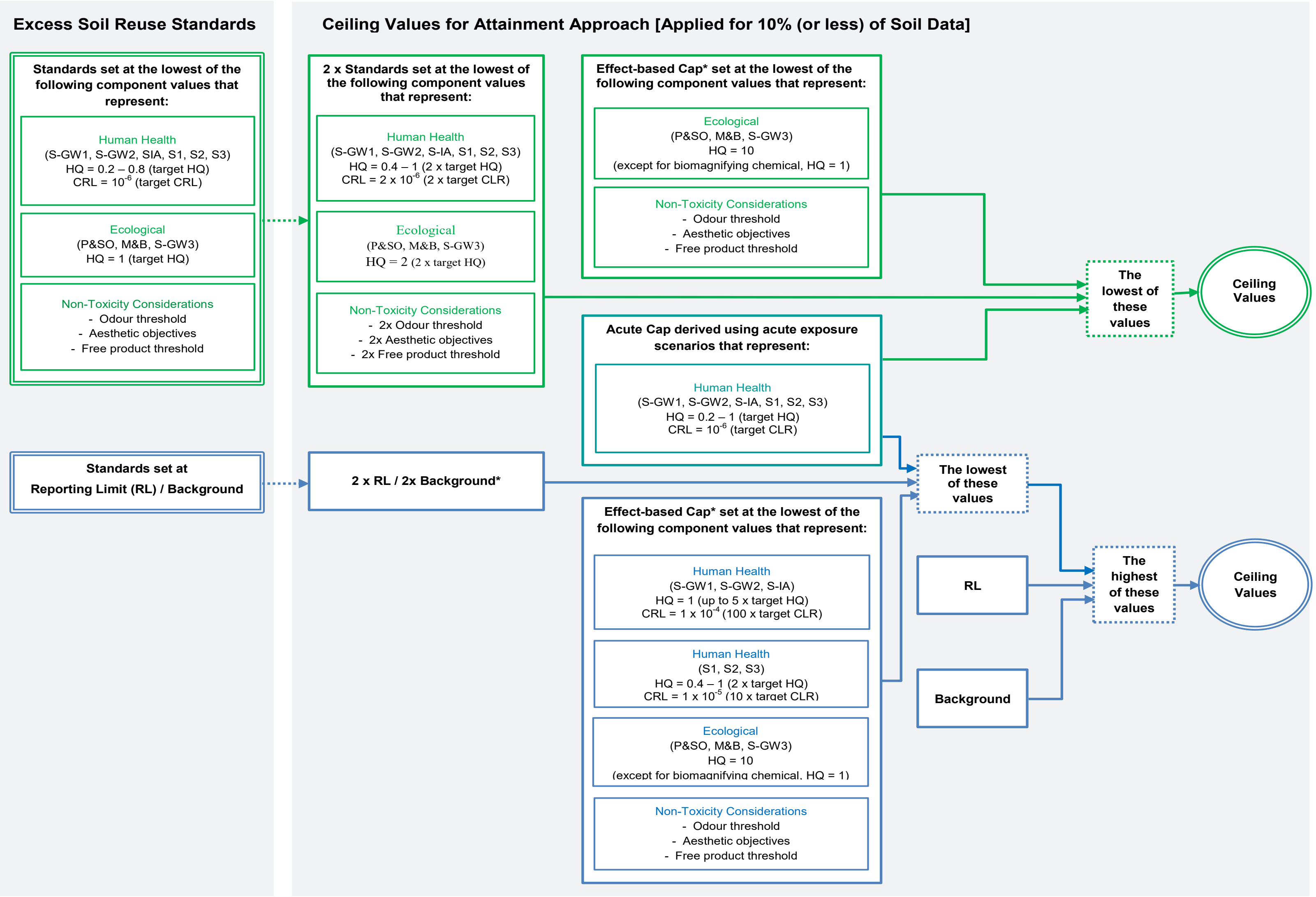

Figure V.1. Overview of Ceiling Value Development Process

* Some special considerations (i.e. Table 1 standards) included in Sections 2, 3, and 4

V.3. Derivation of Effects-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 reuse standards. The final cap is the lowest of the risk-based and other non-toxicity values that are derived using the following approach:

a. 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 1x10^{-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 (R/P/I, based on Table 1 value) and 1000 µg/g (I/C/C, 1993 MOECC criteria); and,
    - S1-S3 component values for uranium are not calculated and are set at 23 µg/g (R/P/I) and 300 µg/g (I/C/C) based on 2006 CCME values.

b. Calculation of an eco-protection cap is based on a HQ of 10 per eco-protection component value with the exception of biomagnifying substances (i.e. HQ retained at 1 for biomagnifying substances).

c. 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.

