

Vapour Investigation and Remediation

Introduction

On January 1, 2009, the Stage 6 amendments to the Contaminated Sites Regulation (the Regulation) under the *Environmental Management Act* came into effect [1]. These included the addition of vapour as a regulated environmental medium and a new Schedule 11 “Generic Numerical Vapour Standards”. The ministry has written this document to clarify its expectations for the assessment of sites in the context of these amendments. It is divided into four general activities (see Figure 1):

- identifying site use, areas of potential environmental concern (APECs), and potential contaminants of concern (PCOCs);
- refining the list of vapour PCOCs;
- investigating vapour contamination; and
- remediating vapour contamination.

Supplementary notes and final comments are also included.

Identifying site use, APECs and PCOCs

To begin, identify APECs, PCOCs and site use as per standard practice for Stage 1 preliminary site investigations (PSIs) [2]. Vapour PCOCs include all substances that are both a) associated with activities listed in Schedule 2 of the Regulation carried out on or near the site and b) listed in Schedule 11. Site use is determined in accordance with subsection 12 (2.2) of the Regulation and footnotes 5, 6, and 7 of Schedule 11.

Note

Regarding footnote 5 of Schedule 11, vapours that pass vertically from water through soil to the receptor breathing zone are considered to originate from soil. Thus, for example, where vapours arise from groundwater, pass through soil, and enter a commercial building at the surface of a commercial site, the site use is commercial.

Refining the list of vapour PCOCs

Once you have sufficient soil, sediment, and water data (likely at PSI stage 2), refine the list of vapour PCOCs to include only those substances which are a) detectable (i.e., equal to or greater than the detection limit¹) in soil, sediment, or water on the site or b) detectable or likely to be detectable in soil, sediment, or water near the site². In other words, only retain as vapour PCOCs those substances which have an identifiable onsite or offsite source in soil, sediment, or water³. If none of the vapour

¹ The detection limit is that reported by a CAEAL certified laboratory using analytical methods specified in a director’s protocol or alternate methods acceptable to the director.

² The ministry recommends limiting the search for detectable substances in soil, sediment, or water to within 30 metres of the site boundary, except where a preferential pathway (e.g., utility corridor) exists that connects the site to detectable substances in soil, sediment, or water further than 30 metres away.

³ The authority to limit the list of vapour PCOCs to substances which are detectable in soil, sediment, or water comes from subsection 1 (b) of the Regulation which

PCOCs has an identifiable onsite or offsite source in soil, sediment, or water, then vapour investigation is not recommended, and the site is not considered contaminated with respect to substances in Schedule 11 of the Regulation.

Note

Possession of vapour data does not prevent you from taking this vapour PCOC refinement step. If you collect vapour samples at the same time as you collect soil, sediment, or water samples, you can still refine your vapour PCOC list based solely on the soil, sediment, and water data.

Investigating vapour contamination

Vapour delineation requirements

Vapour investigations must proceed with the goal of delineating the entire extent of vapour contamination (i.e., vapour PCOC concentrations greater than or equal to Schedule 11 standards) in the breathing zone⁴ onsite and offsite. To estimate the vapour PCOC concentration in the breathing zone, use either of the following approaches:

- a) Calculate PCOC concentrations in vapour from measured PCOC concentrations in soil and groundwater using the partitioning equations in Exhibit 2 of reference 5. Apply an appropriate ministry default vapour attenuation factor (see discussion below) to estimate the PCOC concentrations in the breathing zone. Note that the calculation of PCOC concentrations in vapour from measured PCOC concentrations in soil is only permitted for substances with a liquid

defines vapour as “gaseous emissions from soil, sediment or water”.

⁴ The receptor breathing zone includes any area where humans can come into direct contact with vapours.

specific gravity less than one⁵.

- b) Measure PCOC concentrations in vapour by collecting vapour samples from any of the following locations: subsurface, subslab, outdoors, or indoors. For subsurface and subslab samples, apply an appropriate ministry default vapour attenuation factor (see discussion below) to estimate the PCOC concentrations in the breathing zone.

If, after sufficient vapour investigation, the concentrations of all vapour PCOCs in the breathing zone are found to be less than the applicable Schedule 11 values, then the site is considered not contaminated with respect to vapours, and no additional vapour investigation is recommended. If, on the other hand, the concentration of any vapour PCOC in the breathing zone is equal to or greater than the applicable Schedule 11 standard, then the site is considered contaminated with respect to vapours and must be remediated before a Certificate of Compliance will be issued.

