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APPENDIX A SUMMARY OF JOHNSON AND ETTINGER VAPOUR INTRUSION MODELS

Indoor Air Concentrations above Basements

Approach

The concentration of volatile COPCs (derived from a subsurface source) in floors above the basement (the commercial properties on the ground floor and residential units on the first-floor) is difficult to model due to the large number of variables which affect migration from the basement air to indoor air and between floors.

Multi-storey buildings may consist of a range of different building types which include:

- Single family homes with two or more storeys;
- Multi-family dwellings such as units in low-rise developments (including townhouses) and high-rise developments;
- Mixed commercial and residential developments (multi family units); and
- Non-residential buildings of varying sizes and uses (including retail, commercial, business and school use).

In the case of multi-family dwellings, these may consist of units or flats on one level or over many levels which may include low-rise and high-rise buildings. The problem of vapour migration in the buildings is complex due to the partition wall between units as well as the size of the building air envelope. Other key influences include adjacent units, stairwell doors, garbage chutes, elevator shafts, electrical and plumbing ducts, ventilation shafts (air conditioning) and windows. All of these factors vary between buildings and constructions (including the age of the construction) and modelling vapour migration in a multi-storey building is very complex and difficult. It is even more difficult when the proposed building is not defined.

However based on review of the available information a simple approach has been adopted to estimate concentrations within indoor air on floors located above a basement or on upper floors of a building constructed as slab on grade or on piers with a crawl-space as follows:

- Calculate the concentration in the lowest floor of the building, namely the basement or ground floor, using the most appropriate model for the building type considered; and
- Use an attenuation factor to estimate concentrations in floors above.

Attenuation Factor

An attenuation factor has been adopted to estimate a potential concentration in air within upper basement levels as well as within the ground floor and upper floors of the proposed building on-site. The attenuation factors adopted are:

- Adoption of a conservative method from Olson and Corsi (2001[1]) that relates the concentration in air within an upper floor of a building with openings and good air

[1] Olson, D.A., Corsi, R.L. 2001. Characterizing exposure to chemicals from soil vapor intrusion using a two-compartment model. Atmospheric Environment 35, 4201-4209.

exchanges such as a residential 2-storey home or in this case basement levels connected by open ramps. The attenuation factor adopted between the open basement levels is a factor of 2. That is the concentration in air within the basement level above the lowest level is ½ of that estimated using the J&E model (or other appropriate model) for the lowest level.

- Adoption of an attenuation factor of 10 to estimate the concentration in air within the ground floor or other upper floors of the proposed building. This factor has been adopted on the basis that the ground floor and subsequent floors are not well connected with large openings. The attenuation factor relates the concentration in the ground floor (1/10th) to the estimated air concentration in the basement level directly below the ground floor. The 10 fold attenuation factor used in this assessment is derived from a number of sources as follows:

    - Data collected by Olson and Corsi (2001) based on tracer experiments within a multi-storey home (with internal stairway access) indicates that the concentration within the first-floor is approximately 10 times lower than the concentration within the basement.

    - Review of the transfer of tobacco smoke between apartments within multi-storey buildings (between levels and across floors) indicated (CEE, 2004[2]) that the transfer of air between floors of a multi-floor building was 2% for the lower floors, 7% for the middle floors and 19% for the upper floors. The trend was associated with the thermal stack effect during the heating season. During this period, warmer air inside the building is less dense than the outside air resulting in cold air from outside entering the lower portion of the building, rising and exiting through the upper floors. Hence the lower floors tend to get most of the air exchange from outside and upper floors get a more significant air exchange from floors beneath. When evaluating vapour migration from a subsurface source, the migration into the ground floor is considered more significant than outside air. Hence concentrations within the first-floor above the ground floor are expected to be diluted with outdoor air resulting in lower concentrations between 2% and 7% of the lower floor concentration.

    - Review of radon simulation results for a range of multistorey buildings (Fang J.B and Persily A.K., 1995[3]) indicates that under a range of temperature and wind conditions the concentration difference between the basement and first floors was between a factor of 0 and 100. A 10-fold factor between concentrations within the basement and the first-floor would provide a conservative estimation of first floor concentrations (derived from ground floor or basement concentrations) under most conditions.

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[2] CEE, 2004. Reduction of Environmental Tobacco Smoke Transfer in Minnesota Multifamily Buildings Using Air Sealing and Ventilation Treatments, Center for Energy and Environment, November 2004, CEE/TR04-1 MF.

[3] Fang J.B. and Persily A.K, 1995. Airflow and Radon Transport Modelling in Four Large Buildings. ASHRAE Transactions 1995 Volume 101 Part 1. American Society of Heating, Refrigeration and Air-Conditioning Engineers.

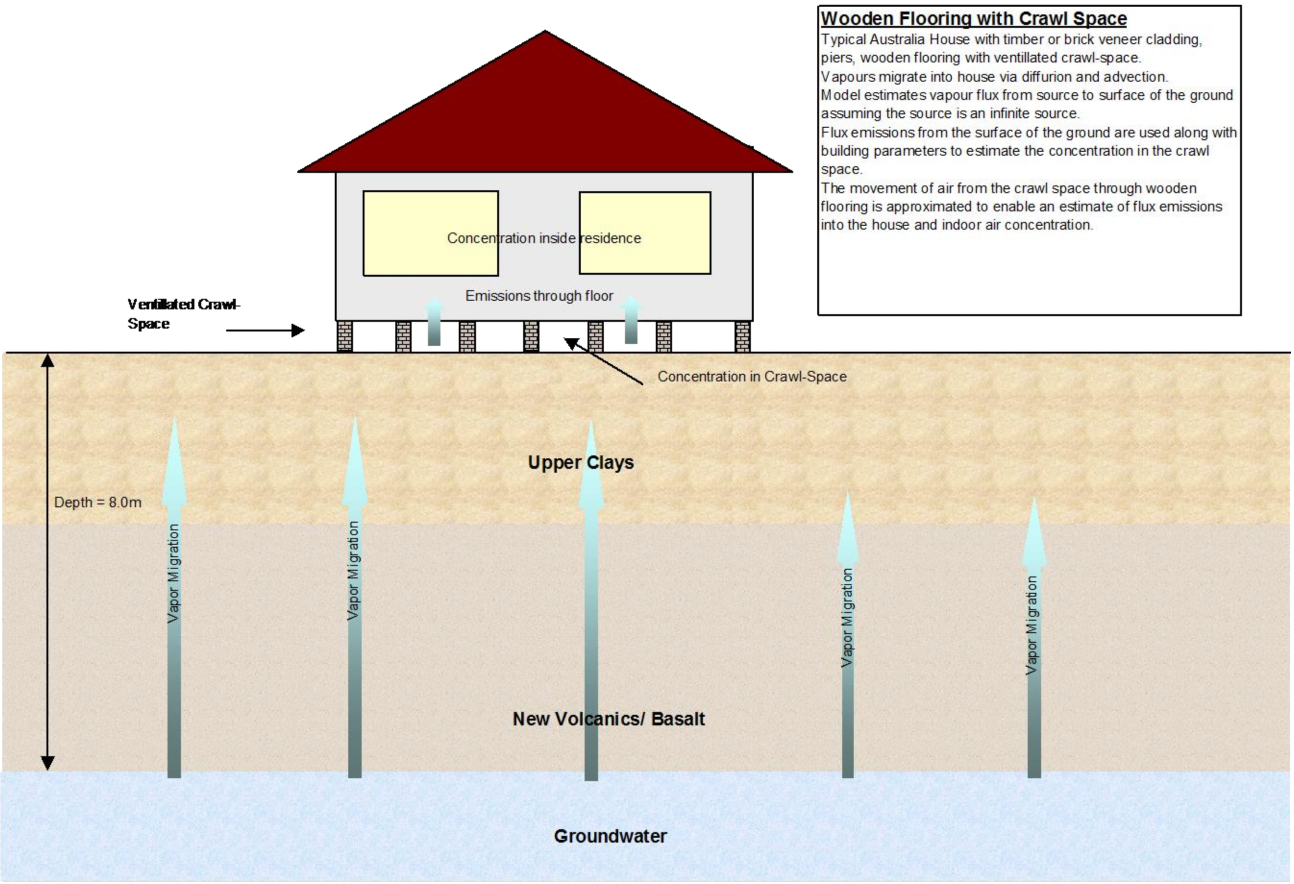
Crawl-Space Vapour Intrusion Model

Introduction

There are a number of models available for estimating potential concentrations of chemicals within the indoor air environment associated with the migration from a subsurface source. Most of these models are simple and have been developed for houses constructed with no flooring or on concrete slabs both with and without underground basements (which are more typical in the US). The model available for the assessment of houses constructed with piers, crawl-spaces and wooden floors is derived from Turczynowicz (2002[1]).

The model is used to assess vapour intrusion indoors only and assumed that the source is non-depleting.

Conceptual Model



[1] Turczynowicz L., 2002. Establishing Health-Based Investigation Levels for benzene, toluene, ethylbenzene, xylenes, naphthalene and aromatic and aliphatic ≤EC16 TPH fractions. Site Contamination Technical Workshop, Adelaide 13 to 15th May 2002

Crawl-Space Vapour Intrusion Model

Equations

The model presented in Turczynowicz (2002) is relevant to the assessment of finite sources (in this case shallow soil sources) and is based on subsurface migration as described by the model presented by Jury et al (1983) with additional equations applied to concentrations within the crawl-space and indoor air. The potential migration of vapours from the infinite shallow groundwater source have been directly measured and the subsurface migration model refined to match measured vapour emissions. The equations presented for migration into a crawl-space and indoor air presented by Turczynowicz can then be used assuming an infinite source.

The model is designed to estimate indoor air concentrations (and subsequent inhalation exposures) associated with the movement of volatile subsurface soil contaminants via a crawl-space into a brick veneer building with piers and wooden flooring. The model considers movement into the crawl-space, subsequent dilution by crawl-space ventilation and movement into indoor air through floor, wall and roof spaces. The model considers volatile sinks and sources, indoor air ventilation and degradation of the volatiles in indoor air.

The equations presented by Turczynowicz (2002) are a summary of the equations presented by Robinson (2000) and Turczynowicz and Robinson (2001). The soil transport and soil flux equations presented are based on Jury and are relevant to the assessment of finite sources. While an infinite source solution to the Jury equations is available, they have not been used in this assessment. In a number of off-site residential areas which overly potential dissolved phase impacts (assumed to be infinite sources), direct measurement of emission fluxes has been undertaken. However the highest concentration detected during sampling was from the soil gas measurements therefore have been used as the source concentrations during calculations. Turczynowicz (2002) presents the following equations for crawl-space transportation and dwelling transportation:

$$V_{cs} \bullet \left[\frac{\partial C_{cs}}{\partial t} + \mu a \bullet C_{cs} \right] + V_{cs} \bullet X_{cs} \bullet C_{cs} = A \bullet J_{cs} \qquad \text{...Equation CS1}$$

$$V_D \bullet \left[\frac{\partial C_D}{\partial t} + \mu a \bullet C_D \right] + V_D \bullet X_D \bullet C_D + s \bullet C_D = Q_{CD} \bullet C_{cs} \qquad \text{...Equation CS2}$$

Where

V_x = volume of crawl-space (cs) and dwelling (D) with plan area A (in m^3, area in m^2);
C_x = concentration in crawl-space (cs) and dwelling (D) ($\mu g/m^3$)
μa = volatile degradation rate in air (per day)
X_x = air exchange rate for crawl-space (cs) and dwelling (D) (per day)
s = total sinks assumed to be inhalation by occupants (2 adults and 1 child) (m^3/day)
J_{cs} = emission flux entering crawl-space ($\mu g/m^2$/day), refer to Equation CS5
Q_{CD} = volumetric flow rate of air from crawl-space to indoor air via floor, walls and ceiling space (m^3/day)

Crawl-Space Vapour Intrusion Model

The air exchange rate within the crawl-space is derived from studies undertaken on six homes in Melbourne where rate varies from 201.6 to 585.6 per day for brick veneer and 556.8 to 2085.6 per day for well ventilated weatherboard (Delsante et al, 1998[2]). As the data is limited a conservative value relevant for more closed in crawl-space is set at 10% of the lower value (ie 20.2 per day).

Assuming an infinite source and steady-state emissions, then Equations 1 and 2 can be simplified to the following equations that can be used to calculate concentrations within the crawl-space and indoor air:

$$C_{cs} = \frac{A \bullet J_{cs}}{V_{cs} \bullet (\mu a + X_{CS})} \quad (\mu g/m^3) \qquad \text{...Equation CS3}$$

$$C_D = \frac{Q_{CD} \bullet C_{cs}}{V_D \bullet (\mu a + X_D) + s} \quad (\mu g/m^3) \qquad \text{...Equation CS4}$$

The emissions flux from the surface of the ground can be measured, however it is is also calculated suing the following:

$$J_{cs} = \frac{C_{source} \bullet D_T^{eff} \bullet A}{L_T} \quad \mu g/s \qquad \text{...Equation CS5}$$

Where

C_{source} = vapour concentration at the source, refer to Equations VS1 to VS5 ($\mu g/cm^3$).
D_T^{eff}. = total overall effective diffusion coefficient. (cm^2/s) Refer to Equations D1 and D2
L_T = separation distance between the source and the building (cm)
A = area for the emission (cm^2)

[2] Delsante A., Chan C. Threlfall G., Williamson T and Olweny M., 1998. Further measurements of Ventilation Rates in the Sub-Floor Spaces of Houses with Suspended Timber Floors. Environmentally Responsible Housing for Australia, Proceedings of the ARC/NAFI Research Seminar.

Delsante A., Chan C. Threlfall G., Williamson T and Olweny M., 1998. A Progress Report on the Measurement of Ventilation Rates in Sub-floor Spaces of Houses with Suspended Timber Floors. Environmentally Responsible Housing for Australia, Proceedings of the ARC/NAFI Research Seminar

Crawl-Space Vapour Intrusion Model

Model Assumptions

The following represent the major assumptions/limitations of the crawl-space model.

1. A building constructed with a sub-surface crawl-space is also assumed to have residential areas on the ground floor of the building. It is considered unlikely that a subsurface crawl-space would be used for residential purposes as the majority of the area would be exposed soils. In the event that such an area is converted to a residential area, then it would be expected that flooring and walls would be constructed making the exposure scenario more like that assessed for a building with concrete flooring and subsurface basement.

2. Diffusion dominates vapour transport between the source of contamination and the building zone of influence.

3. All soil properties in any horizontal plane are homogeneous.

4. The contaminant is homogeneously distributed within the zone of contamination.

5. The aerial extent of contamination is greater than that of the building floor in contact with the soil.

6. Vapour transport occurs in the absence of convective water movement within the soil column (i.e., evaporation or infiltration), and in the absence of mechanical dispersion.

7. The model does not account for transformation processes (e.g., biodegradation, hydrolysis, etc.).

8. The crawl-space and building ventilation rates are constant values.

Use of the crawl-space model as a first-tier screening tool to identify sites needing further assessment requires careful evaluation of the assumptions listed in the previous section to determine whether any conditions exist that would require further investigation. If the model is deemed applicable at the site, care must be taken to ensure reasonably conservative and self-consistent model parameters are used as input to the model. Considering the limited site data typically available in preliminary site assessments, the model can be expected to predict only whether or not a risk-based exposure level will be exceeded at the site. Precise prediction of concentration levels is not possible with this approach.

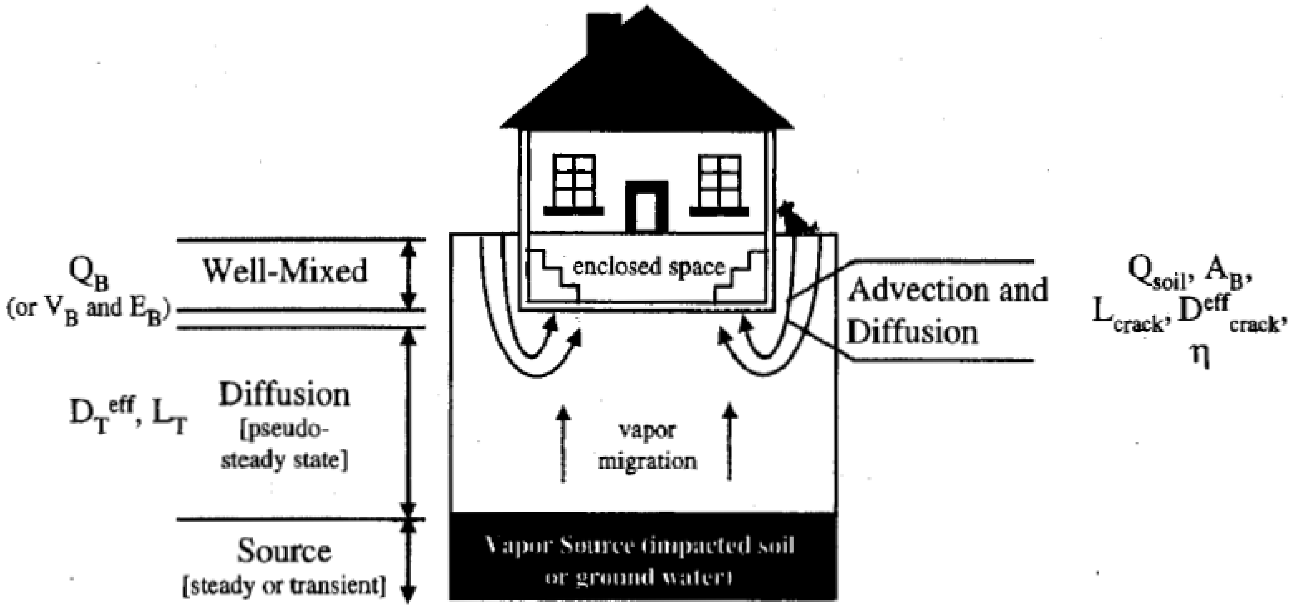
Johnson & Ettinger Vapour Intrusion Model

Introduction

The potential concentration of volatile chemicals inside a building constructed on a concrete slab with or without a sub-surface basement has been estimated using the Johnson & Ettinger Model (USEPA 2003[1]). This model is consistent with the Johnson & Ettinger equations (1991[2]) recommended in the Soil Screening Guidelines (USEPA, 1996[3]) and the Risk Based Corrective Action at Petroleum Release Sites (ASTM, 2002[4]).