V.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 standards with the exception of the following:

a. Selection of Acute TRVs

Acute TRVs 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 V.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 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 contaminants 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 contaminants.

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 nickel, styrene, 1,1,1- trichloroethane, and vanadium.

b. Acute Incidental Soil Ingestion Rate (SIR):

The toddler is the receptor used for R/P/I sites; recommendations of acute 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 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.

c. Acute exposure duration (ED), averaging time (AT), & exposure frequency (EF)

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). [Note 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 V.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/m3)	Is inhalation Acute TRV based on reproductive or developmental effects?	Reference
Acenaphthene	3.00E-01		Extrapolated from Chronic TRV			
Acenaphthylene	3.00E-01		Extrapolated from Chronic TRV			
Acetone	4.50E+00		Extrapolated from Chronic TRV	6.20E+01		ATSDR 1994
Aldrin	2.00E-03	YES	ATSDR 2002			
Anthracene	1.50E+00		Extrapolated from Chronic TRV			
Antimony	2.00E-03		Extrapolated from Chronic TRV	1.00E-03		Extrapolated from Chronic TRV
Arsenic	1.50E-03		MOE 2005	1.50E-05	YES	Cal EPA 2016 (8h)
Barium	3.00E-01		NYS 2006	5.00E-03		Extrapolated from Chronic TRV
Benzene	1.50E-02	YES	MDH 2009	3.00E-02		ATSDR 2007
Benz[a]anthracene						
Benzo[a]pyrene	1.30E-03		MDH 2012			
Benzo[b]fluoranthene						
Benzo[ghi]perylene						
Benzo[k]fluoranthene						
Beryllium	1.00E-02		Extrapolated from Chronic TRV	3.50E-05		Extrapolated from Chronic TRV
Biphenyl 1,1'-	1.90E-01		Extrapolated from Chronic TRV	2.80E+01		US EPA 2007 (8h AEGL 2)
Bis(2-chloroethyl)ether						
Bis(2-chloroisopropyl)ether	2.00E-01		Extrapolated from Chronic TRV			
Bis(2-ethylhexyl)phthalate	2.90E-02		MDH 2015			
Boron (Hot Water Soluble)*						
Boron (total)	2.00E-01	YES	ATSDR 2010	3.00E-01		ATSDR 2010
Bromodichloromethane	4.00E-02		ATSDR 1989			
Bromoform	7.00E-01		ATSDR 2005			
Bromomethane	3.00E-03		EFSA 2011	2.00E-01		ATSDR 1992

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/m3)	Is inhalation Acute TRV based on reproductive or developmental effects?	Reference
Cadmium	7.00E-03		NYS 2006	3.00E-05		ATSDR 2012
Carbon Tetrachloride	2.00E-02		ATSDR 2005	3.60E+01		US EPA 2014 (8h AEGL 2)
Chlordane	1.00E-03	YES	ATSDR 1994	3.50E-03		Extrapolated from Chronic TRV
Chloroaniline p-	1.00E-02		Extrapolated from Chronic TRV			
Chlorobenzene	3.00E-01		Extrapolated from Chronic TRV	4.70E+01		US EPA 2012 (8h AEGL 1)
Chloroform	3.00E-01		ATSDR 1997	5.00E-01		ATSDR 1997
Chlorophenol, 2-	1.50E-02		Extrapolated from Chronic TRV			
Chromium Total	7.50E+00		Extrapolated from Chronic TRV	3.00E-01		Extrapolated from Chronic TRV
Chromium VI	4.15E-02		Extrapolated from Chronic TRV	5.00E-04		Extrapolated from Chronic TRV
Chrysene						
Cobalt	5.00E-03		Extrapolated from Chronic TRV	2.50E-03		Extrapolated from Chronic TRV
Copper	1.00E-02		ATSDR 2004	2.50E-01		Extrapolated from Chronic TRV
Cyanide (CN-)	1.10E-01		HSWMR 1999	1.10E+00		US EPA 2002 (8h AEGL 1)
Dibenz[a h]anthracene						
Dibromochloromethane	1.00E-01		ATSDR 2005			
Dichlorobenzene, 1,2-	7.00E-01		ATSDR 2006	3.00E+00		Extrapolated from Chronic TRV
Dichlorobenzene, 1,3-	4.00E-01		ATSDR 2006			
Dichlorobenzene, 1,4-	4.00E-01		(proxy)	1.20E+01		ATSDR 2006
Dichlorobenzidine, 3,3'-						
Dichlorodifluoromethane	1.00E+00		Extrapolated from Chronic TRV			
DDD	5.00E-04	YES (proxy)	(proxy)			
DDE	5.00E-04	YES (proxy)	(proxy)			
DDT	5.00E-04	YES	ATSDR 2002			
Dichloroethane, 1,1-	6.00E-01		MDH 2016	8.25E-01		Extrapolated from