Vapour sampling and analysis

For guidance for vapour sampling and analysis, use either of the following, giving preference to the first where they conflict:

- Chapter 7, Chapter 8, and appended checklists of Health Canada’s guidance manual for environmental site characterization [3]
- Science Advisory Board guidance on site characterization for vapour intrusion [4]

Both documents provide extensive direction on and discussion of conceptual site models, study objectives, sampling design, sampling

⁵ Substances with a liquid specific gravity greater than one have the potential to form dense nonaqueous phase liquids. The equations from Exhibit 2 of reference 5 are considered unreliable for such substances.

equipment and procedures, sample analysis, quality assurance/quality control procedures, and data interpretation for subsurface, subslab, and above ground sampling. Also both discuss vapour intrusion theory, provide the rationale for sampling procedures, and provide references to sampling literature, all which can be useful when documenting the rationale for professional judgement decisions at your site. All environmental consultants carrying out or interpreting the results of vapour investigations should have a thorough understanding of these documents before proceeding.

Regardless of the vapour sampling approach taken, vapour delineation must capture worst-case concentrations expected in the breathing zone over the period of time any Determination of Contaminated Site or Certificate of Compliance for the site is expected to remain valid. Accordingly, please take note of the following when collecting and interpreting vapour data:

- The sampling program must evaluate expected seasonal and year-over-year variability in vapour concentrations. In practice, this will typically require a minimum of two sampling events over two different seasons.
- Environmental consultants must indicate, with supporting documentation, whether or not the vapour plume is at steady state. If the vapour plume is not at steady state, then the vapour data may not be representative of worst-case conditions.
- Samples collected within or beneath (i.e., subslab) a building will only be valid for that building unless sufficient documentation is provided to support the conclusion that the results are also valid for other buildings.
- In some cases, subsurface vapour collected from uncovered areas of a site will not be

representative of vapour concentrations beneath adjacent buildings or beneath a building erected above the sampling site in the future. For details, see page 146, Table 7-1, Table 7-2, and Figure 7-1 of reference 3.

Vapour attenuation factors

Where subsurface or subslab data are being used to delineate vapour contamination, vapour concentrations can be adjusted by a vapour attenuation factor using the following equations:

$$(1) C_{V-I} = C_{V-SS} * \alpha$$

$$(2) C_{V-O} = C_{V-SS} * \alpha$$

Where C_{V-I} ($\mu\text{g}/\text{m}^3$) is the calculated PCOC concentration in indoor vapour, C_{V-O} ($\mu\text{g}/\text{m}^3$) is the calculated PCOC concentration in outdoor vapour, C_{V-SS} ($\mu\text{g}/\text{m}^3$) is the measured or calculated PCOC concentration in subsurface vapour or subslab vapour, and α (unitless) is the vapour attenuation factor.

For vapour delineation purposes, the ministry default vapour attenuation factors (Table 1) must be used. The use of alternative vapour attenuation factors is only permitted under risk assessments. Both the indoor and outdoor vapour attenuation factors in Table 1 are based on a scenario of benzene attenuating through coarse-grained soil. The indoor vapour attenuation factors are the same as those recommended by Health Canada under preliminary quantitative risk assessment (PQRA), while the outdoor vapour attenuation factors were derived by the ministry using Health Canada's PQRA spreadsheet [6].

Note the following when applying vapour attenuation factors:

- The default vapour attenuation factors do not apply laterally, they only apply to vertical vapour attenuation. Lateral

attenuation must be assessed by lateral vapour delineation as described above.

- There are a number of precluding conditions to the use of the default vapour attenuation factors – see the footnotes to Table 1.
- The choice of a vapour attenuation factor depends on the current and reasonable potential future configuration of the site (e.g., location and foundation depth of buildings), as per subsection 12 (5) of the Regulation.

