



Ministry of
Environment
and Parks

PROTOCOL 22 ***FOR CONTAMINATED SITES***

Application of Vapour Attenuation Factors to
Characterize Vapour Contamination

Version 4.0

Prepared pursuant to Section 64 of the
Environmental Management Act

Approved:

A handwritten signature in black ink, consisting of several loops and a long horizontal stroke.

Director of Waste Management

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Date

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1.0 Definitions

Terms defined in the *Environmental Management Act* (EMA) and the Contaminated Sites Regulation (CSR) shall apply to this protocol, with the addition of the following:

“Attenuation adjustment divisor” [AAD]: a unitless divisor that can be applied to a ministry vertical vapour attenuation factor. There are two classes of AADs: biodegradation AADs and lateral AADs.

“Biodegradation” the process by which organic substances are biotransformed by organisms.

“Biodegradation attenuation adjustment divisor” [BAAD] is a unitless divisor that can be applied to a ministry vertical vapour attenuation factor for substances that have been demonstrated to biodegrade efficiently under aerobic conditions.

“Biologically active soil” refers to soil that has the capability to support the growth and survival of aerobic microorganisms such that aerobic biodegradation of contaminants can occur.

“Breathing zone” means any place where humans could come into direct contact with contaminated vapour, including indoor and outdoor environments that exist at the time of site investigation or have a reasonable potential to exist after a site investigation is complete.

“Certification document” includes an Approval in Principle, Certificate of Compliance, Determination, Transfer Agreement or Voluntary Remediation Agreement.

“Lateral attenuation adjustment divisor” [LAAD] is a unitless divisor that can be used to modify a ministry vertical vapour attenuation factor in circumstances where the target breathing zone is offset laterally from the point at which vapours have been characterized.

“Nonaqueous phase liquid” [NAPL] means a liquid that exists as a separate, immiscible phase when in contact with water.

“Preferential pathway” means a pathway that allows for the preferential transport/migration of vapours compared to typical soil or concrete building foundations. Pathways may be anthropogenic (including but not limited to underground utilities and wooden basements) or natural (including but not limited to fractured bedrock and earthen basements).

“Qualified professional” [QP], in relation to a duty or function under this protocol, means an individual who:

- (a) is registered in British Columbia with a professional organization, acts under that organization’s code of ethics and is subject to disciplinary action by that organization; and
- (b) through suitable education, experience, accreditation and knowledge may reasonably be relied on to provide advice within the individual’s area of expertise, which area of expertise is applicable to the duty or function.

“**Risk-based standards**” means the standards prescribed in CSR sections 18 and 18.1.

“**Vapour attenuation factor**” means the ratio of the breathing zone concentration of a volatile substance to the subsurface concentration of that substance.

“**Vapour conduit**” means a subset of preferential pathways that provide little or no resistance to vapour flow (e.g., pipes of a sanitary sewer utility conduit).

2.0 Introduction

This protocol describes the requirements for estimating vapour concentrations in breathing zone air at contaminated sites in B.C. using subsurface (or sub-slab) vapour measurements in combination with vapour attenuation factors (VAFs) and attenuation adjustment divisors (AADs).

Default VAFs include those for indoor air (VAF_{in}) and outdoor air (VAF_{out}); they are discussed further in Section 3. Default AADs include lateral AADs (LAAD) and biodegradation AADs (BAAD); they are discussed further in Section 4.

VAFs and AADs must be applied as shown in Equation 1 assuming all conditions for their use have been met.

Equation 1

$$C_{BZ} = C_{SS} \times \left(\frac{VAF}{LAAD \times BAAD} \right)$$

Where:

- C_{BZ} = Concentration of vapour in breathing zone air (µg/m³)
- C_{SS} = Concentration of vapour in subsurface or sub-slab air (µg/m³)
- VAF = Vapour attenuation factor (unitless; **described in Section 3**)
- LAAD = Lateral attenuation adjustment divisor (unitless; **described in Section 4.1**)
- BAAD = Biodegradation attenuation adjustment divisor (unitless; **described in Section 4.2**)

3.0 Vertical Vapour Attenuation Factors

Subsurface and sub-slab vapours can attenuate as they migrate vertically upwards and into a breathing zone. The default VAFs are provided in Table 1.