The model is used to assess vapour intrusion indoors only and assumed that the source is non-depleting.

Conceptual Model



(from Johnson and Ettinger 1991)

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[1] USEPA, 2003. User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings. June 2003.

[2] Johnson, P.C. and Ettinger, R.A. 1991. "Heuristic Model for Predicting the Intrusion Rate of Contaminant Vapours Into Buildings". Environmental Science and Technology, Vol 25 (8), 1991, pp.1445-1452.

[3] USEPA 1996. Soil Screening Guidance. Publication 9355.4-23, July 1996

[4] ASTM, 2002. Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites. ASTM E 1739-95 (2002)

Johnson & Ettinger Vapour Intrusion Model

Equations

The steady-state vapour-phase concentration of a contaminant inside a building ($C_{building}$) is calculated by applying the Johnson and Ettinger model assuming a steady-state mass transfer (i.e., infinite). This is calculated using Equation JE1.

$$C_{indoor} = C_{source} \bullet \alpha$$ **...Equation JE1**

Where

C_{indoor} = the steady-state vapor-phase concentration of a contaminant inside a building (μg/m^3)

α = attenuation coefficient [unitless], refer to Equation JE2

C_{source} = vapour concentration at the source (μg/m^3), refer to equations VS1 to VS5 (as relevant).

The attenuation factor is calculated using the following:

$$\alpha = \frac{\left[\frac{D_T^{eff} \bullet A_B}{Q_{building} \bullet L_T}\right] \bullet \exp\left[\frac{Q_{soil} \bullet L_{crack}}{D^{crack} \bullet A_{crack}}\right]}{\left[\exp\left[\frac{Q_{soil} \bullet L_{crack}}{D^{crack} \bullet A_{crack}}\right] + \left[\frac{D_T^{eff} \bullet A_B}{Q_{building} \bullet L_T}\right] + \left[\frac{D_T^{eff} \bullet A_B}{Q_{soil} \bullet L_T}\right] \bullet \exp\left[\frac{Q_{soil} \bullet L_{crack}}{D^{crack} \bullet A_{crack}}\right]^{-1}\right]}$$ **Equation JE2**

Where:

D_T^{eff}. = total overall effective diffusion coefficient. Refer to Equations D1 and D2.

A_B = area of the enclosed space below the ground level which will vary depending on whether the building has a basement below the ground or not (cm^2).

$Q_{building}$. = building ventilation rate which is calculated using building parameters and air exchange rate (cm^3/s). Refer to Equation JE3.

L_T = separation distance between the source or soil gas measurement and the building (cm).

Q_{soil}. = volumetric flowrate of soil gas into the enclosed space. This represents the convective flow of vapours into a building though cracks in the floor and walls. It incorporates pressure driven flows and a default value of 5 L/min is recommended (2003), however it can be calculated using Equation JE5.

L_{crack} = enclosed space foundation or slab thickness (cm).

D^{crack} = effective diffusion coefficient through the cracks (cm^2/s).

A_{crack} = area of total cracks which varies depending on whether there is a basement or not (cm^2), refer to Equation JE4.

Johnson & Ettinger Vapour Intrusion Model

The building ventilation rate is calculated using Equation JE3 for the building dimensions representing the living space of the building. It assumes that the total air volume entering the structure is mixed and that the vapour entering the structure is instantaneously and homogeneously distributed.

$$Q_{building} = \frac{(L_B \bullet W_B \bullet H_B \bullet ER)}{3600} \qquad \text{...Equation JE3}$$

Where:
L_B = length of building, (cm)
W_B = width of building, (cm)
H_B = height of building, (cm)
ER = air exchange rate, (per hour)
3600 = conversion from hours to seconds

$$A_{crack} = n \bullet AB$$
$$AB = L_B \bullet W_B + (2 \bullet L_B \bullet L_h + 2 \bullet W_B \bullet L_h) \qquad \text{...Equation JE4}$$

Where:
AB = area of enclosed space below ground, (cm^2)
n = ratio of crack area to total area (unitless)
A_{crack} = total crack area, (cm^2)
L_h = depth below ground, (cm)

The volumetric flow rate of soil gas into the building is calculated using Equation JE5. This represents the advective/convective flow rate of contaminant vapours in soil surrounding the building via the cracks in the building floor and walls. It incorporates pressure driven flows into the building that may be associated with wind effects on the structure, stack effects due to heating or an unbalanced mechanical ventilation. This is of particular importance where a basement is present and where heating /ventilation effects are of significance.

Tracer testing of buildings where advection is the primary mechanism for intrusion into the building suggested a typical range for Qsoil from 1 to 10 L/min, with 5 L/min selected as a default by the USEPA (2003). The equation represents potential openings for soil vapour entry into a building. These openings include floor/wall joints associated with floating concrete slabs or a perimeter drain /sump system. The soil vapour permeability used is that for the type of material immediately under the slab.

Johnson & Ettinger Vapour Intrusion Model

$$Q_{soil} = \frac{2 \bullet \pi \bullet P \bullet k_v \bullet X_{crack}}{\mu \bullet \ln\left[2 \bullet \frac{Z_{crack}}{r_{crack}}\right]}$$ **…Equation JE5**

Where:

P	= pressure differential between the soil surface and the enclose space, (g/cm.s^2) which may range from negligible (0.001-20Pa, or 0.0001 to 2 g/cm.s^2)
k_v	= soil vapour permeability, (cm^2), calculated based on soil type benath slab as per USEPA 2003
X_{crack}	= floor-wall seam perimeter, (cm)
μ	= viscosity of air, (g/cm.s)
Z_{crack}	= crack depth below ground level, (cm)
r_{crack}	= equivalent crack radius, (cm), refer to USEPA 2003 for approach.

However, for buildings constructed as slab-on-grade in climates where the potential for pressure differences to be driven by long term heating or unbalanced ventilation systems, the potential for pressure driven flows (advection) is considered negligible, consistent with the approach adopted in the ASTM guidance (2002). This results in Qsoil to be essentially negligible and hence the attenuation factor is simplified and can be calculated using the following (as per ASTM 2002):

$$\alpha = \frac{\left[\frac{D_T^{eff} / L_T}{ER \bullet L_B}\right]}{\left[1 + \left[\frac{D_T^{eff} / L_T}{ER \bullet L_B}\right] + \left[\frac{D_T^{eff} / L_T}{(D^{crack} / L^{crack}) \bullet \eta}\right]\right]}$$ **Equation JE6**

Where:

D_T^{eff}.	= total overall effective diffusion coefficient. Refer to Equations D1 and D2.
L_B	= enclosed-space volume: infiltration area ratio (cm).
ER	= enclosed-space air exchange rate (1/sec).
L_T	= separation distance between the source or soil gas measurement and the building (cm).
L_{crack}	= enclosed space foundation or slab thickness (cm).
D^{crack}	= effective diffusion coefficient through the cracks (cm^2/s).

Johnson & Ettinger Vapour Intrusion Model

Model Assumptions

The following represent the major assumptions/limitations of the J&E Model.

1. Contaminant vapours enter the structure primarily through cracks and openings in the walls and foundation.

2. Convective transport occurs primarily within the building zone of influence and vapour velocities decrease rapidly with increasing distance from the structure.

3. Diffusion dominates vapour transport between the source of contamination and the building zone of influence.

4. All vapours originating from below the building will enter the building unless the floors and walls are perfect vapour barriers.

5. All soil properties in any horizontal plane are homogeneous.

6. The contaminant is homogeneously distributed within the zone of contamination.

7. The aerial extent of contamination is greater than that of the building floor in contact with the soil.

8. Vapour transport occurs in the absence of convective water movement within the soil column (i.e., evaporation or infiltration), and in the absence of mechanical dispersion.

9. The model does not account for transformation processes (e.g., biodegradation, hydrolysis, etc.).

10. The soil layer in contact with the structure floor and walls is isotropic with respect to permeability.

11. Both the building ventilation rate and the difference in dynamic pressure between the interior of the structure and the soil surface are constant values.

Use of the J&E Model as a first-tier screening tool to identify sites needing further assessment requires careful evaluation of the assumptions listed in the previous section to determine whether any conditions exist that would render the J&E Model inappropriate for the site. If the model is deemed applicable at the site, care must be taken to ensure reasonably conservative and self-consistent model parameters are used as input to the model. Considering the limited site data typically available in preliminary site assessments, the J&E Model can be expected to predict only whether or not a risk-based exposure level will be exceeded at the site. Precise prediction of concentration levels is not possible with this approach.

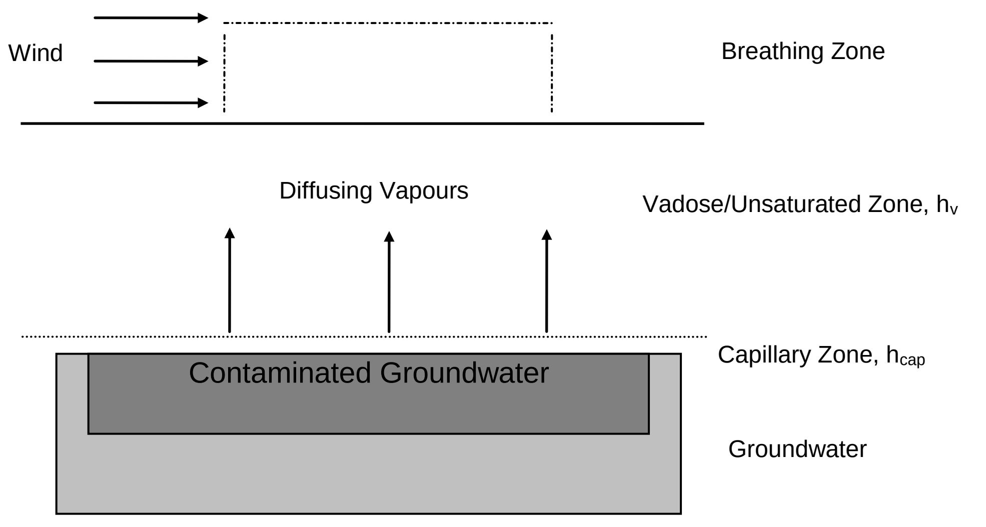
Outdoor Air and Excavations

Introduction

There are a number of models available for estimating potential concentrations of chemicals within the outdoor air environment associated with the migration from a subsurface source. Limited guidance is available for the estimation of concentrations in an excavation, hence the outdoor model adopted has also been utilised for calculations of concentrations within an excavation. The estimation of concentrations in outdoor air can be undertaken using two different methodologies outlined in the Soil Screening Guidelines (USEPA, 1996[1]) and the Risk Based Corrective Action at Petroleum Release Sites (ASTM, 2002[2]).

The model is used to assess vapour intrusion indoors only and assumed that the source is non-depleting.

Conceptual Model



Volatilisation from Soil and Groundwater to Ambient Air

[1] USEPA 1996. Soil Screening Guidance. Publication 9355.4-23, July 1996

[2] ASTM, 2002. Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites. ASTM E 1739-95 (2002)

Outdoor Air and Excavations

Equations

The relevant equations associated with the estimation of outdoor air concentrations based on the approach outlined in the USEPA document "Soil Screening Guidance" (1996 and Supplement 2001 Exhibit D-3). This model uses air dispersion models to provide an estimate of potential dispersion of emissions above the ground as presented below.

$$C_o = \frac{J_S}{Q/C \bullet 10^{-9}}$$ **…Equation O1**

Where:

C_o = Outdoor air concentration (μg/m^3)
J_S = Contaminant flux from the surface of the ground (measured) (g/s/m^2)
Q/C = Dispersion term calculated for area (g/s/m^2 per kg/m^3)
10^{-9} = Units conversion to from kg/m^3 to μg/m^3

$$Q/C = 11.91 \bullet \exp\left(\frac{(\ln(Acres) - 18.4385)^2}{209.7845}\right)$$ **…Equation O2**

Where:

Q/C = Dispersion term calculated for area (g/s/m^2 per kg/m^3) based on climates similar to Los Angeles which is considered relevant for much of Australia, however for other areas, relevant parameters are selected.
Acres = Area of the source outside (acres)

A simpler approach more commonly used for small subsurface sources is the outdoor model presented in the ASTM (2002) guidance. Outdoor air concentrations have been estimated using a simple box model, which accounts for some atmospheric mixing. The concentration of volatile contaminants within the breathing zone of outdoor air has been estimated using Equation O3.

$$C_{outdoor} = C_S \bullet VF$$ (mg/m^3) **…Equation O3**

Where:

C_s = concentration at the source (mg/m^3)
VF = volatilisation factor calculated for emissions from the source to air, refer to Equation O4.

As noted with the indoor air model, the vapour phase concentration at the source can be estimated using the following relationships:

- Where soil gas data is available and relevant to the quantification of vapour migration, the measured soil gas concentration is considered to be the concentration at the source, with migration modelled through overlying soils (from point of measurement to the surface); and

Outdoor Air and Excavations

- Where no soil gas data is available, the concentration at the source is based on theoretical partitioning from the groundwater or soil source, as presented in Equations VS1 to VS5 (as required).

The volatilisation factor is calculated using the following:

$$VF = \frac{D_s^{eff} \bullet W}{U_{air} \bullet \delta \bullet L_{GW}} \quad \text{....Equation O4}$$

where:

U_{air} = Wind speed above the ground surface in the ambient mixing zone (cm/s)

δ_{air} = Ambient air mixing zone height (cm)

L_{GW} = Depth to groundwater (= height of capillary zone, h_{cap}, + height of unsaturated zone, h_v) (cm)

W = Width of source area parallel to wind or groundwater flow direction (cm) (i.e. width and breadth of breathing zone)

D_{ws}^{eff} = Effective diffusion coefficient between the groundwater and soil surface (cm^2/s), refer to Equations D1 and D2.

Emissions into Excavation or Trench

Volatile COPC have the potential to accumulate within trenches or excavations in areas where excavations intersect or are located directly above contaminated soil or groundwater. Workers have the potential to be exposed to these COPC when working in or near the trench or excavation. It is unlikely that workers would spend an entire workday within any excavation or trench, and any exposure near the trench or excavation would result in exposure to significantly lower concentrations due to dilution.

Concentrations within an excavation have been estimated using the ASTM (2002) outdoor air model presented above, however the depth to the source is adjusted to reflect to depth from the base of the excavation to the source, the dimensions of the excavation are used and the wind speed is adjusted to reflect a more confined space scenario. A typical excavation is estimated as 1m x 10m x 1 to 1.5m depth (ANZECC 1992[3] notes the depth of most services is between 1 to 2m below ground surface). A wind speed considered representative of a more confined space within an excavation is 0.5 m/s.

[3] ANZECC 1992. Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites. Australian and New Zealand Environment and Conservation Council, National Health and Medical Research Council, January 1992.

Vapour Phase Partitioning and Diffusion

Introduction

The assessment of vapour migration and vapour intrusion into buildings can be undertaken using a number of different models depending of the building type considered. While the model and approach adopted for the different building types differs, the initial processes associated wit the source) is the same. In addition, all the models currently used consider diffusion as a key mechanism for vapour phase transport through the subsurface. The methodology for estimating vapour diffusion is the same in each model.

The vapour phase concentration at the source can be estimated using the following relationships:

- Where soil gas data is available and relevant to the quantification of vapour intrusion, the measured soil gas concentration is considered to be the concentration at the source, with diffusion modelled through overlying soils (from point of measurement to the surface of building); and
- Where no soil gas data is available, the concentration at the source is based on theoretical partitioning from the groundwater or soil source, see below, with subsequent diffusion modelled through the overlying soils.

The following presents the equations (Johnson et al 1990[1] and Johnson and Ettinger 1991[2]) used to estimate the vapour phase concentration directly above the source and diffusion through overlying soils.

Vapour Phase-Partitioning

Groundwater Source

For a groundwater source, it is assumed that the vapour phase concentration directly above the groundwater is in equilibrium with the groundwater and the concentration is related to the groundwater concentration by Henry's Law:

$$C_{source} = C_{water} \bullet HL \qquad (g/cm^3) \qquad \textbf{...Equation VS1}$$

Where:

C_{water} = concentration in water (at top of groundwater, g/cm^3)

HL = Henry's Law constant (unitless)

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[1] Johnson, P.C., Hertx M.B. and Beyers D.L., 1990. Estimates for Hydrocarbon vapour emissions resulting from service station remediation and buried gasoline-contaminated soils. In: Petroleum Contaminated Soils, Vol. 3. Lewis Publishers, Michigan.

[2] Johnson, P.C. and Ettinger R.A., 1991. Heuristic model for predicting the intrusion rate of contaminant vapours into buildings. Environ. Sci. Technology, Volume 25: 1445-1452.