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/m3)	Is inhalation Acute TRV based on reproductive or developmental effects?	Reference
						Chronic TRV
Dichloroethane, 1,2-	2.30E-01		MDH 2013	2.00E+00		Extrapolated from Chronic TRV
Dichloroethylene, 1,1-	1.00E+00		(proxy)	8.00E-01		proxy
Dichloroethylene, 1,2-cis-	1.00E+00		ATSDR 1996	5.54E+02		US EPA 2010 (8h AEGL 1)
Dichloroethylene, 1,2-trans-	1.00E+00		(proxy)	8.00E-01		ATSDR 1996
Dichlorophenol, 2,4-	1.50E-02		Extrapolated from Chronic TRV			
Dichloropropane, 1,2-	1.00E-01		ATSDR 1989	2.30E-01		ATSDR 1989
Dichloropropene,1,3-	2.00E-01		EFSA 2009	1.00E-01		Extrapolated from Chronic TRV
Dieldrin	1.10E-04	YES	MDH 2017			
Diethyl Phthalate	7.00E+00		ATSDR 1995			
Dimethylphthalate	2.50E+01		Extrapolated from Chronic TRV			
Dimethylphenol, 2,4-	1.00E-01		Extrapolated from Chronic TRV			
Dinitrophenol, 2,4-	1.00E-02		ATSDR 1995			
Dinitrotoluene, 2,4 & 2,6-	5.00E-02		ATSDR 2016			
Dioxane, 1,4	5.00E+00	YES	ATSDR 2012	7.20E+00		ATSDR 2012
Dioxin/Furan (TEQ)	2.00E-07		ATSDR 1998	2.00E-07		Extrapolated from Chronic TRV
Endosulfan	7.00E-03		ATSDR 2015			
Endrin	1.10E-04	YES (proxy)	(proxy)			
Ethylbenzene	5.00E-01		Extrapolated from Chronic TRV	2.20E+01		ATSDR 2010
Ethylene dibromide	4.50E-02		Extrapolated from Chronic TRV	4.00E-03		Extrapolated from Chronic TRV
Fluoranthene	2.00E-01		Extrapolated from Chronic TRV			
Fluorene	2.00E-01		Extrapolated from Chronic TRV			
Heptachlor	6.00E-04		ATSDR 2007			
Heptachlor Epoxide	6.00E-04		(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/m3)	Is inhalation Acute TRV based on reproductive or developmental effects?	Reference
Hexachlorobenzene	8.00E-03	YES	ATSDR 2015			
Hexachlorobutadiene	1.70E-03		Extrapolated from Chronic TRV			
Hexachlorocyclohexane Gamma-	3.00E-03		ATSDR 2005			
Hexachloroethane	1.00E+00		ATSSR 1997	5.80E+01		ATSDR 1997
Hexane (n)				10,000		US EPA 2013 (8h AEGL 2)
Indeno[1 2 3-cd]pyrene						
Lead						
Mercury	1.50E-03		Extrapolated from Chronic TRV	6.00E-05	YES	Cal EPA 2016 (8h)
Methoxychlor	2.00E-05		Extrapolated from Chronic TRV			
Methyl Ethyl Ketone	6.00E-01		Extrapolated from Chronic TRV	5.86E+02		US EPA 2011b (8h AEGL 1)
Methyl Isobutyl Ketone	1.00E+00		Extrapolated from Chronic TRV	3.00E+00		Extrapolated from Chronic TRV
Methyl Mercury **	1.00E-04		Extrapolated from Chronic TRV			
Methyl tert-Butyl Ether (MTBE)	4.00E-01		ATSDR 1996	7.20E+00		ATSDR 1996
Methylene Chloride	2.00E-01		ATSDR 2000	2.00E+00		ATSDR 2000
Methlynaphthalene, 2-(1-) ***	2.00E-02		Extrapolated from Chronic TRV			
Molybdenum	2.50E-02		Extrapolated from Chronic TRV	6.00E-02		Extrapolated from Chronic TRV
Naphthalene	6.00E-01		ATSDR 2005	1.85E-02		Extrapolated from Chronic TRV
Nickel	0.02		Set at chronic TRV (Acute TRV of 1.2 E-02 mg/kg-day reported in WHO DW 2005)	1.10E-03		TCEQ 2011 (used by MOE in 2013)
Pentachlorophenol	5.00E-03	YES	ATSDR 2001			
Petroleum Hydrocarbons F1****						
Aliphatic C6-C8	2.50E+01		Extrapolated from Chronic TRV	9.20E+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/m3)	Is inhalation Acute TRV based on reproductive or developmental effects?	Reference