Site-specific VAFs may be proposed by a Qualified Professional, but only in a Detailed Risk Assessment and only if sufficient detail is provided to allow a thorough review of how they were calculated.

A VAF must not be used if any of the following “precluding conditions” exist:

- (1) Preferential pathways: Subsurface or sub-slab vapours are migrating to a breathing zone directly via a preferential pathway (e.g., something non-compliant with the B.C. Building Code, or something that invalidates the assumptions of the Johnson and Ettinger model used to derive the VAFs).
- (2) Shallow groundwater: Groundwater is in contact with the building, or groundwater is actively being pumped or drawn down from the building. The only exception is parkades built to the most recent B.C. Building Code.
- (3) Pressurized vapour: Subsurface/sub-slab vapours are under pressure.

When a precluding condition is present, a QP must estimate vapour concentrations in breathing zone air and consider unattenuated soil vapour data against the applicable CSR standards. At the discretion of the Director, a QP may estimate vapour concentrations in breathing zone air using an alternate scientifically defensible rationale with sufficient detail to allow a thorough review.

Table 1: Vapour Attenuation Factor Values

| Subsurface / Sub-slab Vapour Depth (m) ^{(a)(b)(c)} | VAF (unitless) | | | | |
|---|---|---|---|---|---|
| | Outdoor Exposures (VAF _{out}) | Indoor Exposures (VAF _{in}) | | | |
| | | Residential (RL), Agricultural (AL) Use | Commercial (CL), Industrial (IL), Urban Park (PL) Use | Parkade Use (Non-Risk-Managed) ^(e) | Parkade Use (Risk-Managed) ^(f) |
| 0 to < 1.0 ^(d) | 9.5 x 10 ⁻⁵ | 0.03 | 0.01 | 0.01 | 0.003 |
| 1.0 | 1.8 x 10 ⁻⁶ | 2.8 x 10 ⁻³ | 3.7 x 10 ⁻⁴ | 5.8 x 10 ⁻⁴ | 1.3 x 10 ⁻⁴ |
| 1.5 | 1.2 x 10 ⁻⁶ | 2.4 x 10 ⁻³ | 3.4 x 10 ⁻⁴ | 5.6 x 10 ⁻⁴ | 1.2 x 10 ⁻⁴ |
| 2.0 | 9.2 x 10 ⁻⁷ | 2.0 x 10 ⁻³ | 3.1 x 10 ⁻⁴ | 5.3 x 10 ⁻⁴ | 1.1 x 10 ⁻⁴ |
| 3.0 | 6.1 x 10 ⁻⁷ | 1.6 x 10 ⁻³ | 2.7 x 10 ⁻⁴ | 4.9 x 10 ⁻⁴ | 9.0 x 10 ⁻⁵ |
| 5.0 | 3.7 x 10 ⁻⁷ | 1.1 x 10 ⁻³ | 2.1 x 10 ⁻⁴ | 4.3 x 10 ⁻⁴ | 6.9 x 10 ⁻⁵ |
| 7.0 | 2.6 x 10 ⁻⁷ | 8.3 x 10 ⁻⁴ | 1.7 x 10 ⁻⁴ | 3.8 x 10 ⁻⁴ | 5.6 x 10 ⁻⁵ |
| 10.0 | 1.8 x 10 ⁻⁷ | 6.1 x 10 ⁻⁴ | 1.3 x 10 ⁻⁴ | 3.3 x 10 ⁻⁴ | 4.3 x 10 ⁻⁵ |
| 15.0 | 1.2 x 10 ⁻⁷ | 4.3 x 10 ⁻⁴ | 9.9 x 10 ⁻⁵ | 2.6 x 10 ⁻⁴ | 3.2 x 10 ⁻⁵ |
| 20.0 | 9.2 x 10 ⁻⁸ | 3.3 x 10 ⁻⁴ | 7.8 x 10 ⁻⁵ | 2.2 x 10 ⁻⁴ | 2.5 x 10 ⁻⁵ |
| 30.0 | 6.1 x 10 ⁻⁸ | 2.2 x 10 ⁻⁴ | 5.5 x 10 ⁻⁵ | 1.7 x 10 ⁻⁴ | 1.8 x 10 ⁻⁵ |