Vapour Phase Partitioning and Diffusion

The concentration within the vapour phase will increase proportionally with the concentration in groundwater (at the top of the groundwater table), until it reaches saturation. At some point the saturated vapour phase concentration will be reached, which is an upper limit of the vapour phase concentration. The saturated vapour phase concentration is estimated using the following relationship:

$$SVPC = \frac{VP \bullet MW}{T \bullet 62361} \qquad (g/cm^3) \qquad \text{...Equation VS2}$$

Where:

VP = vapour pressure of the contaminant (mmHg)
MW = molecular weight (g/mol)
T = soil temperature (K)
62361 = conversion (mmHg/K* cm^3/mol)

Soil Source

For a soil source, it is assumed that the vapour phase concentration directly above the soil is in equilibrium with the source and the concentration is related to the soil concentration by the following:

$$C_{source} = \frac{C_{soil} \bullet H' \bullet \rho_S}{\theta_{ws} + k_d \bullet \rho_S + H' \bullet \theta_{as}} \qquad (g/cm^3) \qquad \text{...Equation VS3}$$

where:

Csoil = Concentration in soil source zone (g/g)
H' = Henry's Law constant (unitless)
ρ_S = Soil bulk density (g soil/cm^3 soil)
θ_{ws} = Volumetric water content in soil source zone (cm^3 water/cm^3 soil)
θ_{as} = Volumetric air content in soil source zone (cm^3 air/cm^3 soil)
K_d = Soil-water partition coefficient (cm^3 air/g soil) = K_{oc} x f_{oc}
Koc = Soil organic carbon partition coefficient, chemical specific (cm^3/g)
f_{oc} = Soil organic carbon fraction (unitless)

The equilibrium vapour phase concentration is proportional to the soil concentration up to the soil saturation limit (C_{sat}), which is calculated using the following (with the saturated vapour phase calculated using Equation VS2):

$$C_{sat} = \frac{S}{\rho_s} \bullet [H' \bullet \theta_{as} + \theta_{ws} + K_d \bullet \rho_s] \qquad (mg/kg) \qquad \text{...Equation VS4}$$

where:

S = Pure component solubility in water (mg/L)

Vapour Phase Partitioning and Diffusion

When residual phase is present the vapour concentration is independent of the soil concentration but proportional to the mole fraction of the individual component of the residual phase mixture as below.

Vapour Phase above Free Phase (NAPL)

Where free phase or NAPL is present at the top of the groundwater or within a soil profile, the concentration of vapour directly above the NAPL is estimated using Raoult's Law:

$$C_{NAPLsource} = \frac{x_i \bullet P_i(T_S) \bullet MW}{1000 \bullet R \bullet T_S}$$ **…Equation VS5**

where:

x_i = mole fraction of chemical in NAPL (mol/mol);
$P_i(T_S)$ = vapour pressure of chemical at average soil temperature (atm);
M_w = molecular weight (g/mol);
R = Universal Gas Constant, 0.08206 L (atm)mol^{-1}K^{-1};
T_S = Average soil temperature (^{o}K);
1000 = Units conversion factor (L/ml).

Effective Diffusion

The total overall effective diffusion coefficient can be calculated for n different soil layers between the source and the enclosed floor (including the capillary fringe where relevant). This is estimated using Equation D1.

$$D_T^{eff} = \frac{L_T}{\sum_{i=1}^{n} L_i / D_i^{eff}}$$ **…Equation D1**

L_T = separation distance between the source and the building (cm)
L_i = thickness of the soil layer i (cm)
D_i^{eff} = effective diffusion coefficient across soil layer i (cm^2/s) – refer to Equation D2

$$D_i^{eff} = D_a \bullet \left[\frac{\theta_{ai}^{3.33}}{n_i^2}\right] + \left[\frac{D_w}{H'}\right] \bullet \left[\frac{\theta_{wi}^{3.33}}{n_i^2}\right]$$ **…Equation D2**

D_a = diffusivity in air, chemical specific (cm^2/s)
θ_{ai} = soil air-filled volume of layer i (cm^3/cm^3)
n_i = soil total porosity of layer i (cm^3/cm^3)
= 1-ρ_b/ρ_s
ρ_b = soil dry bulk density, (g/cm^3)
ρ_s = soil particle density, (g/cm^3) - typically 2.65
D_w = diffusivity in water, chemical specific (cm^2/s)
θ_{wi} = soil water-filled volume of layer i, (cm^3/cm^3)

APPENDIX B MODELLING INPUT AND OUTPUT SPREADSHEETS

VAPOUR PARTITIONING, EMISSION AND AIR DISPERSION MODEL FOR CONTAMINATED SOILS

For Houses on Piers with Crawl-Spaces, migration from Infinite Source. Reference: Turczynowicz 2002

Site Specific Physical Input Parameters	Units	Abbrev.	Value	Comments
Thickness of Vadose Zone	[m]	d	1	Calculated from layers
Soil Temperature	[C]	T	**15**	site-specific assumption
Vadose Zone Layer 1 Characteristics				***CRC Care - Sand, Sandy Clay***
Depth of Layer 1	[m]	vd1	**1**	1 m soil vapour bore beneath child care centre
Moisture Content	[cm^3/g]	mocon	**0.08**	assumption for clays
Organic Carbon Fraction	-	foc	**0.003**	based on field data
Soil Bulk Density	[g/cm^3]	rhob	**1.625**	Estimated for clays
Density of Solids	[g/cm^3]	sd	2.65	site-specific assumption
Total Soil Porosity	[cm^3/cm^3]	theta	0.39	1 - (rhob/sd)
Volumetric Water Content	[cm^3/cm^3]	wacon	0.130	mocon*rhob
Volumetric Air Content	[cm^3/cm^3]	acon	0.257	theta-wacon
Vadose Zone Layer 2 Characteristics				***Sandy Clay***
Depth of Layer 1	[m]	vd2	**0**	Typical depth from logs
Moisture Content	[cm^3/g]	mocon2	**0.26**	site-specific assumption
Organic Carbon Fraction	-	foc2	**0.003**	based on field data
Soil Bulk Density	[g/cm^3]	rhob2	**1.56**	Estimated for fractured basalts
Density of Solids	[g/cm^3]	sd2	2.67	site-specific assumption
Total Soil Porosity	[cm^3/cm^3]	theta2	0.42	1 - (rhob2/sd2)
Volumetric Water Content	[cm^3/cm^3]	wacon2	0.406	mocon2*rhob2
Volumetric Air Content	[cm^3/cm^3]	acon2	0.01	theta2-wacon2

Receptor Specific Input Parameters	Units	Abbrev.	Value	Comments
Building Characteristics				
Height of Building (internal)	[m]	bheight	**3**	Default Value for type of building, CRC Care 2011
Width of Building	[m]	bwidth	**12.5**	Assume whole building above source
Length of Building	[m]	blength	**25**	Assume whole building above source
Area of Emission - Building Area	[m^2]	emarea	312.5	Default calculation assuming whole house is over source
Volume of Dwelling Space	[m^3]	bvolume	937.5	Calculated using building height and area as per Turczynowicz, 2002
Air Exchange Rate in Dwelling	[exch/day]	exchanges	**24**	assumed 2 per hour for commercial
Height of Crawl Space	[m]	cheight	**0.30**	Approximate depth of CCC crawl space
Volume of Crawl Space	[m^3]	cvolume	93.75	Calculated using crawl space height and area as per Turczynowicz, 2002
Air Exchange Rate in Crawl Space	[exch/day]	cexchanges	**72**	Calibrated value from soil vapour to crawl-space
Qcsd	[m^3/day]	Qcsb	**2242**	911 m3/d for 127 m2 house - Turczynowicz 2002, based on Australian studies
Indoor Air Sinks	[m^3/day]	Qs	**0.0**	Typical value from Turczynowicz 2002, based on 2 adults indoors
Outdoor Air Characteristics				
Length of Contaminated Area	[m]	length	**20**	site-specific assumption
Width of Contaminated Area	[m]	width	**100**	site-specific assumption
Wind Speed Outdoors	[m/s]	wspd	**2.5**	site-specific assumption
Height of Outdoor Mixing Zone	[m]	outboxh	1.5	Default Value

Chemical Specific Parameters	Water Solubility (mg/L)	MW (g/mol)	Koc (cm^3/g)	Air Diffusion Coefficient (cm^2/s)	Water Diffusion Coefficient (cm^2/s)	Vapour Pressure (mmHg)	Henry's Law Constant (unitless)	Degradation Rate in Air (per day)
Trichloroethene	1280	131	60.7	0.0687	1.0E-05	69	0.403	0
Tetrachloroethene	206	166	94.9	0.0505	9.5E-06	18.5	0.724	0
cis-1,2-Dichloroethene	6410	96.9	39.6	0.0884	1.1E-05	201	0.167	0

Vapour Transport Calculations	Deff Layer 1 (cm^2/s)	Deff Layer 2 (cm^2/s)	Total Effective Diffusion (GW to surface) (cm^2/s)
Trichloroethene	4.94E-3	7.32E-6	4.94E-3
Tetrachloroethene	3.63E-3	3.80E-6	3.63E-3
cis-1,2-Dichloroethene	6.36E-3	1.95E-5	6.36E-3

Calculated Air Concentrations	Vapour Phase Concentration at Source (ug/m^3)	Flux Emission Rate from Surface ($ug/day/m^2$)	Concentration in Crawl Space (ug/m^3)	Concentration in Dwelling ($\mu g/m^3$)	Crawl Space to indoor Air Attenuation Factor	Outdoor Air Concentration ($\mu g/m^3$)
Trichloroethene	**2000**	8.5E+01	4.0E+00	**3.9E-01**	**10.0**	**0.026**
Tetrachloroethene	**6.5**	2.0E-01	9.4E-03	**9.4E-04**	**10.0**	**0.0001**
cis-1,2-Dichloroethene	**280**	1.5E+01	7.1E-01	**7.1E-02**	**10.0**	**0.005**

VAPOUR PARTITIONING, EMISSION AND AIR DISPERSION MODEL FOR CONTAMINATED GROUNDWATER
Using USEPA Vapor Migration Guidance (2003), Johnson Ettinger Model

Site Specific Physical Input Parameters	Units	Abbrev.	Value	Comments
Depth of Top of Contaminated Aquifer (BGS)	[m]	d	3.5	Calculated from layers
Thickness of Capillary Fringe	[m]	cd	0.2	Estimated for Sandy Clay
Thickness of Vadose Zone	[m]	vd	3.3	Calculated from layers
Average Soil Temperature	[C]	T	**25**	site-specific assumption
Vadose Zone Layer 1 Characteristics				***CRC Care - Sand, Sandy Clay***
Depth of Layer 1 from Foundations	[m]	vd1	**2**	Typical depth from logs
Moisture Content	[ml/g]	mocon	0.08	Estimated for CRC Care - Sand, Sandy Clay
Organic Carbon Fraction	-	foc	0.003	Estimated for CRC Care - Sand, Sandy Clay
Soil Bulk Density	[g/ml]	rhob	1.625	Estimated for CRC Care - Sand, Sandy Clay
Density of Solids	[g/ml]	sd	2.65	default
Total Soil Porosity	[ml/ml]	theta	0.39	1 - (rhob/sd)
Volumetric Water Content	[ml/ml]	wacon	0.130	mocon*rhob
Volumetric Air Content	[ml/ml]	acon	0.257	theta-wacon
Vadose Zone Layer 2 Characteristics				***Sandy Clay***
Depth of Layer 2 to Water Table	[m]	vd2	**1.3**	Typical depth from logs
Moisture Content	[ml/g]	mocon2	0.26	Estimated for Sandy Clay
Organic Carbon Fraction	-	foc2	0.003	Estimated for Sandy Clay
Soil Bulk Density	[g/ml]	rhob2	1.56	Estimated for Sandy Clay
Density of Solids	[g/ml]	sd2	2.67	default
Total Soil Porosity	[ml/ml]	theta2	0.42	1 - (rhob2/sd2)
Volumetric Water Content	[ml/ml]	wacon2	0.406	mocon2*rhob2
Volumetric Air Content	[ml/ml]	acon2	0.010	theta2-wacon2
Capillary Fringe				
Volumetric Water Content	[ml/ml]	cfwacon	0.406	Value representative of capillary fringe, ASTM (2002)
Volumetric Air Content	[ml/ml]	cfacon	0.010	theta2-cfwacon

VAPOUR PARTITIONING, EMISSION AND AIR DISPERSION MODEL FOR CONTAMINATED GROUNDWATER
Using USEPA Vapor Migration Guidance (2003), Johnson Ettinger Model

Receptor Specific Input Parameters	Units	Abbrev.	Value	Comments
Building Characteristics				***Residential - Slab On Ground***
Depth of Basement	[m]	basement	0	Depth of basement below ground level
Width of Building	[m]	bwidth	10	Assume whole building above source
Length of Building	[m]	blength	10	Assume whole building above source
Area of Emission - Building Area	[m^2]	emarea	100	Assume whole building above source
Foundation/wall thickness	[m]	fthick	0.1	Default Value BCA
Height of Room	[m]	boxh	2.4	Default Value for type of building, USEPA 2003
Hourly Volume Exchange of Fresh Air	[exch/hr]	exchanges	0.6	CRC CARE 2011 for residential
Fraction of Cracks in Walls and foundation	-	cracks	0.001	CRC CARE 2011
Qbuilding	[cm^3/s]	Qb	40000	Calculated from building volume and exchange rate
Qsoil	[cm^3/s]	Qs	83.33333333	Calculated from default of Qs:Qb (CRC Care 2010)
Ratio of Qs:Qb	-	Qs/Qb	0.005	Defaults are 0.005 (Res) and 0.001 (Comm) (CRC CARE)
Area of Cracks (ACrack)	[cm^2]	Ac	1000	Calculated from building area and crack ratio, USEPA 2003
Volumetric Water Content in foundation/wall cracks	[ml/ml]	fwacon	0.12	Default Value ASTM 1739-95
Volumetric Air Content in foundation/wall cracks	[ml/ml]	facon	0.26	Default Value ASTM 1739-95
Outdoor Air Characteristics				
Length of Contaminated Area	[m]	length	10	site-specific assumption
Width of Contaminated Area	[m]	width	10	site-specific assumption
Wind Speed Outdoors	[m/s]	wspd	2.5	site-specific assumption
Height of Outdoor Mixing Zone	[m]	outboxh	1.5	Default Value

VAPOUR PARTITIONING, EMISSION AND AIR DISPERSION MODEL FOR CONTAMINATED GROUNDWATER
Using USEPA Vapor Migration Guidance (2003), Johnson Ettinger Model

Chemical Specific Parameters	Water Solubility (mg/L)	MW (g/mol)	Koc (cm^3/g)	Air Diffusion Coefficient (cm^2/s)	Water Diffusion Coefficient (cm^2/s)	Vapour Pressure (mmHg)	Henry's Law Constant (unitless)
Tetrachloroethene	206	165.83	1.07E+02	5.05E-02	9.46E-06	53.200	7.2E-01
Trichloroethene	1280.0	131.40	6.77E+01	6.87E-02	1.02E-05	72.50	4.03E-01
cis-1,2-dichloroethene	3500	96.95	3.55E+01	7.60E-02	1.13E-05	201.00	1.67E-01

Vapour Transport Calculations	Deff Layer 1 (cm^2/s)	Deff Layer 2 (cm^2/s)	Deff Foundations and Cracks (cm^2/s)	Deff Capillary Fringe (cm^2/s)	Total Effective Diffusion (cm^2/s) to indoor air
Tetrachloroethene	3.63E-3	3.80E-6	3.79E-3	3.80E-6	8.85E-6
Trichloroethene	4.94E-3	7.32E-6	5.15E-3	7.33E-6	1.70E-5
cis-1,2-dichloroethene	5.47E-3	1.94E-5	5.70E-3	1.95E-5	4.51E-5

Phase Partitioning Results	Dissolved Phase Concentration (mg/L)	Vapour Phase Concentration (g/cm^3)	Saturated Vapour Conentration (g/cm^3)	Free Phase Mole Fraction (mol/mol)	Concentration above Free Phase (g/cm^3)	Calculation Vapour Phase Concenration Adopted (g/cm^3)
Tetrachloroethene	0.00018	1.3E-10	4.7E-04			**1.3E-10**
Trichloroethene	0.47	1.9E-07	5.1E-04			**1.9E-07**
cis-1,2-dichloroethene	0.0581	9.7E-09	1.0E-03			**9.7E-09**

Calculated Air Concentrations (with advection)	Vapour Phase Concentration at Source (ug/m^3)	Vapour Phase Concentration at Source (mg/m^3)	JE Attenuation Coefficient (unitless)	Indoor Air Concentration (mg/m^3)	Indoor Air Concentration (µg/m^3)
Tetrachloroethene	1.3E+02	1.3E-01	6.3E-07	**8.23E-08**	**0.0001**
Trichloroethene	1.9E+05	1.9E+02	1.2E-06	**2.3E-04**	**0.23**
cis-1,2-dichloroethene	9.7E+03	9.7E+00	3.2E-06	**3.1E-05**	**0.03**

Calculated Air Concentrations ASTM Guidance (without advection)	Vapour Phase Concentration at Source (g/cm3)	Vapour Phase Concentration at Source (mg/m^3)	Emission Rate from Surface of Ground (g/s)	Indoor Air Concentration (mg/m^3)	Indoor Air Concentration (µg/m^3)	Outdoor Air Concentration (µg/m^3)
Tetrachloroethene	1.3E-10	1.3E-01	3.3E-12	**7.72E-08**	**0.0001**	**8.8E-08**
Trichloroethene	1.9E-07	1.9E+02	9.2E-09	**2.1E-04**	**0.21**	**2.5E-04**
cis-1,2-dichloroethene	9.7E-09	9.7E+00	1.3E-09	**2.6E-05**	**0.03**	**3.3E-05**

Toxicity and Dermal Absorption Parameters

C = calculated from chronic value, Ch = chronic value adopted

Chemical	Oral/Dermal Exposures							
	Non-Threshold Slope Factor $(mg/kg/day)^{-1}$	Ref	Threshold Chronic TDI (mg/kg/day)	Ref	Threshold Subchronic TDI (mg/kg/day)	Ref	Dermal Permeability (cm/hr)	Dermal Adsorption (Unitless)
Tetrachloroethene			1.40E-02	ADWG/WHO		-	4.81E-02	3.00E-02
Trichloroethene	7.80E-04	WHO	1.46E-03	WHO	1.46E-03	-	1.57E-02	3.00E-02
cis-1,2-dichloroethene		-	2.00E-03	USEPA 2010	3.00E-01	ATSDR	1.49E-02	3.00E-02
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Toxicity and Derma