Delineation for shallow vapour sources

Defensible subsurface vapour samples may be difficult to obtain at some sites including those with shallow water tables or detectable substances in shallow soil. In such cases, the ministry will accept one of the following vapour delineation options:

- a) Calculate PCOC concentrations in vapour from measured PCOC concentrations in soil and groundwater using the partitioning equations in Exhibit 2 of reference 5. Apply a maximum vapour attenuation factor of 0.1 to delineate indoor vapour contamination and a maximum vapour attenuation factor of 0.01 to delineate outdoor vapour contamination. Note that the calculation of PCOC concentrations in vapour from measured PCOC concentrations in soil is only permitted for substances with a liquid specific gravity less than one.
- b) To delineate indoor vapour contamination, either (i) collect multiple indoor ambient vapour samples, or (ii) collect multiple subslab (i.e., sub-building) vapour samples and apply a maximum vapour attenuation factor of 0.1⁶. To delineate outdoor vapour

contamination, either (i) collect multiple outdoor ambient vapour samples, or (ii) collect multiple outdoor subslab (i.e., sub-pavement, sub-roadway, sub-temporary slab, etc.) vapour samples and apply a maximum vapour attenuation factor of 0.01⁶.

- c) Collect vapour data using an alternative, defensible approach. Do not apply a vapour attenuation factor. Thoroughly defend the approach and its application to the site. Include references to supporting technical literature where relevant.

Offsite migration

Vapour contamination originating onsite and migrating offsite must be fully delineated in accordance with the preceding sections of this document. When delineating offsite vapours, pay particular attention to the location of any preferential pathways – these have the potential to carry vapour contamination far from the site. In addition, base the offsite site use and selection of vapour attenuation factors on the current and reasonable potential future configuration of the offsite area (e.g., location and foundation depth of buildings), as per subsection 12 (5) of the Regulation.

Note

If, during a site investigation or independent remediation, one or more substances has migrated (or is likely to have migrated) to a neighbouring property and is causing (or is likely to cause) contamination of that property, the neighbouring property owner and ministry must be notified within 15 days of the responsible person becoming aware of the situation. Go to the following link for a copy of the notification of offsite migration form: <http://www.env.gov.bc.ca/epd/remediation/forms/index.htm>

⁶ Use of these indoor and outdoor vapour attenuation factors is not permitted if, at any time of the year, groundwater is in contact with the slab.

Remediating vapour contamination

Under Section 16 of the Regulation, you may remediate a site to either the numerical or risk-based standards. In practice this usually consists of the development of a remediation plan and the completion of one or more of the following: source reduction or removal, risk assessment, or risk management.

Develop a remediation plan

The first step to vapour remediation is development of a vapour remediation plan, likely as part of a broader remediation plan for the site. See Regulation Section 1 for some of the required components in the definition of “remediation plan”. Once completed, the remediation plan may be included along with other relevant documents in an application for an Approval in Principle. Note that delineation of vapour contamination must be completed before an Approval in Principle will be issued.

Source reduction or removal

Vapour remediation may include source reduction and removal techniques such as soil excavation, groundwater extraction, or biodegradation under monitored natural attenuation. In such cases, the site will be eligible for a Certificate of Compliance with numerical standards when it is confirmed that the concentration of each vapour contaminant is either less than the applicable Schedule 11 standard in the breathing zone or less than the detection limit in soil, sediment, and water.

Risk assessment

Where vapour remediation includes risk assessment, the site will be eligible for a Certificate of Compliance with risk-based standards when it is demonstrated that the risks associated with exposure to vapour contaminants meet the risk-based standards under Section 18 of the Regulation.

See Technical Guidance 7 [8] for general guidance on vapour risk assessments. In addition, note that under risk assessment any vapour assessment approach that is supported by defensible scientific rationale is acceptable. For instance, you can derive your own site-specific vapour attenuation factors by modifying the default parameters used to derive Table 1 (see references 5 and 7 for guidance); you can conduct a groundwater mass flux check (refer to Figure 8 and Exhibit 4 of reference 5); and you can model PCOC concentrations in vapour from PCOC concentrations in soil and groundwater (see references 6, 9, and 10).

Risk management

Risk management of vapour contamination (e.g., installation of vapour barriers or engineered works) is also an acceptable remedial option for sites. Where vapour management is used, note the following:

- The choice of management system is up to the applicant.
- A site under vapour management is only eligible for an Approval in Principle or a risk-based Certificate of Compliance.
- A risk-based Certificate of Compliance will not be issued unless all of the following conditions are met:
 - a) the vapour management system has been installed;
 - b) a professional engineer has certified that the installed system is performing as designed; and
 - c) an Approved Professional numerical standards assessment specialist has certified that vapour contaminant concentrations in the breathing zone will be, at the time of occupancy, less than Schedule 11 substance concentrations, or an Approved Professional risk assessment specialist has certified that

vapour contaminant concentrations in the breathing zone will meet, at the time of occupancy, the risk-based standards of Section 18 of the Regulation.