- a) The depth is the vertical distance between (1) the subsurface or sub-slab vapour sampling depth and (2) the depth of the underside of the building foundation slab (for indoor vapour characterization) or the ground surface (for outdoor vapour characterization). The subsurface vapour sampling depth is the depth at the bottom of the bentonite seal for a probe installed within a borehole, or the depth at the top of the sampling screen for a driven vapour probe.
- b) If the subsurface or sub-slab vapour sample was collected from a depth between two of the increments, then the VAF must be selected based on the shallower depth. For example, if the subsurface vapour is at a depth between 2 m and 3 m, then the VAF corresponding to the 2 m depth must be selected.

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- c) If the subsurface or sub-slab vapour sample was collected from a preferential pathway that is limited to the subsurface, then the VAF must be selected based on the shallowest depth of the preferential pathway. For example, if the preferential pathway is in the interval of 2 m to 7 m depth, and if the subsurface vapour sample was collected from within that interval (e.g., at 5 m depth), then the VAF corresponding to the 2 m depth must be selected.
 - d) If the vapour sample is collected lateral to a foundation slab or basement, then indoor vapour concentrations must be estimated using the 0 m to <1.0 m indoor VAFs. If the lateral distance is sufficient, then a LAAD may also be applied.
 - e) If a parkade meets the applicable CSR numerical standards with these VAFs, then the site will be eligible for a numerical certification document.
 - f) If a parkade meets the applicable CSR numerical standards with these VAFs, then the site will be eligible for a risk-based certification document.

4.0 Attenuation Adjustment Divisors

AADs include lateral AADs (discussed in Section 4.1) and biodegradation AADs (discussed in Section 4.2).

4.1 Lateral attenuation adjustment divisor

Some subsurface vapours can be expected to attenuate to a greater degree than estimated by the Table 1 vertical VAFs if the breathing zone is located at a lateral distance away from the source. The default LAADs are provided in Tables 2 through 6.

Note that when selecting a LAAD:

- Its vertical depth must match the depth of the VAF that was selected. If a VAF was precluded from being used, then a LAAD is also precluded from being used.
- Its lateral offset distance must be the minimum distance between the breathing zone and the vapour plume. If the lateral offset distance is between two of the default increments (e.g., between 10 and 15 m), then the shorter distance must be selected to identify the LAAD (i.e., in this example, 10 m).

Table 2: Lateral Attenuation Adjustment Divisors for Indoor Exposure – RL/AL use

| Vertical depth (m) | Lateral offset distance (m) | | | | | | | | | |
|--------------------|-----------------------------|-----|-----|-----|-----|-----|------|------|------|------|
| | 1.0 | 1.5 | 2.0 | 3.0 | 5.0 | 7.0 | 10.0 | 15.0 | 20.0 | 30.0 |
| ≤ 1.0 | 1 | 1 | 1 | 2 | 3 | 3 | 5 | 7 | 9 | 13 |
| 1.5 | 1 | 1 | 1 | 2 | 2 | 3 | 4 | 6 | 7 | 11 |
| 2.0 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 5 | 6 | 9 |
| 3.0 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 4 | 5 | 7 |
| 5.0 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 3 | 5 |
| 7.0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 4 |
| 10.0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 3 |
| 15.0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| 20.0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| 30.0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

Table 3: Lateral Attenuation Adjustment Divisors for Indoor Exposure - CL/IL/PL use

| Vertical depth (m) | Lateral offset distance (m) | | | | | | | | | |
|--------------------|-----------------------------|-----|-----|-----|-----|-----|------|------|------|------|
| | 1.0 | 1.5 | 2.0 | 3.0 | 5.0 | 7.0 | 10.0 | 15.0 | 20.0 | 30.0 |
| ≤ 1.0 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 4 | 5 | 7 |
| 1.5 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 6 |
| 2.0 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 4 | 6 |
| 3.0 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 3 | 5 |
| 5.0 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 4 |
| 7.0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 3 |
| 10.0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 |
| 15.0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| 20.0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 30.0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