C = calculated from chronic va

Chemical	Inhalation Exposures							Background Intake (% TDI)	
	Inhalation Unit Risk (ug/m^3)$^{-1}$	Ref	Threshold Chronic TC (mg/m^3)	Threshold Chronic TDI (mg/kg/day)	Ref	Threshold Subchronic TC (mg/m^3)	Ref	Chronic Assessment (%)	Subchronic Assessment
Tetrachloroethene		-	2.00E-01		WHO	2.00E-01	-		10.00%
Trichloroethene	4.10E-06	US EPA	2.00E-03	4.10E-06	US EPA	2.00E-03	-	10.00%	10.00%
cis-1,2-dichloroethene		-	7.00E-03		USEPA 2010	7.90E-01	ATSDR		
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Inhalation of Volatile Chemicals

Chronic Exposures

General Data/ Equations	Units	Residential Exposure Parameters (RME) Inhalation Indoors by Adult	
Exposure Parameters			
Exposure Frequency (EF)	days/year	365	Exposure every day
Exposure Duration (ED)	years	14	Exposure for 30 years less childhood exposure
Body Weight (BW)	kg	70	USEPA 1989 and CSMS 1996
Averaging Time - NonThreshold (ATc)	hours	613200	USEPA 2009
Averaging Time - Threshold (ATn)	hours	122640	USEPA 2009
Advection	Y		
Exposure Time (ET)	hr/day	20	Time spent indoors (CRC CARE) less time spent in basement
Fraction Inhaled from Contaminated Source (FI)	-	1	Assume all of residence above groundwater/soils
Intake Factor = ET*FI*EF*ED / AT	-	**1.7E-01**	**NonThreshold**
		8.3E-01	**Threshold**

Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)
NonThreshold Risk = Inhalation Exposure Concentration x Unit Risk
Hazard Quotients = (Inhalation Exposure Concentration/Allowable TC air)

Chemical	Toxicity Data				Concentration	Daily Exposure		Calculated Risk	
	Inhalation Unit Risk	Chronic TC air	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background)	in Indoor Air	Inhalation Exposure Concentration - NonThreshold	Inhalation Exposure Concentration - Threshold	NonThreshold Risk	Chronic Hazard Quotient
	$(mg/m^3)^{-1}$	(mg/m^3)		(mg/m^3)	(mg/m^3)	(mg/m^3)	(mg/m^3)	(unitless)	(unitless)
							TOTAL	**1.6E-7**	**1.1E-1**
Tetrachloroethene		2.0E-01		2.0E-01	8.2E-08	1.4E-08	6.9E-08	--	3.4E-7
Trichloroethene	4.1E-03	2.0E-03	10%	1.8E-03	2.3E-04	3.8E-05	1.9E-04	1.6E-7	1.1E-1
cis-1,2-dichloroethene		7.0E-03		7.0E-03	3.1E-05	5.2E-06	2.6E-05	--	3.7E-3
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Add comments regarding concentrations here

Inhalation of Volatile Chemicals

Chronic Exposures

General Data/ Equations	Units	Residential Exposure Parameters (RME) Inhalation Outdoors by Adult	
Exposure Parameters			
Exposure Frequency (EF)	days/year	365	Exposure every day
Exposure Duration (ED)	years	14	Exposure for 30 years less childhood exposure
Body Weight (BW)	kg	70	USEPA 1989 and CSMS 1996
Averaging Time - NonThreshold (ATc)	hours	613200	USEPA 2009
Averaging Time - Threshold (ATn)	hours	122640	USEPA 2009
Advection	NA		
Exposure Time (ET)	hr/day	2	CRC Care 2011
Fraction Inhaled from Contaminated Source (FI)	-	1	Assume all of residence above groundwater/soils
Intake Factor = ET*FI*EF*ED / AT	-	**1.7E-02**	**NonThreshold**
		8.3E-02	**Threshold**

Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)
NonThreshold Risk = Inhalation Exposure Concentration x Unit Risk
Hazard Quotients = (Inhalation Exposure Concentration/Allowable TC air)

Chemical	Toxicity Data				Concentration	Daily Exposure		Calculated Risk	
	Inhalation Unit Risk	Chronic TC air	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background)	in Outdoor Air	Inhalation Exposure Concentration - NonThreshold	Inhalation Exposure Concentration - Threshold	NonThreshold Risk	Chronic Hazard Quotient
	$(mg/m^3)^{-1}$	(mg/m^3)		(mg/m^3)	(mg/m^3)	(mg/m^3)	(mg/m^3)	(unitless)	(unitless)
							TOTAL	**1.7E-11**	**1.2E-5**
Tetrachloroethene		2.0E-01		2.0E-01	8.8E-11	1.5E-12	7.3E-12	--	3.7E-11
Trichloroethene	4.1E-03	2.0E-03	10%	1.8E-03	2.5E-07	4.1E-09	2.1E-08	1.7E-11	1.1E-5
cis-1,2-dichloroethene		7.0E-03		7.0E-03	3.3E-08	5.6E-10	2.8E-09	--	4.0E-7
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Add comments regarding concentrations here

Inhalation of Volatile Chemicals

Chronic Exposures

General Data/ Equations	Units	Residential Exposure Parameters (RME) Inhalation Indoors by Older Child (5-15 yrs)	
Exposure Parameters			
Exposure Frequency (EF)	days/year	365	Exposure every day
Exposure Duration (ED)	years	10	Total exposure during ages 6 to 15 years
Body Weight (BW)	kg	34.5	USEPA 1989 and CSMS 1996
Averaging Time - NonThreshold (ATc)	hours	613200	USEPA 2009
Averaging Time - Threshold (ATn)	hours	87600	USEPA 2009
Advection	Y		
Exposure Time (ET)	hr/day	20.0	Time spent indoors (CRC CARE) less time spent in basement
Fraction Inhaled from Contaminated Source (FI)	-	1	Assume all of residence above groundwater/soils
Intake Factor = ET*FI*EF*ED / AT	-	**1.2E-01**	**NonThreshold**
		8.3E-01	**Threshold**

Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)
NonThreshold Risk = Inhalation Exposure Concentration x Unit Risk
Hazard Quotients = (Inhalation Exposure Concentration/Allowable TC air)

Chemical	Toxicity Data: Inhalation Unit Risk	Chronic TC air	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background)	Concentration in Indoor Air	Daily Exposure: Inhalation Exposure Concentration - NonThreshold	Inhalation Exposure Concentration - Threshold	Calculated Risk: NonThreshold Risk	Chronic Hazard Quotient
	$(mg/m^3)^{-1}$	(mg/m^3)		(mg/m^3)	(mg/m^3)	(mg/m^3)	(mg/m^3)	(unitless)	(unitless)
							TOTAL	**1.1E-7**	**1.1E-1**
Tetrachloroethene		2.0E-01		2.0E-01	8.2E-08	9.8E-09	6.9E-08	--	3.4E-07
Trichloroethene	4.1E-03	2.0E-03	10%	1.8E-03	2.3E-04	2.7E-05	1.9E-04	1.1E-07	1.1E-01
cis-1,2-dichloroethene		7.0E-03		7.0E-03	3.1E-05	3.7E-06	2.6E-05	--	3.7E-03
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Add comments regarding concentrations here

Inhalation of Volatile Chemicals

Chronic Exposures

General Data/ Equations	Units	Residential Exposure Parameters (RME) Inhalation Outdoors by Older Child (5-15 yrs)	
Exposure Parameters			
Exposure Frequency (EF)	days/year	365	Exposure every day
Exposure Duration (ED)	years	10	Total exposure during ages 6 to 15 years
Body Weight (BW)	kg	34.5	USEPA 1989 and CSMS 1996
Averaging Time - NonThreshold (ATc)	hours	613200	USEPA 2009
Averaging Time - Threshold (ATn)	hours	87600	USEPA 2009
Advection	NA		
Exposure Time (ET)	hr/day	2	CRC CARE
Fraction Inhaled from Contaminated Source (FI)	-	1	Assume all of residence above groundwater/soils
Intake Factor = ET*FI*EF*ED / AT	-	**1.2E-02**	**NonThreshold**
		8.3E-02	**Threshold**

Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)
NonThreshold Risk = Inhalation Exposure Concentration x Unit Risk
Hazard Quotients = (Inhalation Exposure Concentration/Allowable TC air)

Chemical	Toxicity Data				Concentration	Daily Exposure		Calculated Risk	
	Inhalation Unit Risk	Chronic TC air	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background)	in Outdoor Air	Inhalation Exposure Concentration - NonThreshold	Inhalation Exposure Concentration - Threshold	NonThreshold Risk	Chronic Hazard Quotient
	$(mg/m^3)^{-1}$	(mg/m^3)		(mg/m^3)	(mg/m^3)	(mg/m^3)	(mg/m^3)	(unitless)	(unitless)
							TOTAL	**1.2E-11**	**1.2E-5**
Tetrachloroethene		2.0E-01		2.0E-01	8.8E-11	1.0E-12	7.3E-12	--	3.7E-11
Trichloroethene	4.1E-03	2.0E-03	10%	1.8E-03	2.5E-07	2.9E-09	2.1E-08	1.2E-11	1.1E-5
cis-1,2-dichloroethene		7.0E-03		7.0E-03	3.3E-08	4.0E-10	2.8E-09	--	4.0E-7
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↑ Add comments regarding concentrations here

Inhalation of Volatile Chemicals

Chronic Exposures

General Data/ Equations	Units	Residential Exposure Parameters (RME) Inhalation Indoors by Young Child (0-5 yrs)	
Exposure Parameters			
Exposure Frequency (EF)	days/year	365	Exposure every day
Exposure Duration (ED)	years	6	Lifetime exposure for age group
Body Weight (BW)	kg	13.2	NEPM 1999 and CSMS 1996
Averaging Time - NonThreshold (ATc)	hours	613200	USEPA 2009
Averaging Time - Threshold (ATn)	hours	52560	USEPA 2009
Advection	Y		
Exposure Time (ET)	hr/day	20.0	Time spent indoors (CRC CARE) less time spent in basement
Fraction Inhaled from Contaminated Source (FI)	-	1	Assume all of residence above groundwater/soils
Intake Factor = ET*FI*EF*ED / AT	-	**7.1E-02**	**NonThreshold**
		8.3E-01	**Threshold**

Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)
NonThreshold Risk = Inhalation Exposure Concentration x Unit Risk
Hazard Quotients = (Inhalation Exposure Concentration/Allowable TC air)

Chemical	Toxicity Data				Concentration	Daily Exposure		Calculated Risk	
	Inhalation Unit Risk $(mg/m^3)^{-1}$	Chronic TC air (mg/m^3)	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background) (mg/m^3)	in Indoor Air (mg/m^3)	Inhalation Exposure Concentration - NonThreshold (mg/m^3)	Inhalation Exposure Concentration - Threshold (mg/m^3)	NonThreshold Risk (unitless)	Chronic Hazard Quotient (unitless)
							TOTAL	**6.8E-8**	**1.1E-1**
Tetrachloroethene		2.0E-01		2.0E-01	8.2E-08	5.9E-09	6.9E-08	-	3.4E-7
Trichloroethene	4.1E-03	2.0E-03	1.0E-01	1.8E-03	2.3E-04	1.6E-05	1.9E-04	6.8E-8	1.1E-1
cis-1,2-dichloroethene		7.0E-03		7.0E-03	3.1E-05	2.2E-06	2.6E-05	-	3.7E-3
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Add comments regarding concentrations here

Inhalation of Volatile Chemicals

Chronic Exposures

General Data/ Equations	Units	Residential Exposure Parameters (RME) Inhalation Outdoors by Young Child (0-5 yrs)	
Exposure Parameters			
Exposure Frequency (EF)	days/year	365	Exposure every day
Exposure Duration (ED)	years	6	Lifetime exposure for age group
Body Weight (BW)	kg	13.2	NEPM 1999 and CSMS 1996
Averaging Time - NonThreshold (ATc)	hours	613200	USEPA 2009
Averaging Time - Threshold (ATn)	hours	52560	USEPA 2009
Advection	NA		
Exposure Time (ET)	hr/day	2	CRC CARE
Fraction Inhaled from Contaminated Source (FI)	-	1	Assume all of residence above groundwater/soils
Intake Factor = ET*FI*EF*ED / AT	-	**7.1E-03**	**NonThreshold**
		8.3E-02	**Threshold**

Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)
NonThreshold Risk = Inhalation Exposure Concentration x Unit Risk
Hazard Quotients = (Inhalation Exposure Concentration/Allowable TC air)

Chemical	Toxicity Data: Inhalation Unit Risk $(mg/m^3)^{-1}$	Chronic TC air (mg/m^3)	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background) (mg/m^3)	Concentration in Outdoor Air (mg/m^3)	Daily Exposure: Inhalation Exposure Concentration - NonThreshold (mg/m^3)	Inhalation Exposure Concentration - Threshold (mg/m^3)	Calculated Risk: NonThreshold Risk (unitless)	Chronic Hazard Quotient (unitless)
							TOTAL	**7.2E-12**	**1.2E-5**
Tetrachloroethene		2.0E-01		2.0E-01	8.8E-11	6.3E-13	7.3E-12	-	3.7E-11
Trichloroethene	4.1E-03	2.0E-03	10%	1.8E-03	2.5E-07	1.8E-09	2.1E-08	7.2E-12	1.1E-5
cis-1,2-dichloroethene		7.0E-03		7.0E-03	3.3E-08	2.4E-10	2.8E-09	-	4.0E-7
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Add comments regarding concentrations here

Summary of Risk for RME Exposure

Pathway	NonThreshold Risks	Threshold Risks Hazard Index
Adult Residents (Chronic Exposures)		
Inhalation of COPC Indoors	1.6E-07	0.110
Inhalation of COPC Outdoors	1.7E-11	0.0000118
Incidental Ingestion of COPC in Water		
Dermal Contact with COPC in Water		
Total Risk	**1.6E-07**	**0.110**
Older Child Residents (Chronic Exposures)		
Inhalation of COPC Indoors	1.1E-07	0.110
Inhalation of COPC Outdoors	1.2E-11	0.0000118
Incidental Ingestion of COPC in Water		
Dermal Contact with COPC in Water		
Total Risk	**1.1E-07**	**0.110**
Young Child Residents (Chronic Exposures)		
Inhalation of COPC Indoors	6.8E-08	0.110
Inhalation of COPC Outdoors	7.2E-12	0.0000118
Incidental Ingestion of COPC in Water		
Dermal Contact with COPC in Water		
Total Risk	**6.8E-08**	**0.110**
Lifetime Risk (Chronic)	**3.4E-07**	**0.110**

Using USEPA Vapor Migration Guidance (2003), Johnson Ettinger Model

Site Specific Physical Input Parameters	Units	Abbrev.	Value	Comments
Thickness of Soil Above Contaminated Layer	[m]	d	1	Calculated from layers
Thickness of Contaminated Layer	[m]	surfd	2	Estimated for soil types
Soil Temperature	[C]	T	**25**	site-specific assumption
Vadose Zone Layer 1 Characteristics				***CRC Care - Sand, Sandy Clay***
Depth of Layer 1	[m]	vd1	**0**	Typical depth from logs
Moisture Content	[cm^3/g]	mocon	0.08	Estimated for CRC Care - Sand, Sandy Clay
Organic Carbon Fraction	-	foc	0.003	Estimated for CRC Care - Sand, Sandy Clay
Soil Bulk Density	[g/cm^3]	rhob	1.625	Estimated for CRC Care - Sand, Sandy Clay
Density of Solids	[g/cm^3]	sd	2.65	site-specific assumption
Total Soil Porosity	[cm^3/cm^3]	theta	0.39	1 - (rhob/sd)
Volumetric Water Content	[cm^3/cm^3]	wacon	0.130	mocon*rhob
Volumetric Air Content	[cm^3/cm^3]	acon	0.257	theta-wacon
Vadose Zone Layer 2 Characteristics				***CRC Care - Sand, Sandy Clay***
Depth of Clean Soil overlying impact in Layer 2	[m]	vd2	**1**	Typical depth from logs
Moisture Content	[cm^3/g]	mocon2	0.08	Estimated for CRC Care - Sand, Sandy Clay
Organic Carbon Fraction	-	foc2	0.003	Estimated for CRC Care - Sand, Sandy Clay
Soil Bulk Density	[g/cm^3]	rhob2	1.625	Estimated for Estimated for CRC Care - Sand, Sandy Clay
Density of Solids	[g/cm^3]	sd2	2.65	site-specific assumption
Total Soil Porosity	[cm^3/cm^3]	theta2	0.39	1 - (rhob2/sd2)
Volumetric Water Content	[cm^3/cm^3]	wacon2	0.130	mocon2*rhob2
Volumetric Air Content	[cm^3/cm^3]	acon2	0.257	theta2-wacon2

Receptor Specific Input Parameters	Units	Abbrev.	Value	Comments
Building Characteristics				***Residential - Slab On Ground*** ***(Building Type)***
Depth of Basement	[m]	basement	0	Depth of basement below ground level
Width of Building	[m]	bwidth	10	Site specific assumption
Length of Building	[m]	blength	10	Site specific assumption
Area of Building Below Ground Level	[m^2]	area	100	Assume whole building above source
Foundation/wall thickness	[m]	fthick	0.1	Site specific assumption
Building Mixing Height	[m]	boxh	2.4	Assumption for room
Hourly Volume Exchange of Fresh Air	[exch/hr]	exchanges	0.6	CRC CARE for residential
Fraction of Cracks in Walls and foundation	-	cracks	0.001	Max from CRC CARE 2011
Qbuilding	[cm^3/s]	Qb	40000	Calculated from building volume and exchange rate
Qsoil	[cm^3/s]	Qs	83.33333333	Calculated from default of Qs:Qb (CRC Care 2010)
Ratio of Qs:Qb	-	Qs/Qb	0.005	Defaults are 0.005 (Res) and 0.001 (Comm) (CRC CARE)
Acrack	[cm^2]	Ac	1000	Calculated from building area and crack ratio, USEPA 2003
Volumetric Water Content in foundation/wall cracks	[cm^3/cm^3]	fwacon	0.12	Default Value ASTM 1739-95
Volumetric Air Content in foundation/wall cracks	[cm^3/cm^3]	facon	0.26	Default Value ASTM 1739-95
Outdoor Air Characteristics				
Length of Contaminated Area	[m]	length	10	site-specific assumption
Width of Contaminated Area	[m]	width	10	site-specific assumption
Wind Speed Outdoors	[m/s]	wspd	2.5	site-specific assumption
Height of Outdoor Mixing Zone	[m]	outboxh	1.5	Default Value