- Until all the above conditions are met, the site will only be eligible for an Approval in Principle. Note, that depending on the circumstances of the site and system, post implementation monitoring and maintenance may be required as a condition of the Certificate of Compliance.
- At sites where vapour concentrations are managed to meet the Regulation's numerical standards, and where no risk assessment other than screening level risk assessment in accordance with ministry Protocol 13 is conducted, a recommendation for a Certificate of Compliance with risk-based standards may be made by an Approved Professional numerical standards assessment specialist.

Supplementary notes

Background releases

Currently, the ministry does not have an approved protocol for assessing background vapour concentrations. As a result, responsible persons seeking a background release for a site that is contaminated due to site vapour concentrations must achieve such a release either as part of a risk assessment for the site or as a site-specific background determination request. If you wish to use the site-specific background determination approach, draft a sampling and analysis plan modelled conceptually on Protocol 4 [11] and submit it to the Director for review and approval.

Soil relocation

For general information on the vapour

characterization procedures and vapour quality standards applicable to relocated soil, see Administrative Guidance 7 [12], Administrative Guidance 8 [13], and Fact Sheet 41 [14]. In addition, note the following:

- Vapour characterization is only required for substances which are detectable in relocated soil and listed in Schedule 11.
- Vapour samples can be collected either while soil is in the ground or while it is stockpiled (e.g., in a biopile) on the source site.
- The ministry does not have technical guidance for assessing vapours in stockpiled soil, so environmental consultants should consult the literature, use professional judgment, and provide defensible scientific rationale if they choose this characterization approach.

Contaminated sites legal instruments

Please note the following for Determinations of Contaminated Site, Certificates of Compliance, and Contaminated Soil Relocation Agreements:

- The site configuration (e.g., building types, foundation depths, and building locations) authorized under the contaminated sites legal instrument (legal instrument) is restricted to the range of site configurations considered during the vapour assessment. Any deviation from the permitted range may invalidate the legal instrument and/or trigger the requirement for additional site investigations.
- An application for a risk-based legal instrument cannot be signed off by an Approved Professional numerical standards assessment specialist except where noted in the section above on risk management.
- The use of site-specific vapour attenuation factors is only permitted under risk assessment.

Grandfathering

Grandfathering for the transition from no vapour guidance to interim vapour guidance

The grandfathering process for the transition from no vapour guidance to the Interim Vapour Guidance, described in Section 6 of the Interim Vapour Guidance [15], has been extended until April 30, 2009. Applications received after April 30, 2009 will not be eligible for grandfathering under the Interim Vapour Guidance.

Grandfathering for the transition from interim vapour guidance to technical guidance 4

Vapour assessments received by the ministry before May 1, 2009 may be completed in accordance with either Technical Guidance 4 or the Interim Vapour Guidance (with Schedule 11 used in place of the draft Air Concentration Criteria). Vapour assessments received on or after May 1, 2009 are expected to be completed in accordance with Technical Guidance 4.

Final comments

Vapour intrusion science is an area of active research and thus the ministry intends to update this document from time to time to reflect advances in technical knowledge, user feedback, and changes in ministry policy. Given this, please note the following:

- Where vapour assessment guidance is lacking or considered inappropriate, contaminated sites professionals should exercise defensible and documented professional judgement.
- Communication from users of this document to the ministry is important for keeping this document relevant. Please send your questions and suggestions to the following address: remediationFAQs@gov.bc.ca.
- Questions and answers about this document will be posted to our internet site:

<http://www.env.gov.bc.ca/epd/remediation/index.htm>

For more information, contact the Environmental Management Branch at site@gov.bc.ca

References

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3. Health Canada (2008). Final Draft Guidance Manual for Environmental Site Characterization in Support of Human Health Risk Assessment. Volume 1 Technical Guidance. To obtain a copy of this document, send a request to the following e-mail address: cs-sc@hc-sc.gc.ca
4. Science Advisory Board for Contaminated Sites in British Columbia (February 2006). Guidance on Site Characterization for Evaluation of Soil Vapour Intrusion into Buildings. Available at the following: <http://www.sabcs.chem.uvic.ca/guidance%20on%20site%20characterization%20for%20evaluation%20of%20soil%20vapour%20intrusion%20into%20buildings.pdf>
5. Health Canada (2008). Federal Contaminated Risk Assessment in Canada: Guidance on Human Health Risk Assessment of Soil Vapour Intrusion to the Indoor Environment.