Aliphatic C>8-C10	5.00E-01		Extrapolated from Chronic TRV	5.00E+00		Extrapolated from Chronic TRV
Aromatic C>8-C10	2.00E-01		Extrapolated from Chronic TRV	1.00E+00		Extrapolated from Chronic TRV
Petroleum Hydrocarbons F2						
Aliphatic C>10-C12	5.00E-01		Extrapolated from Chronic TRV	5.00E+00		Extrapolated from Chronic TRV
Aliphatic C>12-C16	5.00E-01		Extrapolated from Chronic TRV	5.00E+00		Extrapolated from Chronic TRV
Aromatic C>10-C12	2.00E-01		Extrapolated from Chronic TRV	1.00E+00		Extrapolated from Chronic TRV
Aromatic C>12-C16	2.00E-01		Extrapolated from Chronic TRV	1.00E+00		Extrapolated from Chronic TRV
Petroleum Hydrocarbons F3						
Aliphatic C>16-C21	1.00E+01		Extrapolated from Chronic TRV			
Aliphatic C>21-C34	1.00E+01		Extrapolated from Chronic TRV			
Aromatic C>16-C21	1.50E-01		Extrapolated from Chronic TRV			
Aromatic C>21-C34	1.50E-01		Extrapolated from Chronic TRV			
Petroleum Hydrocarbons F4						
Aliphatic C>34	1.00E+02		Extrapolated from Chronic TRV			
Aromatic C>34	1.50E-01		Extrapolated from Chronic TRV			
Phenanthrene						
Phenol	1.00E+00		ATSDR 2008	2.40E+01		US EPA (2009) 8h AEGL 1
Polychlorinated Biphenyls	1.00E-04		Extrapolated from Chronic TRV	2.50E-03		Extrapolated from Chronic TRV
Pyrene	1.50E-01		Extrapolated from Chronic TRV			
Selenium	2.50E-02		Extrapolated from Chronic TRV			
Silver	2.50E-02		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/m3)	Is inhalation Acute TRV based on reproductive or developmental effects?	Reference
Styrene	0.12		Set at chronic TRV (Acute TRV of 1.0 E-01 mg/kg-day reported in ATSDR 2010c)	2.10E+01		ATSDR 2010
Tetrachloroethane, 1,1,1,2-	1.50E-01		Extrapolated from Chronic TRV			
Tetrachloroethane, 1,1,2,2-	5.00E-02		Extrapolated from Chronic TRV			
Tetrachloroethylene	8.00E-03		ATSDR 2014 draft	4.00E-02		ATSDR 2014 draft
Thallium	6.75E-05		Extrapolated from Chronic TRV			
Toluene	8.00E-01		ATSDR 2015 draft	7.50E+00		ATSDR 2015 draft
Trichlorobenzene, 1,2,4-	1.70E-01		MDH 2013	4.00E-02		Extrapolated from Chronic TRV
Trichloroethane, 1,1,1-	2		Set at chronic TRV (Acute TRV of 3.0E-01 mg/kg-day based on a proxy, (ATSDR 1989)	1.10E+01		ATSDR 2006
Trichloroethane, 1,1,2-	3.00E-01		ATSDR 1989	1.10E+01		(proxy)
Trichloroethylene	5.00E-04		Extrapolated from Chronic TRV	2.00E-03		Extrapolated from Chronic TRV
Trichlorofluoromethane	1.50E+00		Extrapolated from Chronic TRV			
Trichlorophenol, 2,4,5-	1.50E-02		Extrapolated from Chronic TRV			
Trichlorophenol, 2,4,6-	1.50E-02		Extrapolated from Chronic TRV			
Uranium	2.00E-03	YES	ATSDR 2013	1.50E-03		Extrapolated from Chronic TRV
Vanadium	4.00E-02		FDEP 2005	0.001		Set at chronic TRV (Acute TRV of 8.0 E-04 mg/m^3 reported in ATSDR 2012c)
Vinyl Chloride	1.50E-02		Extrapolated from Chronic TRV	1.30E+00	YES	ATSDR 2006
Xylene Mixture	1.00E+00		ATSDR 2007	8.70E+00		ATSDR 2007

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/m3)	Is inhalation Acute TRV based on reproductive or developmental effects?	Reference
Zinc	1.50E+00		Extrapolated from Chronic TRV			

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