Chemical Specific Parameters	Water Solubility (mg/L)	MW (g/mol)	Koc (cm^3/g)	Air Diffusion Coefficient (cm^2/s)	Water Diffusion Coefficient (cm^2/s)	Vapour Pressure (mmHg)	Henry's Law Constant (unitless)
Tetrachloroethene	206	165.83	107	0.051	9.5E-06	53.20	7.24E-01
Trichloroethene	1280	131.40	68	0.069	1.0E-05	72.50	4.03E-01
cis-1,2-dichloroethene	3500	96.95	36	0.076	1.1E-05	201.00	1.67E-01

Vapour Transport Calculations	Deff Layer 1 (cm^2/s)	Deff Layer 2 (cm^2/s)	Deff Foundations and Cracks (cm^2/s)	Total Effective Diffusion (source to indoor (cm^2/s)	Total Effective Diffusion (source to outdoor (cm^2/s)
Tetrachloroethene	3.63E-3	3.63E-3	3.79E-3	3.63E-3	3.63E-3
Trichloroethene	4.94E-3	4.94E-3	5.15E-3	4.94E-3	4.94E-3
cis-1,2-dichloroethene	5.47E-3	5.47E-3	5.70E-3	5.47E-3	5.47E-3

Subsurface Soils Phase Partitioning Results	Soil Concentration (mg/kg)	Vapour Phase Concentration (g/cm^3)	Pure Component Saturated Soil Concentration (mg/kg)	Pure Component Saturated Vapour Conentration (g/cm^3)	Free Phase Mole Fraction (mol/mol)	Concentration above Free Phase (g/cm^3)	Mixture Saturated Soil Concentration (mg/kg)
Tetrachloroethene			3379.3	4.7E-04			
Trichloroethene			4411	5.1E-04			
cis-1,2-dichloroethene			13367	1.0E-03			

Calculated Air Concentrations (with advection)	Measured Soil Vapour (ug/m^3)	Vapour Phase Concentration at Source (ug/m^3)	Vapour Phase Concentration at Source (mg/m^3)	JE Attenuation Coefficient (unitless)	Emission Rate to Indoor Air (g/s)	Depletion Time (years)	Indoor Concentration (µg/m^3)
Tetrachloroethene	6.5	6.5E+00	6.5E-03	6.3E-04	1.6E-10		**0.004**
Trichloroethene	8400	8.4E+03	8.4E+00	7.8E-04	2.6E-07		**6.5**
cis-1,2-dichloroethene	280	2.8E+02	2.8E-01	8.3E-04	9.2E-09		**0.2**

Calculated Air Concentrations ASTM Guidance (without advection)	Vapour Phase Concentration at Source (ug/m3)	Vapour Phase Concentration at Source (g/cm3)	Vapour Phase Concentration at Source (mg/m^3)	Emission Rate into building (g/s)	Depletion Time (years)	Indoor Concentration (µg/m^3)	Outdoor Air Concentration (µg/m^3)
Tetrachloroethene	6.5E+00	6.5E-12	6.5E-03	2.4E-12		**0.0001**	**0.00001**
Trichloroethene	8.4E+03	8.4E-09	8.4E+00	4.3E-09		**0.11**	**0.011**
cis-1,2-dichloroethene	2.8E+02	2.8E-10	2.8E-01	1.6E-10		**0.0039**	**0.0004**

Toxicity and Dermal Absorption Parameters

C = calculated from chronic value, Ch = chronic value adopted

Chemical	Oral/Dermal Exposures							
	Non-Threshold Slope Factor $(mg/kg/day)^{-1}$	Ref	Threshold Chronic TDI (mg/kg/day)	Ref	Threshold Subchronic TDI (mg/kg/day)	Ref	Dermal Permeability (cm/hr)	Dermal Adsorption (Unitless)
Tetrachloroethene	0.00E+00	0	1.40E-02	ADWG/WHO	0.00E+00	-	4.81E-02	3.00E-02
Trichloroethene	7.80E-04	WHO	1.46E-03	WHO	1.46E-03	-	1.57E-02	3.00E-02
cis-1,2-dichloroethene	0.00E+00	-	2.00E-03	USEPA 2010	3.00E-01	ATSDR	1.49E-02	3.00E-02
	-	-	-	-	-	-	-	-

Toxicity and Derma

C = calculated from chronic va

Chemical	Inhalation Exposures						Background Intake (% TDI)	
	Inhalation Unit Risk $(ug/m^3)^{-1}$	Ref	Threshold Chronic TC (mg/m^3)	Ref	Threshold Subchronic TC (mg/m^3)	Ref	Chronic Assessment (%)	Subchronic Assessment
Tetrachloroethene	0.00E+00	-	2.00E-01	WHO	2.00E-01	-	0.00%	10.00%
Trichloroethene	4.10E-06	US EPA	2.00E-03	US EPA	2.00E-03	-	10.00%	10.00%
cis-1,2-dichloroethene	0.00E+00	-	7.00E-03	USEPA 2010	7.90E-01	ATSDR	0.00%	0.00%
	-	-	-	-	-	-	-	-

Inhalation of Volatile Chemicals

Chronic Exposures

General Data/ Equations	Units	Residential Exposure Parameters (RME) Inhalation Indoors by Adult	
Exposure Parameters			
Exposure Frequency (EF)	days/year	365	Every day of the year
Exposure Duration (ED)	years	14	30 year lifetime exposure less childhood years
Body Weight (BW)	kg	70	CRC CARE
Averaging Time - NonThreshold (ATc)	hours	613200	USEPA 2009
Averaging Time - Threshold (ATn)	hours	122640	USEPA 2009
Include Source Depletion	*N*		
Exposure Time (ET)	hr/day	20	CRC CARE
Fraction Inhaled from Contaminated Source (FI)	-	1	Assume all of residence above groundwater/soils
Intake Factor = ET*FI*EF*ED / AT	-	**1.7E-01**	**NonThreshold**
		8.3E-01	**Threshold**

Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)
NonThreshold Risk = Inhalation Exposure Concentration x Unit Risk
Hazard Quotients = (Inhalation Exposure Concentration/Allowable TC air)

Chemical	Toxicity Data: Inhalation Unit Risk $(mg/m^3)^{-1}$	Chronic TC air (mg/m^3)	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background) (mg/m^3)	Depletion Time (years)	Exposure Duration (ED) (years)	Averaging Time (AT) Non-Threshold (hours)	Averaging Time (AT) Threshold (hours)	Intake Factor (Non-Threshold)	Intake Factor (Threshold)	Concentration in Indoor Air (mg/m^3)	Daily Exposure: Inhalation Exposure Concentration - NonThreshold (mg/m^3)	Inhalation Exposure Concentration - Threshold (mg/m^3)	Calculated Risk: Non Threshold Risk (unitless)	Max Chronic Hazard Quotient (unitless)
					NOT USED								**TOTAL**	**4.5E-6**	**3.0E+0**
Tetrachloroethene		2.0E-01		2.0E-01		14.0	6.1E+05	1.2E+05		8.3E-01	4.1E-06		3.4E-06	--	1.7E-05
Trichloroethene	4.1E-03	2.0E-03	10%	1.8E-03		14.0	6.1E+05	1.2E+05	1.7E-01	8.3E-01	6.5E-03	1.1E-03	5.4E-03	4.5E-06	3.0E+00
cis-1,2-dichloroethene		7.0E-03		7.0E-03		14.0	6.1E+05	1.2E+05		8.3E-01	2.3E-04		1.9E-04	--	2.8E-02
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Inhalation of Volatile Chemicals

Chronic Exposures

General Data/ Equations	Units	Residential Exposure Parameters (RME) Inhalation Outdoors by Adult	
Exposure Parameters			
Exposure Frequency (EF)	days/year	365	Every day of the year
Exposure Duration (ED)	years	14	30 year lifetime exposure less childhood years
Body Weight (BW)	kg	70	USEPA 1989 and CSMS 1996
Averaging Time - NonThreshold (ATc)	hours	613200	USEPA 2009
Averaging Time - Threshold (ATn)	hours	122640	USEPA 2009
Include Source Depletion	*N*		
Exposure Time (ET)	hr/day	2	CRC CARE
Fraction Inhaled from Contaminated Source (FI)	-	1	Assume all of residence above groundwater/soils
AT			

Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)
NonThreshold Risk = Inhalation Exposure Concentration x Unit Risk
Hazard Quotients = (Inhalation Exposure Concentration/Allowable TC air)

Chemical	Toxicity Data										Concentration	Daily Exposure		Calculated Risk	
	Inhalation Unit Risk	Chronic TC air	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background)	Depletion Time	Exposure Duration (ED)	Averaging Time (AT) Non-Threshold	Averaging Time (AT) Threshold	Intake Factor (Non-Threshold)	Intake Factor (Threshold)	in Outdoor Air	Inhalation Exposure Concentration - NonThreshold	Inhalation Exposure Concentration - Threshold	Non Threshold Risk	Max Chronic Hazard Quotient
	$(mg/m^3)^{-1}$	(mg/m^3)		(mg/m^3)	(years)	(years)	(hours)	(hours)			(mg/m^3)	(mg/m^3)	(mg/m^3)	(unitless)	(unitless)
					NOT USED								**TOTAL**	**7.6E-10**	**5.2E-4**
Tetrachloroethene		2.0E-01		2.0E-01		14.0	6.1E+05	1.2E+05		8.3E-02	6.3E-09		5.2E-10	--	2.6E-09
Trichloroethene	4.1E-03	2.0E-03	10%	1.8E-03		14.0	6.1E+05	1.2E+05	1.7E-02	8.3E-02	1.1E-05	1.8E-07	9.2E-07	7.6E-10	5.1E-04
cis-1,2-dichloroethene		7.0E-03		7.0E-03		14.0	6.1E+05	1.2E+05		8.3E-02	4.1E-07		3.4E-08	--	4.9E-06
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Inhalation of Volatile Chemicals

Chronic Exposures

General Data/ Equations	Units	Residential Exposure Parameters (RME) Inhalation Indoors by Older Children	
Exposure Parameters			
Exposure Frequency (EF)	days/year	365	Every day of the year
Exposure Duration (ED)	years	10	Total exposure during ages 6 to 15 years
Body Weight (BW)	kg	70	USEPA 1989 and CSMS 1996
Averaging Time - NonThreshold (ATc)	hours	613200	USEPA 2009
Averaging Time - Threshold (ATn)	hours	87600	USEPA 2009
Include Source Depletion	*N*		
Exposure Time (ET)	hr/day	20	CRC CARE
Fraction Inhaled from Contaminated Source (FI)	-	1	Assume all of residence above groundwater/soils
Intake Factor = ET*FI*EF*ED / AT	-	**1.2E-01**	**NonThreshold**
		8.3E-01	**Threshold**

Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)
NonThreshold Risk = Inhalation Exposure Concentration x Unit Risk
Hazard Quotients = (Inhalation Exposure Concentration/Allowable TC air)

Chemical	Toxicity Data: Inhalation Unit Risk $(mg/m^3)^{-1}$	Chronic TC air (mg/m^3)	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background) (mg/m^3)	Depletion Time (years)	Exposure Duration (ED) (years)	Averaging Time (AT) Non-Threshold (hours)	Averaging Time (AT) Threshold (hours)	Intake Factor (Non-Threshold)	Intake Factor (Threshold)	Concentration in Indoor Air (mg/m^3)	Daily Exposure: Inhalation Exposure Concentration - NonThreshold (mg/m^3)	Inhalation Exposure Concentration - Threshold (mg/m^3)	Calculated Risk: Non Threshold Risk (unitless)	Max Chronic Hazard Quotient (unitless)
					NOT USED								TOTAL	3.2E-6	3.0E+0
Tetrachloroethene		2.0E-01		2.0E-01		10.0	6.1E+05	8.8E+04		8.3E-01	4.1E-06		3.4E-06	--	1.7E-05
Trichloroethene	4.1E-03	2.0E-03	10%	1.8E-03		10.0	6.1E+05	8.8E+04	1.2E-01	8.3E-01	6.5E-03	7.8E-04	5.4E-03	3.2E-06	3.0E+00
cis-1,2-dichloroethene		7.0E-03		7.0E-03		10.0	6.1E+05	8.8E+04		8.3E-01	2.3E-04		1.9E-04	--	2.8E-02
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Inhalation of Volatile Chemicals

Chronic Exposures

General Data/ Equations	Units	Residential Exposure Parameters (RME) Inhalation Outdoors by Older Children	
Exposure Parameters			
Exposure Frequency (EF)	days/year	365	Every day of the year
Exposure Duration (ED)	years	10	Total exposure during ages 6 to 15 years
Body Weight (BW)	kg	70	USEPA 1989 and CSMS 1996
Averaging Time - NonThreshold (ATc)	hours	613200	USEPA 2009
Averaging Time - Threshold (ATn)	hours	87600	USEPA 2009
Include Source Depletion	*N*		
Exposure Time (ET)	hr/day	2	CRC CARE
Fraction Inhaled from Contaminated Source (FI)	-	1	Assume all of residence above groundwater/soils
AT			

Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)
NonThreshold Risk = Inhalation Exposure Concentration x Unit Risk
Hazard Quotients = (Inhalation Exposure Concentration/Allowable TC air)

Chemical	Toxicity Data: Inhalation Unit Risk	Toxicity Data: Chronic TC air	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background)	Depletion Time	Exposure Duration (ED)	Averaging Time (AT) Non-Threshold	Averaging Time (AT) Threshold	Intake Factor (Non-Threshold)	Intake Factor (Threshold)	Concentration in Outdoor Air	Daily Exposure: Inhalation Exposure Concentration - NonThreshold	Daily Exposure: Inhalation Exposure Concentration - Threshold	Calculated Risk: Non Threshold Risk	Calculated Risk: Max Chronic Hazard Quotient
	$(mg/m^3)^{-1}$	(mg/m^3)		(mg/m^3)	(years)	(years)	(hours)	(hours)			(mg/m^3)	(mg/m^3)	(mg/m^3)	(unitless)	(unitless)
					NOT USED								**TOTAL**	**5.4E-10**	**5.2E-4**
Tetrachloroethene		2.0E-01		2.0E-01		10.0	6.1E+05	8.8E+04		8.3E-02	6.3E-09		5.2E-10	--	2.6E-09
Trichloroethene	4.1E-03	2.0E-03	10%	1.8E-03		10.0	6.1E+05	8.8E+04	1.2E-02	8.3E-02	1.1E-05	1.3E-07	9.2E-07	5.4E-10	5.1E-04
cis-1,2-dichloroethen		7.0E-03		7.0E-03		10.0	6.1E+05	8.8E+04		8.3E-02	4.1E-07		3.4E-08	--	4.9E-06
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Inhalation of Volatile Chemicals

Chronic Exposures

General Data/ Equations	Units	Residential Exposure Parameters (RME) Inhalation Indoors by Younger Children	
Exposure Parameters			
Exposure Frequency (EF)	days/year	365	Every day of the year
Exposure Duration (ED)	years	6	Total exposure during ages 0 to 5 years
Body Weight (BW)	kg	70	USEPA 1989 and CSMS 1996
Averaging Time - NonThreshold (ATc)	hours	613200	USEPA 2009
Averaging Time - Threshold (ATn)	hours	52560	USEPA 2009
Include Source Depletion	*N*		
Exposure Time (ET)	hr/day	20	CRC CARE
Fraction Inhaled from Contaminated Source (FI)	-	1	Assume all of residence above groundwater/soils
Intake Factor = ET*FI*EF*ED / AT	-	**7.1E-02**	**NonThreshold**
		8.3E-01	**Threshold**

Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)
NonThreshold Risk = Inhalation Exposure Concentration x Unit Risk
Hazard Quotients = (Inhalation Exposure Concentration/Allowable TC air)

Chemical	Toxicity Data: Inhalation Unit Risk $(mg/m^3)^{-1}$	Chronic TC air (mg/m^3)	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background) (mg/m^3)	Depletion Time (years)	Exposure Duration (ED) (years)	Averaging Time (AT) Non-Threshold (hours)	Averaging Time (AT) Threshold (hours)	Intake Factor (Non-Threshold)	Intake Factor (Threshold)	Concentration in Indoor Air (mg/m^3)	Daily Exposure: Inhalation Exposure Concentration - NonThreshold (mg/m^3)	Inhalation Exposure Concentration - Threshold (mg/m^3)	Calculated Risk: Non Threshold Risk (unitless)	Max Chronic Hazard Quotient (unitless)
					NOT USED								**TOTAL**	**1.9E-6**	**3.0E+0**
Tetrachloroethene		2.0E-01		2.0E-01		6.0	6.1E+05	5.3E+04		8.3E-01	4.1E-06		3.4E-06	--	1.7E-05
Trichloroethene	4.1E-03	2.0E-03	10%	1.8E-03		6.0	6.1E+05	5.3E+04	7.1E-02	8.3E-01	6.5E-03	4.7E-04	5.4E-03	1.9E-06	3.0E+00
cis-1,2-dichloroether		7.0E-03		7.0E-03		6.0	6.1E+05	5.3E+04		8.3E-01	2.3E-04		1.9E-04	--	2.8E-02
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Inhalation of Volatile Chemicals