To obtain a copy of this document, send a request to the following e-mail address: cs-sc@hc-sc.gc.ca

http://www.env.gov.bc.ca/epd/remediation/policy_procedure_protocol/protocols/background_soil.htm

6. Health Canada (2008). Federal Contaminated Risk Assessment in Canada Part IV: Spreadsheet Tool for Human Health Preliminary Quantitative Risk Assessment (PQRA). To obtain a copy of this model, send a request to the following e-mail address: cs-sc@hc-sc.gc.ca
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10. American Society for Testing and Materials (ASTM) (1998). Standard Provisional Guide for Risk-Based Corrective Action. PS 104-98
11. British Columbia Ministry of Environment. Protocol 4: Determining Background Soil Quality. Available at:
12. British Columbia Ministry of Environment (2009). Administrative Guidance 7: Completing and Submitting an Application for a Contaminated Soil Relocation Agreement. Available at: <http://www.env.gov.bc.ca/epd/remediation/guidance/administrative/ag07.pdf>
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14. British Columbia Ministry of Environment (2009). Fact Sheet 41: Relocation of Soils from Contaminated Sites. Available at: http://www.env.gov.bc.ca/epd/remediation/fact_sheets/pdf/fs41.pdf
15. British Columbia Ministry of Environment (2008). Interim Guidance for Contaminated Sites: Site Vapour Assessment. Available at: http://www.env.gov.bc.ca/epd/remediation/guidance/interim/site_vapour.pdf