Table 4: Lateral Attenuation Adjustment Divisors for Indoor Exposure – Parkade Use (Non-Risk-Managed)

| Vertical depth (m) | Lateral Offset Distance (m) | | | | | | | | | |
|--------------------|-----------------------------|-----|-----|-----|-----|-----|------|------|------|------|
| | 1.0 | 1.5 | 2.0 | 3.0 | 5.0 | 7.0 | 10.0 | 15.0 | 20.0 | 30.0 |
| ≤ 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 4 |
| 1.5 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 3 |
| 2 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 3 |
| 3 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 3 |
| 5 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 3 |
| 7 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 |
| 10 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 |
| 15 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| 20 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 30 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

Table 5: Lateral Attenuation Adjustment Divisors for Indoor Exposure – Parkade Use (Risk-Managed)

| Vertical depth (m) | Lateral offset distance (m) | | | | | | | | | |
|--------------------|-----------------------------|-----|-----|-----|-----|-----|------|------|------|------|
| | 1.0 | 1.5 | 2.0 | 3.0 | 5.0 | 7.0 | 10.0 | 15.0 | 20.0 | 30.0 |
| ≤ 1.0 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 4 | 5 | 7 |
| 1.5 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 4 | 5 | 7 |
| 2.0 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 6 |
| 3.0 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 4 | 5 |
| 5.0 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 4 |
| 7.0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 3 |
| 10.0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 |
| 15.0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| 20.0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 30.0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

Table 6: Lateral Attenuation Adjustment Divisors for Outdoor Exposure

| Vertical depth (m) | Lateral offset distance (m) | | | | | | | | | |
|--------------------|-----------------------------|-----|-----|-----|-----|-----|------|------|------|------|
| | 1.0 | 1.5 | 2.0 | 3.0 | 5.0 | 7.0 | 10.0 | 15.0 | 20.0 | 30.0 |
| ≤ 1.0 | 1 | 2 | 2 | 3 | 5 | 7 | 10 | 15 | 20 | 30 |
| 1.5 | 1 | 1 | 1 | 2 | 3 | 5 | 7 | 10 | 13 | 20 |
| 2.0 | 1 | 1 | 1 | 2 | 2 | 4 | 5 | 8 | 10 | 15 |
| 3.0 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 5 | 7 | 10 |
| 5.0 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 4 | 6 |
| 7.0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 4 |
| 10.0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 3 |
| 15.0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| 20.0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| 30.0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

4.2 Biodegradation Attenuation Adjustment Divisor

Some subsurface or sub-slab vapours can be expected to attenuate to a greater degree than estimated by the Table 1 vertical VAFs if the contaminant undergoes biodegradation. The default BAADs are provided in Table 7.

A BAAD may be used only if both (1) the vapour contaminant is susceptible to biodegradation, and (2) there is biologically active soil between the subsurface vapours and the entire extent of the breathing zone. The QP must provide evidence of both conditions being met (guidance can be found in Health Canada (*Health Canada. 2023. Federal Contaminated Site Risk Assessment Guidance in Canada: Supplemental Guidance for Soil Vapour Intrusion Assessment at Federal Contaminated Sites. Version 2.0. ISBN: 978-0-660-45526-6*).

If a VAF was precluded from being used, then a BAAD is also precluded from being used.

Table 7: Biodegradation Attenuation Adjustment Divisors

| Thickness of Biologically Active Soil (vertical or lateral) (m) | BAAD | |
|---|-------------------------------------|---------------------------|
| | If Vapour Source is Dissolved Phase | If Vapour Source is LNAPL |
| 0 to 1 | 1 | 1 |
| > 1 to 2 | 10 | 1 |
| > 2 to 5 | 100 | 1 |
| >5 | 100 | 10 |