Chronic Exposures

General Data/ Equations	Units	Residential Exposure Parameters (RME) Inhalation Outdoors by Younger Children	
Exposure Parameters			
Exposure Frequency (EF)	days/year	365	Every day of the year
Exposure Duration (ED)	years	6	Total exposure during ages 0 to 5 years
Body Weight (BW)	kg	70	USEPA 1989 and CSMS 1996
Averaging Time - NonThreshold (ATc)	hours	613200	USEPA 2009
Averaging Time - Threshold (ATn)	hours	52560	USEPA 2009
Include Source Depletion	*N*		
Exposure Time (ET)	hr/day	2	CRC CARE
Fraction Inhaled from Contaminated Source (FI)	-	1	Assume all of residence above groundwater/soils
AT			

Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)
NonThreshold Risk = Inhalation Exposure Concentration x Unit Risk
Hazard Quotients = (Inhalation Exposure Concentration/Allowable TC air)

Chemical	Toxicity Data: Inhalation Unit Risk	Chronic TC air	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background)	Depletion Time	Exposure Duration (ED)	Averaging Time (AT) Non-Threshold	Averaging Time (AT) Threshold	Intake Factor (Non-Threshold)	Intake Factor (Threshold)	Concentration in Outdoor Air	Daily Exposure: Inhalation Exposure Concentration - NonThreshold	Inhalation Exposure Concentration - Threshold	Calculated Risk: Non Threshold Risk	Max Chronic Hazard Quotient
	$(mg/m^3)^{-1}$	(mg/m^3)		(mg/m^3)	(years)	(years)	(hours)	(hours)			(mg/m^3)	(mg/m^3)	(mg/m^3)	(unitless)	(unitless)
					NOT USED								**TOTAL**	**3.2E-10**	**5.2E-4**
Tetrachloroethene		2.0E-01		2.0E-01		6.0	6.1E+05	5.3E+04		8.3E-02	6.3E-09		5.2E-10	--	2.6E-09
Trichloroethene	4.1E-03	2.0E-03	10%	1.8E-03		6.0	6.1E+05	5.3E+04	7.1E-03	8.3E-02	1.1E-05	7.9E-08	9.2E-07	3.2E-10	5.1E-04
cis-1,2-dichloroethene		7.0E-03		7.0E-03		6.0	6.1E+05	5.3E+04		8.3E-02	4.1E-07		3.4E-08	--	4.9E-06
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Summary of Risk for RME Exposure

Pathway	NonThreshold Risks	Maximum Hazard Quotient
Adult Residents (Chronic Exposures)		
Inhalation of COPC Indoors	4.5E-06	3.04
Inhalation of COPC Outdoors	7.6E-10	0.0005
Total Risk	4.5E-06	3.04
Older Child Residents (Chronic Exposures)		
Inhalation of COPC Indoors	3.2E-06	3.04
Inhalation of COPC Outdoors	5.4E-10	0.0005
Total Risk	3.2E-06	3.04
Young Child Residents (Chronic Exposures)		
Inhalation of COPC Indoors	1.9E-06	3.04
Inhalation of COPC Outdoors	3.2E-10	0.0005
Total Risk	1.9E-06	3.04
Lifetime Risk (Chronic)	9.5E-06	3.04

VAPOUR PARTITIONING, EMISSION AND AIR DISPERSION MODEL FOR CONTAMINATED GROUNDWATER
For Houses on Piers with Crawl-Spaces, migration from Infinite Source. Reference: Turczynowicz 2002

Site Specific Physical Input Parameters	Units	Abbrev.	Value	Comments
Depth of Top of Contaminated Aquifer (BGS)	[m]	d	3.5	Calculated from layers
Thickness of Capillary Fringe	[m]	cd	**0.2**	Estimated for soil types
Thickness of Vadose Zone	[m]	vd	3.3	Calculated from layers
Soil Temperature	[C]	T	**15**	site-specific assumption
Vadose Zone Layer 1 Characteristics				***CRC Care - Sand, Sandy Clay***
Depth of Layer 1	[m]	vd1	**2**	Typical depth from logs
Moisture Content	[ml/g]	mocon	**0.08**	CRC Care 2011
Organic Carbon Fraction	-	foc	**0.003**	CRC Care 2011
Soil Bulk Density	[g/ml]	rhob	**1.625**	CRC Care 2011
Density of Solids	[g/ml]	sd	2.65	default
Total Soil Porosity	[ml/ml]	theta	0.39	1 - (rhob/sd)
Volumetric Water Content	[ml/ml]	wacon	0.130	mocon*rhob
Volumetric Air Content	[ml/ml]	acon	0.257	theta-wacon
Vadose Zone Layer 2 Characteristics				***Sandy Clay***
Depth of Layer 1	[m]	vd2	**1.3**	Typical depth from logs
Moisture Content	[ml/g]	mocon2	**0.26**	CRC Care 2011
Organic Carbon Fraction	-	foc2	**0.003**	CRC Care 2011
Soil Bulk Density	[g/ml]	rhob2	**1.56**	CRC Care 2011
Density of Solids	[g/ml]	sd2	2.67	default
Total Soil Porosity	[ml/ml]	theta2	0.42	1 - (rhob2/sd2)
Volumetric Water Content	[ml/ml]	wacon2	0.406	mocon2*rhob2
Volumetric Air Content	[ml/ml]	acon2	0.010	theta2-wacon2
Capillary Fringe				
Volumetric Water Content	[ml/ml]	cfwacon	0.406	Value representative of capillary fringe, ASTM (2002)
Volumetric Air Content	[ml/ml]	cfacon	0.01	theta2-cfwacon

Receptor Specific Input Parameters	Units	Abbrev.	Value	Comments
Building Characteristics				
Height of Building (internal)	[m]	bheight	**2.4**	As per CRC Care 2011
Width of Building	[m]	bwidth	**10**	Assume whole building above source
Length of Building	[m]	blength	**12.7**	Assume whole building above source
Area of Emission - Building Area	[m^2]	area	127.0	Default calculation assuming whole house is over source
Volume of Dwelling Space	[m^3]	bvolume	304.8	Calculated using building height and area as per Turczynowicz, 2002
Air Exchange Rate in Dwelling	[exch/day]	exchanges	**14.4**	).6 per hour
Height of Crawl Space	[m]	cheight	**0.30**	Default Assumption
Volume of Crawl Space	[m^3]	cvolume	38.1	Calculated using crawl space height and area as per Turczynowicz, 2002
Air Exchange Rate in Crawl Space	[exch/day]	cexchanges	**72**	17.1 exch/hr - Turczynowicz 2002, based on Australian studies
Qcsd	[m^3/day]	Qcsb	**911**	911 m3/d for 127 m2 house - Turczynowicz 2002, based on Australian studies
Indoor Air Sinks	[m^3/day]	Qs	**0.0**	(35.1 Typical value from Turczynowicz 2002, based on 2 adults indoors)
Outdoor Air Characteristics				
Length of Contaminated Area	[m]	length	**20**	site-specific assumption
Width of Contaminated Area	[m]	width	**300**	site-specific assumption
Wind Speed Outdoors	[m/s]	wspd	**2.5**	site-specific assumption
Height of Outdoor Mixing Zone	[m]	outboxh	1.5	Default Value

Chemical Specific Parameters	Water Solubility (mg/L)	MW (g/mol)	Koc (cm^3/g)	Air Diffusion Coefficient (cm^2/s)	Water Diffusion Coefficient (cm^2/s)	Vapour Pressure (mmHg)	Henry's Law Constant (unitless)	Degradation Rate in Air (per day)
Trichloroethene	1280	131	60.7	0.0687	1.0E-05	69	0.403	0.099
Tetrachloroethene	206	166	94.9	0.0505	9.5E-06	18.5	0.724	0.0072
cis-1,2-Dichloroethene	6410	96.9	39.6	0.0884	1.1E-05	201	0.167	0.0866

Vapour Transport Calculations	Deff Layer 1 (cm^2/s)	Deff Layer 2 (cm^2/s)	Deff Capillary Fringe (cm^2/s)	Total Effective Diffusion (GW to surface) (cm^2/s)
Trichloroethene	4.94E-3	7.32E-6	7.33E-6	1.71E-5
Tetrachloroethene	3.63E-3	3.80E-6	3.80E-6	8.85E-6
cis-1,2-Dichloroethene	6.36E-3	1.95E-5	1.95E-5	4.52E-5

Phase Partitioning Results	Dissolved Phase Concentration (mg/L)	Vapour Phase Concentration (g/cm^3)	Saturated Vapour Conentration (g/cm^3)	Free Phase Mole Fraction (mol/mol)	Concentration above Free Phase (g/cm^3)	Calculation Vapour Phase Concenration Adopted (g/cm^3)
Trichloroethene	**0.47**	1.9E-07	5.0E-04	0	0.0E+00	**1.9E-07**
Tetrachloroethene	**0.00018**	1.3E-10	1.7E-04	0	0.0E+00	**1.3E-10**
cis-1,2-Dichloroethene	**0.0581**	9.7E-09	1.1E-03	0	0.0E+00	**9.7E-09**

Calculated Air Concentrations	Vapour Phase Concentration at Source (ug/m^3)	Flux Emission Rate from Surface ($ug/day/m^2$)	Concentration in Crawl Space (ug/m^3)	Concentration in Dwelling ($\mu g/m^3$)	Crawl Space to Indoor Air Attenuation Factor	Outdoor Air Concentration ($\mu g/m^3$)
Trichloroethene	1.9E+05	8.0E+00	3.7E-01	**0.076**	4.9	**7.4E-03**
Tetrachloroethene	1.3E+02	2.8E-03	1.3E-04	**0.00003**	4.8	**2.6E-06**
cis-1,2-Dichloroethene	9.7E+03	1.1E+00	5.0E-02	**0.010**	4.8	**1.0E-03**

Toxicity and Dermal Absorption Parameters

C = calculated from chronic value, Ch = chronic value adopted

Chemical	Oral/Dermal Exposures							
	Non-Threshold Slope Factor $(mg/kg/day)^{-1}$		Threshold Chronic TDI (mg/kg/day)		Threshold Subchronic TDI (mg/kg/day)		Dermal Permeability (cm/hr)	Dermal Adsorption (Unitless)
Trichloroethene	7.80E-04	WHO	0.0015	WHO	0.0015	Ch	1.16E-02	0.03
Tetrachloroethene			0.014	WHO	0.014	Ch	3.34E-02	0.03
cis-1,2-Dichloroethene			0.006	RIVM	0.3	C	1.10E-02	0.03

Toxicity and Derma

C = calculated from chronic va

Chemical	Inhalation Exposures						Background Intake (% TDI)	
	Inhalation Unit Risk (ug/m^3)$^{-1}$		Threshold Chronic TC (mg/m^3)		Threshold Subchronic TC (mg/m^3)		Chronic Assessment (%)	Subchronic Assessment
Trichloroethene	4.00E-06	USEPA	0.002	USEPA	0.002	Ch	10%	10%
Tetrachloroethene			0.25	WHO	0.25	WHO	10%	10%
cis-1,2-Dichloroethene			0.007	USEPA	0.79	ATSDR	0%	0%

Inhalation of Volatile Chemicals

Chronic Exposures

General Data/ Equations	Units	Residential Exposure Parameters Inhalation Indoors by Resident	
Exposure Parameters			
Exposure Frequency (EF)	days/year	365	Exposure every day
Exposure Duration (ED)	years	35	Total lifetime exposure of 35 years as per enHealth 2012
Averaging Time - NonThreshold (ATc)	hours	613200	USEPA 2009
Averaging Time - Threshold (ATn)	hours	306600	USEPA 2009
Exposure Time (ET)	hr/day	20	Time spent indoors as per enHealth 2012
Fraction Inhaled from Contaminated Source (FI)	-	1	Assume all of residence above impacts
Intake Factor = ET*FI*EF*ED / AT	-	**4.2E-01**	**NonThreshold**
		8.3E-01	**Threshold**

Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)
NonThreshold Risk = Inhalation Exposure Concentration x Unit Risk
Hazard Quotients = (Inhalation Exposure Concentration/Allowable TC air)

Chemical	Toxicity Data				Concentration	Daily Exposure		Calculated Risk	
	Inhalation Unit Risk	Chronic TC air	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background)	in Indoor Air	Inhalation Exposure Concentration - NonThreshold	Inhalation Exposure Concentration - Threshold	NonThreshold Risk	Chronic Hazard Quotient
	$(mg/m^3)^{-1}$	(mg/m^3)		(mg/m^3)	(mg/m^3)	(mg/m^3)	(mg/m^3)	(unitless)	(unitless)
							TOTAL	**1.3E-7**	**3.6E-2**
Trichloroethene	4.0E-03	2.0E-03	10%	1.8E-03	7.6E-05	3.2E-05	6.3E-05	1.3E-7	3.5E-2
Tetrachloroethene		2.5E-01	10%	2.3E-01	2.7E-08	1.1E-08	2.3E-08	--	1.0E-7
cis-1,2-Dichloroethene		7.0E-03		7.0E-03	1.0E-05	4.3E-06	8.6E-06	--	1.2E-3
								--	--

Add comments regarding concentrations here

VAPOUR PARTITIONING, EMISSION AND AIR DISPERSION MODEL FOR CONTAMINATED GROUNDWATER
Using USEPA Vapor Migration Guidance (2003), Johnson Ettinger Model

Site Specific Physical Input Parameters	Units	Abbrev.	Value	Comments
Depth of Top of Contaminated Aquifer (BGS)	[m]	d	1.1	Calculated from layers
Thickness of Capillary Fringe	[m]	cd	0.2	Estimated for Sandy Clay
Thickness of Vadose Zone	[m]	vd	0.9	Calculated from layers
Average Soil Temperature	[C]	T	**25**	site-specific assumption
Vadose Zone Layer 1 Characteristics				***CRC Care - Sand, Sandy Clay***
Depth of Layer 1 from Foundations	[m]	vd1	**0**	Typical depth from logs
Moisture Content	[ml/g]	mocon	0.08	Estimated for CRC Care - Sand, Sandy Clay
Organic Carbon Fraction	-	foc	0.003	Estimated for CRC Care - Sand, Sandy Clay
Soil Bulk Density	[g/ml]	rhob	1.625	Estimated for CRC Care - Sand, Sandy Clay
Density of Solids	[g/ml]	sd	2.65	default
Total Soil Porosity	[ml/ml]	theta	0.39	1 - (rhob/sd)
Volumetric Water Content	[ml/ml]	wacon	0.130	mocon*rhob
Volumetric Air Content	[ml/ml]	acon	0.257	theta-wacon
Vadose Zone Layer 2 Characteristics				***Sandy Clay***
Depth of Layer 2 to Water Table	[m]	vd2	**0.9**	Typical depth from logs
Moisture Content	[ml/g]	mocon2	0.26	Estimated for Sandy Clay
Organic Carbon Fraction	-	foc2	0.003	Estimated for Sandy Clay
Soil Bulk Density	[g/ml]	rhob2	1.56	Estimated for Sandy Clay
Density of Solids	[g/ml]	sd2	2.67	default
Total Soil Porosity	[ml/ml]	theta2	0.42	1 - (rhob2/sd2)
Volumetric Water Content	[ml/ml]	wacon2	0.406	mocon2*rhob2
Volumetric Air Content	[ml/ml]	acon2	0.010	theta2-wacon2
Capillary Fringe				
Volumetric Water Content	[ml/ml]	cfwacon	0.406	Value representative of capillary fringe, ASTM (2002)
Volumetric Air Content	[ml/ml]	cfacon	0.010	theta2-cfwacon

VAPOUR PARTITIONING, EMISSION AND AIR DISPERSION MODEL FOR CONTAMINATED GROUNDWATER
Using USEPA Vapor Migration Guidance (2003), Johnson Ettinger Model

Receptor Specific Input Parameters	Units	Abbrev.	Value	Comments
Building Characteristics				***Residential - Basement***
Depth of Basement	[m]	basement	2.4	Depth of basement below ground level
Width of Building	[m]	bwidth	10	Assume whole building above source
Length of Building	[m]	blength	10	Assume whole building above source
Area of Emission - Building Area	[m^2]	emarea	196	Assume whole building above source
Foundation/wall thickness	[m]	fthick	0.1	Default Value BCA
Height of Room	[m]	boxh	2.4	Default Value for type of building, USEPA 2003
Hourly Volume Exchange of Fresh Air	[exch/hr]	exchanges	0.6	CRC CARE 2011 for residential
Fraction of Cracks in Walls and foundation	-	cracks	0.001	CRC CARE 2011
Qbuilding	[cm^3/s]	Qb	40000	Calculated from building volume and exchange rate
Qsoil	[cm^3/s]	Qs	163.3333333	Calculated from default of Qs:Qb (CRC Care 2010)
Ratio of Qs:Qb	-	Qs/Qb	0.005	Defaults are 0.005 (Res) and 0.001 (Comm) (CRC CARE)
Area of Cracks (ACrack)	[cm^2]	Ac	1960	Calculated from building area and crack ratio, USEPA 2003
Volumetric Water Content in foundation/wall cracks	[ml/ml]	fwacon	0.12	Default Value ASTM 1739-95
Volumetric Air Content in foundation/wall cracks	[ml/ml]	facon	0.26	Default Value ASTM 1739-95
Outdoor Air Characteristics				
Length of Contaminated Area	[m]	length	20	site-specific assumption
Width of Contaminated Area	[m]	width	20	site-specific assumption
Wind Speed Outdoors	[m/s]	wspd	2.5	site-specific assumption
Height of Outdoor Mixing Zone	[m]	outboxh	1.5	Default Value

VAPOUR PARTITIONING, EMISSION AND AIR DISPERSION MODEL FOR CONTAMINATED GROUNDWATER
Using USEPA Vapor Migration Guidance (2003), Johnson Ettinger Model