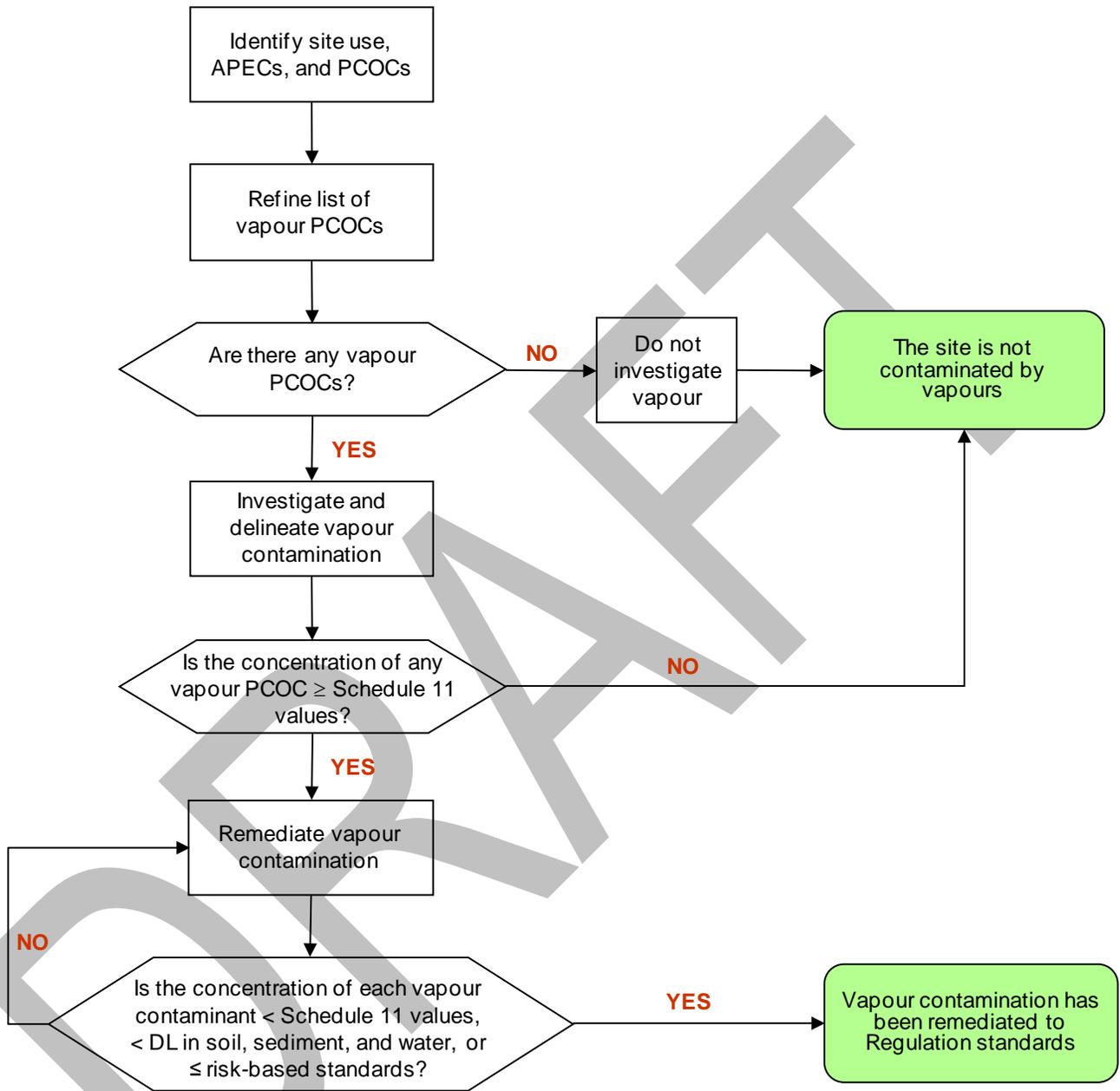


Figure 1. Vapour assessment flowchart
 PCOC means potential contaminant of concern
 APEC means area of potential environmental concern
 DL means detection limit

Table 1. Default vapour attenuation factors

Sample Location	Sample Depth ^{2,3}	Vapour Attenuation Factor (α) ¹		
		Outdoor Exposure	Indoor Exposure	
			Agricultural, Urban Park, Residential Use	Commercial/Industrial Use
Subslab ⁴	n/a	n/a	2.0×10^{-2}	
Subsurface	1.0 m	1.5×10^{-5}	2.8×10^{-3}	3.7×10^{-4}
	1.5 m	1.2×10^{-5}	2.3×10^{-3}	3.4×10^{-4}
	2.0 m	9.2×10^{-6}	2.0×10^{-3}	3.1×10^{-4}
	3.0 m	6.1×10^{-6}	1.6×10^{-3}	2.7×10^{-4}
	5.0 m	3.7×10^{-6}	1.1×10^{-3}	2.1×10^{-4}
	7.0 m	2.6×10^{-6}	8.3×10^{-4}	1.7×10^{-4}
	10.0 m	1.8×10^{-6}	6.2×10^{-4}	1.3×10^{-4}
	15.0 m	1.2×10^{-6}	4.3×10^{-4}	9.9×10^{-5}
	20.0 m	9.2×10^{-7}	3.3×10^{-4}	7.8×10^{-5}
30.0 m	6.1×10^{-7}	2.3×10^{-4}	5.5×10^{-5}	

¹ Use of these attenuation factors for vapour delineation is not permitted if any of the following conditions apply:

- The water table or detectable PCOC concentrations in soil are within 1 metre of a building foundation or ground surface (see page 4 for acceptable attenuation factors for these situations) or within 5 metres of an unlined crawl space, earthen basement, or wooden basement.
- The building or site surface is located above a very high gas permeability media (e.g., fractured bedrock, karst, cobbles).
- There is a preferential pathway (e.g., utility corridor backfill) connecting the vapour source to the breathing zone of the receptor of concern.
- Subsurface or subslab vapour is under pressure (e.g., as at a landfill).
- Groundwater contamination is present in fractured bedrock.
- There is active pumping or drawdown of groundwater at the site.

² Sample depth for subsurface samples is based on the distance from the top of the sampling screen to the bottom of the building foundation for indoor exposure and from the top of the sampling screen to the ground surface for outdoor exposure.

³ If your sample is collected between two depth increments (e.g., between 2 and 3 m), select the attenuation factor associated with the shallower depth increment (i.e., in this example, 2 m).

⁴ The subslab vapour attenuation factor for indoor exposure (2.0×10^{-2}) is intended to be applied to vapour data collected from below an intact slab at the base of a building.