Chemical Specific Parameters	Water Solubility (mg/L)	MW (g/mol)	Koc (cm^3/g)	Air Diffusion Coefficient (cm^2/s)	Water Diffusion Coefficient (cm^2/s)	Vapour Pressure (mmHg)	Henry's Law Constant (unitless)
Tetrachloroethene	206	165.83	1.07E+02	5.05E-02	9.46E-06	53.200	7.2E-01
Trichloroethene	1280.0	131.40	6.77E+01	6.87E-02	1.02E-05	72.50	4.03E-01
cis-1,2-dichloroethene	3500	96.95	3.55E+01	7.60E-02	1.13E-05	201.00	1.67E-01

Vapour Transport Calculations	Deff Layer 1 (cm^2/s)	Deff Layer 2 (cm^2/s)	Deff Foundations and Cracks (cm^2/s)	Deff Capillary Fringe (cm^2/s)	Total Effective Diffusion (cm^2/s) to indoor air
Tetrachloroethene	3.63E-3	3.80E-6	3.79E-3	3.80E-6	3.80E-6
Trichloroethene	4.94E-3	7.32E-6	5.15E-3	7.33E-6	7.32E-6
cis-1,2-dichloroethene	5.47E-3	1.94E-5	5.70E-3	1.95E-5	1.94E-5

Phase Partitioning Results	Dissolved Phase Concentration (mg/L)	Vapour Phase Concentration (g/cm^3)	Saturated Vapour Conentration (g/cm^3)	Free Phase Mole Fraction (mol/mol)	Concentration above Free Phase (g/cm^3)	Calculation Vapour Phase Concenration Adopted (g/cm^3)
Tetrachloroethene	0.179	1.3E-07	4.7E-04			**1.3E-07**
Trichloroethene	0.0781	3.1E-08	5.1E-04			**3.1E-08**
cis-1,2-dichloroethene	0.326	5.4E-08	1.0E-03			**5.4E-08**

Calculated Air Concentrations (with advection)	Vapour Phase Concentration at Source (ug/m^3)	Vapour Phase Concentration at Source (mg/m^3)	JE Attenuation Coefficient (unitless)	Indoor Air Concentration (mg/m^3)	Indoor Air Concentration ($\mu g/m^3$)
Tetrachloroethene	1.3E+05	1.3E+02	1.7E-06	**2.19E-04**	**0.2193**
Trichloroethene	3.1E+04	3.1E+01	3.3E-06	**1.0E-04**	**0.10**
cis-1,2-dichloroethene	5.4E+04	5.4E+01	8.6E-06	**4.7E-04**	**0.47**

Calculated Air Concentrations ASTM Guidance (without advection)	Vapour Phase Concentration at Source (g/cm3)	Vapour Phase Concentration at Source (mg/m^3)	Emission Rate from Surface of Ground (g/s)	Indoor Air Concentration (mg/m^3)	Indoor Air Concentration ($\mu g/m^3$)	Outdoor Air Concentration ($\mu g/m^3$)
Tetrachloroethene	1.3E-07	1.3E+02	8.8E-09	**1.03E-04**	**0.1026**	**7.5E-05**
Trichloroethene	3.1E-08	3.1E+01	4.1E-09	**4.6E-05**	**0.05**	**3.5E-05**
cis-1,2-dichloroethene	5.4E-08	5.4E+01	1.9E-08	**1.8E-04**	**0.18**	**1.6E-04**

Toxicity and Dermal Absorption Parameters

C = calculated from chronic value, Ch = chronic value adopted

Chemical	Oral/Dermal Exposures							
	Non-Threshold Slope Factor $(mg/kg/day)^{-1}$	Ref	Threshold Chronic TDI (mg/kg/day)	Ref	Threshold Subchronic TDI (mg/kg/day)	Ref	Dermal Permeability (cm/hr)	Dermal Adsorption (Unitless)
Tetrachloroethene			1.40E-02	ADWG/WHO		-	4.81E-02	3.00E-02
Trichloroethene	7.80E-04	WHO	1.46E-03	WHO	1.46E-03	-	1.57E-02	3.00E-02
cis-1,2-dichloroethene		-	2.00E-03	USEPA 2010	3.00E-01	ATSDR	1.49E-02	3.00E-02
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Toxicity and Derma

C = calculated from chronic va

Chemical	Inhalation Exposures							Background Intake (% TDI)	
	Inhalation Unit Risk $(ug/m^3)^{-1}$	Ref	Threshold Chronic TC (mg/m^3)	Threshold Chronic TDI (mg/kg/day)	Ref	Threshold Subchronic TC (mg/m^3)	Ref	Chronic Assessment (%)	Subchronic Assessment
Tetrachloroethene		-	2.00E-01		WHO	2.00E-01	-		10.00%
Trichloroethene	4.10E-06	US EPA	2.00E-03	4.10E-06	US EPA	2.00E-03	-	10.00%	10.00%
cis-1,2-dichloroethene		-	7.00E-03		USEPA 2010	7.90E-01	ATSDR		
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Inhalation of Volatile Chemicals

Chronic Exposures

General Data/ Equations	Units	Residential Exposure Parameters (RME) Inhalation Indoors by Adult	
Exposure Parameters			
Exposure Frequency (EF)	days/year	365	Exposure every day
Exposure Duration (ED)	years	14	Exposure for 30 years less childhood exposure
Body Weight (BW)	kg	70	USEPA 1989 and CSMS 1996
Averaging Time - NonThreshold (ATc)	hours	613200	USEPA 2009
Averaging Time - Threshold (ATn)	hours	122640	USEPA 2009
Advection	Y		
Exposure Time (ET)	hr/day	20	Time spent indoors (CRC CARE) less time spent in basement
Fraction Inhaled from Contaminated Source (FI)	-	1	Assume all of residence above groundwater/soils
Intake Factor = ET*FI*EF*ED / AT	-	**1.7E-01**	**NonThreshold**
		8.3E-01	**Threshold**

Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)
NonThreshold Risk = Inhalation Exposure Concentration x Unit Risk
Hazard Quotients = (Inhalation Exposure Concentration/Allowable TC air)

Chemical	Toxicity Data: Inhalation Unit Risk	Toxicity Data: Chronic TC air	Toxicity Data: Background Intake (% Chronic TC)	Toxicity Data: Chronic TC Allowable for Assessment (TC-Background)	Concentration in Indoor Air	Daily Exposure: Inhalation Exposure Concentration - NonThreshold	Daily Exposure: Inhalation Exposure Concentration - Threshold	Calculated Risk: NonThreshold Risk	Calculated Risk: Chronic Hazard Quotient
	$(mg/m^3)^{-1}$	(mg/m^3)		(mg/m^3)	(mg/m^3)	(mg/m^3)	(mg/m^3)	(unitless)	(unitless)
							TOTAL	**7.0E-8**	**1.0E-1**
Tetrachloroethene		2.0E-01		2.0E-01	2.2E-04	3.7E-05	1.8E-04	--	9.1E-4
Trichloroethene	4.1E-03	2.0E-03	10%	1.8E-03	1.0E-04	1.7E-05	8.5E-05	7.0E-8	4.7E-2
cis-1,2-dichloroethene		7.0E-03		7.0E-03	4.7E-04	7.8E-05	3.9E-04	--	5.6E-2
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Add comments regarding concentrations here

Inhalation of Volatile Chemicals

Chronic Exposures

General Data/ Equations	Units	Residential Exposure Parameters (RME) Inhalation Outdoors by Adult	
Exposure Parameters			
Exposure Frequency (EF)	days/year	365	Exposure every day
Exposure Duration (ED)	years	14	Exposure for 30 years less childhood exposure
Body Weight (BW)	kg	70	USEPA 1989 and CSMS 1996
Averaging Time - NonThreshold (ATc)	hours	613200	USEPA 2009
Averaging Time - Threshold (ATn)	hours	122640	USEPA 2009
Advection	NA		
Exposure Time (ET)	hr/day	2	CRC Care 2011
Fraction Inhaled from Contaminated Source (FI)	-	1	Assume all of residence above groundwater/soils
Intake Factor = ET*FI*EF*ED / AT	-	**1.7E-02**	**NonThreshold**
		8.3E-02	**Threshold**

Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)
NonThreshold Risk = Inhalation Exposure Concentration x Unit Risk
Hazard Quotients = (Inhalation Exposure Concentration/Allowable TC air)

Chemical	Toxicity Data: Inhalation Unit Risk $(mg/m^3)^{-1}$	Toxicity Data: Chronic TC air (mg/m^3)	Toxicity Data: Background Intake (% Chronic TC)	Toxicity Data: Chronic TC Allowable for Assessment (TC-Background) (mg/m^3)	Concentration in Outdoor Air (mg/m^3)	Daily Exposure: Inhalation Exposure Concentration - NonThreshold (mg/m^3)	Daily Exposure: Inhalation Exposure Concentration - Threshold (mg/m^3)	Calculated Risk: NonThreshold Risk (unitless)	Calculated Risk: Chronic Hazard Quotient (unitless)
							TOTAL	**2.4E-9**	**3.5E-3**
Tetrachloroethene		2.0E-01		2.0E-01	7.5E-08	1.3E-09	6.3E-09	--	3.1E-8
Trichloroethene	4.1E-03	2.0E-03	10%	1.8E-03	3.5E-05	5.9E-07	2.9E-06	2.4E-9	1.6E-3
cis-1,2-dichloroethene		7.0E-03		7.0E-03	1.6E-04	2.7E-06	1.3E-05	--	1.9E-3
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Add comments regarding concentrations here

Inhalation of Volatile Chemicals

Chronic Exposures

General Data/ Equations	Units	Residential Exposure Parameters (RME) Inhalation Indoors by Older Child (5-15 yrs)	
Exposure Parameters			
Exposure Frequency (EF)	days/year	365	Exposure every day
Exposure Duration (ED)	years	10	Total exposure during ages 6 to 15 years
Body Weight (BW)	kg	34.5	USEPA 1989 and CSMS 1996
Averaging Time - NonThreshold (ATc)	hours	613200	USEPA 2009
Averaging Time - Threshold (ATn)	hours	87600	USEPA 2009
Advection	Y		
Exposure Time (ET)	hr/day	20.0	Time spent indoors (CRC CARE) less time spent in basement
Fraction Inhaled from Contaminated Source (FI)	-	1	Assume all of residence above groundwater/soils
Intake Factor = ET*FI*EF*ED / AT	-	**1.2E-01**	**NonThreshold**
		8.3E-01	**Threshold**

Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)
NonThreshold Risk = Inhalation Exposure Concentration x Unit Risk
Hazard Quotients = (Inhalation Exposure Concentration/Allowable TC air)

Chemical	Toxicity Data: Inhalation Unit Risk	Toxicity Data: Chronic TC air	Toxicity Data: Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background)	Concentration in Indoor Air	Daily Exposure: Inhalation Exposure Concentration - NonThreshold	Daily Exposure: Inhalation Exposure Concentration - Threshold	Calculated Risk: NonThreshold Risk	Calculated Risk: Chronic Hazard Quotient
	$(mg/m^3)^{-1}$	(mg/m^3)		(mg/m^3)	(mg/m^3)	(mg/m^3)	(mg/m^3)	(unitless)	(unitless)
							TOTAL	**5.0E-8**	**1.0E-1**
Tetrachloroethene		2.0E-01		2.0E-01	2.2E-04	2.6E-05	1.8E-04	--	9.1E-04
Trichloroethene	4.1E-03	2.0E-03	10%	1.8E-03	1.0E-04	1.2E-05	8.5E-05	5.0E-08	4.7E-02
cis-1,2-dichloroethene		7.0E-03		7.0E-03	4.7E-04	5.6E-05	3.9E-04	--	5.6E-02
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Add comments regarding concentrations here

Inhalation of Volatile Chemicals

Chronic Exposures

General Data/ Equations	Units	Residential Exposure Parameters (RME) Inhalation Outdoors by Older Child (5-15 yrs)	
Exposure Parameters			
Exposure Frequency (EF)	days/year	365	Exposure every day
Exposure Duration (ED)	years	10	Total exposure during ages 6 to 15 years
Body Weight (BW)	kg	34.5	USEPA 1989 and CSMS 1996
Averaging Time - NonThreshold (ATc)	hours	613200	USEPA 2009
Averaging Time - Threshold (ATn)	hours	87600	USEPA 2009
Advection	NA		
Exposure Time (ET)	hr/day	2	CRC CARE
Fraction Inhaled from Contaminated Source (FI)	-	1	Assume all of residence above groundwater/soils
Intake Factor = ET*FI*EF*ED / AT	-	**1.2E-02**	**NonThreshold**
		8.3E-02	**Threshold**

Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)
NonThreshold Risk = Inhalation Exposure Concentration x Unit Risk
Hazard Quotients = (Inhalation Exposure Concentration/Allowable TC air)

Chemical	Toxicity Data: Inhalation Unit Risk $(mg/m^3)^{-1}$	Toxicity Data: Chronic TC air (mg/m^3)	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background) (mg/m^3)	Concentration in Outdoor Air (mg/m^3)	Daily Exposure: Inhalation Exposure Concentration - NonThreshold (mg/m^3)	Daily Exposure: Inhalation Exposure Concentration - Threshold (mg/m^3)	Calculated Risk: NonThreshold Risk (unitless)	Calculated Risk: Chronic Hazard Quotient (unitless)
							TOTAL	**1.7E-9**	**3.5E-3**
Tetrachloroethene		2.0E-01		2.0E-01	7.5E-08	8.9E-10	6.3E-09	--	3.1E-8
Trichloroethene	4.1E-03	2.0E-03	10%	1.8E-03	3.5E-05	4.2E-07	2.9E-06	1.7E-9	1.6E-3
cis-1,2-dichloroethene		7.0E-03		7.0E-03	1.6E-04	1.9E-06	1.3E-05	--	1.9E-3
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Add comments regarding concentrations here

Inhalation of Volatile Chemicals

Chronic Exposures

General Data/ Equations	Units	Residential Exposure Parameters (RME) Inhalation Indoors by Young Child (0-5 yrs)	
Exposure Parameters			
Exposure Frequency (EF)	days/year	365	Exposure every day
Exposure Duration (ED)	years	6	Lifetime exposure for age group
Body Weight (BW)	kg	13.2	NEPM 1999 and CSMS 1996
Averaging Time - NonThreshold (ATc)	hours	613200	USEPA 2009
Averaging Time - Threshold (ATn)	hours	52560	USEPA 2009
Advection	Y		
Exposure Time (ET)	hr/day	20.0	Time spent indoors (CRC CARE) less time spent in basement
Fraction Inhaled from Contaminated Source (FI)	-	1	Assume all of residence above groundwater/soils
Intake Factor = ET*FI*EF*ED / AT	-	**7.1E-02**	**NonThreshold**
		8.3E-01	**Threshold**

Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)
NonThreshold Risk = Inhalation Exposure Concentration x Unit Risk
Hazard Quotients = (Inhalation Exposure Concentration/Allowable TC air)

Chemical	Toxicity Data: Inhalation Unit Risk ($(mg/m^3)^{-1}$)	Toxicity Data: Chronic TC air (mg/m^3)	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background) (mg/m^3)	Concentration in Indoor Air (mg/m^3)	Daily Exposure: Inhalation Exposure Concentration - NonThreshold (mg/m^3)	Daily Exposure: Inhalation Exposure Concentration - Threshold (mg/m^3)	Calculated Risk: NonThreshold Risk (unitless)	Calculated Risk: Chronic Hazard Quotient (unitless)
							TOTAL	**3.0E-8**	**1.0E-1**
Tetrachloroethene		2.0E-01		2.0E-01	2.2E-04	1.6E-05	1.8E-04	-	9.1E-4
Trichloroethene	4.1E-03	2.0E-03	1.0E-01	1.8E-03	1.0E-04	7.3E-06	8.5E-05	3.0E-8	4.7E-2
cis-1,2-dichloroethene		7.0E-03		7.0E-03	4.7E-04	3.4E-05	3.9E-04	-	5.6E-2
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Add comments regarding concentrations here

Inhalation of Volatile Chemicals

Chronic Exposures

General Data/ Equations	Units	Residential Exposure Parameters (RME) Inhalation Outdoors by Young Child (0-5 yrs)	
Exposure Parameters			
Exposure Frequency (EF)	days/year	365	Exposure every day
Exposure Duration (ED)	years	6	Lifetime exposure for age group
Body Weight (BW)	kg	13.2	NEPM 1999 and CSMS 1996
Averaging Time - NonThreshold (ATc)	hours	613200	USEPA 2009
Averaging Time - Threshold (ATn)	hours	52560	USEPA 2009
Advection	NA		
Exposure Time (ET)	hr/day	2	CRC CARE
Fraction Inhaled from Contaminated Source (FI)	-	1	Assume all of residence above groundwater/soils
Intake Factor = ET*FI*EF*ED / AT	-	**7.1E-03**	**NonThreshold**
		8.3E-02	**Threshold**

Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)
NonThreshold Risk = Inhalation Exposure Concentration x Unit Risk
Hazard Quotients = (Inhalation Exposure Concentration/Allowable TC air)

Chemical	Toxicity Data: Inhalation Unit Risk	Toxicity Data: Chronic TC air	Toxicity Data: Background Intake (% Chronic TC)	Toxicity Data: Chronic TC Allowable for Assessment (TC-Background)	Concentration in Outdoor Air	Daily Exposure: Inhalation Exposure Concentration - NonThreshold	Daily Exposure: Inhalation Exposure Concentration - Threshold	Calculated Risk: NonThreshold Risk	Calculated Risk: Chronic Hazard Quotient
	$(mg/m^3)^{-1}$	(mg/m^3)		(mg/m^3)	(mg/m^3)	(mg/m^3)	(mg/m^3)	(unitless)	(unitless)
							TOTAL	**1.0E-9**	**3.5E-3**
Tetrachloroethene		2.0E-01		2.0E-01	7.5E-08	5.4E-10	6.3E-09	-	3.1E-8
Trichloroethene	4.1E-03	2.0E-03	10%	1.8E-03	3.5E-05	2.5E-07	2.9E-06	1.0E-9	1.6E-3
cis-1,2-dichloroethene		7.0E-03		7.0E-03	1.6E-04	1.2E-06	1.3E-05	-	1.9E-3
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Add comments regarding concentrations here

Summary of Risk for RME Exposure

Pathway	NonThreshold Risks	Threshold Risks Hazard Index
Adult Residents (Chronic Exposures)		
Inhalation of COPC Indoors	7.0E-08	0.104
Inhalation of COPC Outdoors	2.4E-09	0.0035461
Incidental Ingestion of COPC in Water		
Dermal Contact with COPC in Water		
Total Risk	**7.3E-08**	**0.108**
Older Child Residents (Chronic Exposures)		
Inhalation of COPC Indoors	5.0E-08	0.104
Inhalation of COPC Outdoors	1.7E-09	0.0035461
Incidental Ingestion of COPC in Water		
Dermal Contact with COPC in Water		
Total Risk	**5.2E-08**	**0.108**
Young Child Residents (Chronic Exposures)		
Inhalation of COPC Indoors	3.0E-08	0.104
Inhalation of COPC Outdoors	1.0E-09	0.0035461
Incidental Ingestion of COPC in Water		
Dermal Contact with COPC in Water		
Total Risk	**3.1E-08**	**0.108**
Lifetime Risk (Chronic)	**1.6E-07**	**0.108**

VAPOUR PARTITIONING, EMISSION AND AIR DISPERSION MODEL FOR CONTAMINATED SOILS
Using USEPA Vapor Migration Guidance (2003), Johnson Ettinger Model

Site Specific Physical Input Parameters	Units	Abbrev.	Value	Comments
Thickness of Soil above Contaminated layer	[m]	d	2	Calculated from layers to indoor
Thickness of Contaminated Layer	[m]	surfd	2	Estimated from site data
Soil Temperature	[C]	T	**25**	site-specific assumption
Vadose Zone Layer 1 Characteristics				***CRC Care - Sand, Sandy Clay***
Depth of Layer 1	[m]	vd1	**0**	Typical depth from logs
Moisture Content	[cm^3/g]	mocon	**0.08**	Estimated for CRC Care - Sand, Sandy Clay
Organic Carbon Fraction	-	foc	**0.003**	Estimated for CRC Care - Sand, Sandy Clay
Soil Bulk Density	[g/cm^3]	rhob	**1.625**	Estimated for CRC Care - Sand, Sandy Clay
Density of Solids	[g/cm^3]	sd	2.65	site-specific assumption
Total Soil Porosity	[cm^3/cm^3]	theta	0.39	1 - (rhob/sd)
Volumetric Water Content	[cm^3/cm^3]	wacon	0.130	mocon*rhob
Volumetric Air Content	[cm^3/cm^3]	acon	0.257	theta-wacon
Vadose Zone Layer 2 Characteristics				***CRC Care - Sand, Sandy Clay***
Depth of Layer 2	[m]	vd2	**2**	Typical depth from logs
Moisture Content	[cm^3/g]	mocon2	**0.08**	Estimated for CRC Care - Sand, Sandy Clay
Organic Carbon Fraction	-	foc2	**0.003**	Estimated for CRC Care - Sand, Sandy Clay
Soil Bulk Density	[g/cm^3]	rhob2	**1.625**	Estimated for CRC Care - Sand, Sandy Clay
Density of Solids	[g/cm^3]	sd2	2.65	site-specific assumption
Total Soil Porosity	[cm^3/cm^3]	theta2	0.39	1 - (rhob2/sd2)
Volumetric Water Content	[cm^3/cm^3]	wacon2	0.130	mocon2*rhob2
Volumetric Air Content	[cm^3/cm^3]	acon2	0.257	theta2-wacon2

VAPOUR PARTITIONING, EMISSION AND AIR DISPERSION MODEL FOR CONTAMINATED SOILS
Using USEPA Vapor Migration Guidance (2003), Johnson Ettinger Model

Receptor Specific Input Parameters	Units	Abbrev.	Value	Comments
Building Characteristics				***Commercial - Slab On Ground***
Depth of Basement	[m]	basement	0	Depth of basement below ground level
Width of Building	[m]	bwidth	65	Assume whole building above source
Length of Building	[m]	blength	50	Assume whole building above source
Area of Building Below Ground Level	[m^2]	area	3250	Calculated from building dimensions
Foundation/wall thickness	[m]	fthick	0.15	Default Value
Building Mixing Height	[m]	boxh	3	Default Value for type of building, USEPA 2003
Hourly Volume Exchange of Fresh Air	[exch/hr]	exchanges	0.83	Minimum exchange rate as per AS 1668.2 and BCA
Fraction of Cracks in Walls and foundation	-	cracks	0.001	Default Value for type of building, USEPA 2003
Qbuilding	[cm^3/s]	Qb	2247917	Calculated, USEPA 2003
Qsoil	[cm^3/s]	Qs	2708	Calculated from default of 5L/min (USEPA 2003)
Ratio of Qs:Qb	-	Qs/Qb	0.001	Default is 0.005 res and 0.001 comm/ind (CRC)
Area of Cracks (Acrack)	[cm^2]	Ac	32500	Calculated from building area and crack ratio, USEPA 2003
Volumetric Water Content in foundation/wall cracks	[cm^3/cm^3]	fwacon	0.12	Default Value
Volumetric Air Content in foundation/wall cracks	[cm^3/cm^3]	facon	0.26	Default Value
Outdoor Air Characteristics				
Length of Contaminated Area	[m]	length	20	site-specific assumption
Width of Contaminated Area	[m]	width	20	site-specific assumption
Wind Speed Outdoors	[m/s]	wspd	2.5	site-specific assumption
Height of Outdoor Mixing Zone	[m]	outboxh	1.5	Default Value

VAPOUR PARTITIONING, EMISSION AND AIR DISPERSION MODEL FOR CONTAMINATED SOILS
Using USEPA Vapor Migration Guidance (2003), Johnson Ettinger Model

Chemical Specific Parameters	Water Solubility (mg/L)	MW (g/mol)	Koc (cm^3/g)	Air Diffusion Coefficient (cm^2/s)	Water Diffusion Coefficient (cm^2/s)	Vapour Pressure (mmHg)	Henry's Law Constant (unitless)
Tetrachloroethene	206	165.83	1.07E+02	5.05E-02	9.46E-06	5.32E+01	7.24E-01
Trichloroethene	1280	131.4	6.77E+01	6.87E-02	1.02E-05	7.25E+01	4.03E-01
cis-1,2-dichloroethene	3500	96.95	3.55E+01	7.60E-02	1.13E-05	2.01E+02	1.67E-01

Vapour Transport Calculations	Deff Layer 1 (cm^2/s)	Deff Layer 2 (cm^2/s)	Deff Foundations and Cracks (cm^2/s)	Total Effective Diffusion (GW to surface) (cm^2/s)
Tetrachloroethene	3.63E-3	3.63E-3	3.79E-3	3.63E-3
Trichloroethene	4.94E-3	4.94E-3	5.15E-3	4.94E-3
cis-1,2-dichloroethene	5.47E-3	5.47E-3	5.70E-3	5.47E-3

Subsurface Soils Phase Partitioning Results	Soil Concentration (mg/kg)	Vapour Phase Concentration (g/cm^3)	Saturated Soil Concentration (mg/kg)	Saturated Vapour Concentration (g/cm^3)	Free Phase Mole Fraction (mol/mol)	Concentration above Free Phase (g/cm^3)	Calculated Vapour Phase used in Calculation (g/cm^3)
Tetrachloroethene			1.1E+02	4.7E-05			
Trichloroethene			4.4E+02	5.1E-05			
cis-1,2-dichloroethene			7.5E+02	1.0E-04			

VAPOUR PARTITIONING, EMISSION AND AIR DISPERSION MODEL FOR CONTAMINATED SOILS
Using USEPA Vapor Migration Guidance (2003), Johnson Ettinger Model

Calculated Air Concentrations (with Advection)	Measured Soil Vapour (ug/m^3)	Vapour Phase Concentration at Source (ug/m^3)	Vapour Phase Concentration at Source (mg/m^3)	JE Attenuation Coefficient (unitless)	Emission Rate to Indoor Air (g/s)	Depletion Time (years)	Indoor Air Concentration (µg/m^3)
Tetrachloroethene	**28000**	28000	2.8E+01	2.2E-04	1.4E-05		**6.038**
Trichloroethene	**26000**	26000	2.6E+01	2.8E-04	1.6E-05		**7.165**
cis-1,2-dichloroethene	**8480**	8480	8.5E+00	3.0E-04	5.7E-06		**2.524**

Calculated Air Concentrations ASTM Guidance (without Advection)	Vapour Phase Concentration at Source (g/cm3)	Emission Rate from Surface of Ground (g/s)	Emission Rate into building (g/s)	Depletion Time (years)	Indoor Air Concentration (µg/m^3)	Outdoor Air Concentration (µg/m^3)
Tetrachloroethene	2.8E-08	1.7E-05	2.3E-07		**0.10080**	**0.02713**
Trichloroethene	2.6E-08	2.1E-05	2.9E-07		**0.127**	**0.034**
cis-1,2-dichloroethene	8.5E-09	7.5E-06	1.0E-07		**0.04594**	**0.01237**

Toxicity and Dermal Absorption Parameters
C = calculated from chronic value, Ch = chronic value adopted

Chemical	Oral/Dermal Exposures							
	Non-Threshold Slope Factor $(mg/kg/day)^{-1}$		Threshold Chronic TDI (mg/kg/day)		Threshold Subchronic TDI (mg/kg/day)		Dermal Permeability (cm/hr)	Dermal Adsorption (Unitless)
Tetrachloroethene	0.00E+00	0.00E+00	1.40E-02	ADWG/WHO	0.00E+00	-	4.81E-02	3.00E-02
Trichloroethene	7.80E-04	WHO	1.46E-03	WHO	1.46E-03	-	1.57E-02	3.00E-02
cis-1,2-dichloroethene	0.00E+00	-	2.00E-03	USEPA 2010	3.00E-01	ATSDR	1.49E-02	3.00E-02
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Toxicity and Dermal Absorptio
C = calculated from chronic valu

Chemical	Inhalation Exposures						Occupational Exposure		Background Intake (% TDI)	
	Inhalation Unit Risk $(ug/m^3)^{-1}$		Threshold Chronic TC (mg/m^3)		Threshold Subchronic TC (mg/m^3)		TWA (mg/m^3)	TWA (mg/kg/day)	Chronic Assessment (%)	Subchronic Assessment
Tetrachloroethene	0.00E+00	-	2.00E-01	WHO	2.00E-01	-	340.0	48.57	0.00E+00	1.00E-01
Trichloroethene	4.10E-06	US EPA	2.00E-03	US EPA	2.00E-03	-	54.0	7.71	1.00E-01	1.00E-01
cis-1,2-dichloroethene	0.00E+00	-	7.00E-03	USEPA 2010	7.90E-01	ATSDR	793.0	113.29	0.00E+00	0.00E+00
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Inhalation of Volatile Chemicals

Chronic Exposures

General Data/ Equations	Units	Exposure Parameters (RME) Inhalation Indoors by Worker	
Exposure Parameters			
Exposure Frequency (EF)	days/year	240	Exposure for 5 days per week minus 4 weeks holidays
Exposure Duration (ED)	years	30	Duration of exposure as per NEPM 1999 and USEPA 1989
Averaging Time - NonThreshold (ATc)	hours	613200	USEPA 2009
Averaging Time - Threshold (ATn)	hours	262800	USEPA 2009
Advection	***Y***		
Exposure Time (ET)	hr/day	8	Time spent indoors at work
Fraction Inhaled from Contaminated Source (FI)	-	1	Assume all of workplace above groundwater/soils
Intake Factor = ET*FI*EF*ED / AT	-	**9.4E-02** **2.2E-01**	**NonThreshold** **Threshold**

Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)
NonThreshold Risk = Inhalation Exposure Concentration x Unit Risk
Hazard Quotients = (Inhalation Exposure Concentration/Allowable TC air)

Chemical	Toxicity Data: Inhalation Unit Risk (mg/m³)⁻¹	Chronic TC air (mg/m³)	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background) (mg/m³)	Depletion Time (years)	Exposure Duration (ED) (years)	Averaging Time (AT) Non-Threshold (hours)	Averaging Time (AT) Threshold (hours)	Intake Factor (Non-Threshold)	Intake Factor (Threshold)	Concentration in Indoor Air (mg/m³)	Daily Exposure: Inhalation Exposure Concentration - NonThreshold (mg/m³)	Inhalation Exposure Concentration - Threshold (mg/m³)	Calculated Risk: NonThreshold Risk (unitless)	Chronic Hazard Quotient (unitless)
					NOT USED								TOTAL	2.8E-6	9.6E-1
Tetrachloroethene		2.0E-01		2.0E-01			6.1E+05	6.1E+04			6.0E-03	5.7E-04	1.3E-03		6.6E-3
Trichloroethene	4.1E-03	2.0E-03	10%	1.8E-03			6.1E+05	6.1E+04			7.2E-03	6.7E-04	1.6E-03	2.8E-6	8.7E-1
cis-1,2-dichloroethene		7.0E-03		7.0E-03			6.1E+05	6.1E+04			2.5E-03	2.4E-04	5.5E-04		7.9E-2
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Add comments regarding concentrations here

Inhalation of Volatile Chemicals

Chronic Exposures

General Data/ Equations	Units	Exposure Parameters (RME) Inhalation Outdoors by Worker	
Exposure Parameters			
Exposure Frequency (EF)	days/year	240	Exposure for 5 days per week minus 4 weeks holidays
Exposure Duration (ED)	years	30	Duration of exposure as per NEPM 1999 and USEPA 1989
Averaging Time - NonThreshold (ATc)	hours	613200	USEPA 2009
Averaging Time - Threshold (ATn)	hours	262800	USEPA 2009
Advection	*NA*		
Exposure Time (ET)	hr/day	2	Time spent outdoors at work
Fraction Inhaled from Contaminated Source (FI)	-	1	Assume all of workplace above groundwater/soils
Intake Factor = ET*FI*EF*ED / AT	-	**2.3E-02**	**NonThreshold**
		5.5E-02	**Threshold**

Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)
NonThreshold Risk = Inhalation Exposure Concentration x Unit Risk
Hazard Quotients = (Inhalation Exposure Concentration/Allowable TC air)

Chemical	Toxicity Data										Concentration	Daily Exposure		Calculated Risk	
	Inhalation Unit Risk	Chronic TC air	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background)	Depletion Time	Exposure Duration (ED)	Averaging Time (AT) Non-Threshold	Averaging Time (AT) Threshold	Intake Factor (Non- Threshold)	Intake Factor (Threshold)	in Outdoor Air	Inhalation Exposure Concentration - NonThreshold	Inhalation Exposure Concentration - Threshold	NonThreshold Risk	Chronic Hazard Quotient
	$(mg/m^3)^{-1}$	(mg/m^3)		(mg/m^3)	(years)	(years)	(hours)	(hours)			(mg/m^3)	(mg/m^3)	(mg/m^3)	(unitless)	(unitless)
					NOT USED								**TOTAL**	**3.3E-9**	**1.1E-3**
Tetrachloroethene		2.0E-01		2.0E-01			6.1E+05	6.1E+04			2.7E-05	6.4E-07	1.5E-06		7.4E-6
Trichloroethene	4.1E-03	2.0E-03	10%	1.8E-03			6.1E+05	6.1E+04			3.4E-05	8.0E-07	1.9E-06	3.3E-9	1.0E-3
cis-1,2-dichloroethene		7.0E-03		7.0E-03			6.1E+05	6.1E+04			1.2E-05	2.9E-07	6.8E-07		9.7E-5
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Add comments regarding concentrations here

Summary of Risk for RME Exposure

Pathway	NonThreshold Risks	Threshold Risks Hazard Index

Long-Term Workers (Chronic Exposures)

Inhalation of COPC Indoors	2.8E-06	9.6E-01
Inhalation of COPC Outdoors	3.3E-09	1.1E-03
Incidental Ingestion of COPC in Soil		
Dermal Contact with COPC in Soil		
Total Risk	2.8E-06	9.6E-01

APPENDIX C SA HEALTH AND SA EPA TCE ACTION LEVEL RESPONSE FRAMEWORK

Predicted indoor air level range of TCE and associated actions

No Action

Indoor air level: Nothing detected

Safe

- No further action
- The area is safe

Validation

Indoor air level: Above detection - less than 2 (µg/m³)

Safe

- The area is safe
- Consider monitoring and evaluation (if appropriate) and based on site specific conditions

Investigation

Indoor air level: 2 - less than 20 (µg/m³)

No immediate health concerns

Further assessment necessary

- Further assessment of individual circumstances and property construction
- Validate results to improve site specific understanding: external soil, sub slab or crawl space vapour
- Consider mitigation and remediation strategies if required

Intervention

Indoor air level: 20 - less than 200 (µg/m³)

There may be a health risk

Immediately look at next steps and further assessment

- Assessment of individual circumstances and property construction
- Rapid assessment to improve site specific understanding: external soil, sub slab or crawl space vapour
- Consider mitigation and remediation or consider relocation

Accelerated Intervention

Indoor air level: 200 and above (µg/m³)

There is a health risk

Immediate action (relocation or mitigation)

- Assessment of individual circumstances and property construction
- Accelerated assessment program at property level
- Recommend relocation or urgent mitigation strategies
- Remediate sources as necessary, implement further mitigation strategies

Total number of properties in each range for the entire assessment area

No Action	Validation	Investigation	Intervention	Accelerated Intervention
1,352	25	15	8	0

The total number of properties in the "No Action" range is an estimate only. All totals include vacant properties, reserves and houses.