Ministry of Environment and Climate Change Strategy

PROTOCOL 27
FOR CONTAMINATED SITES

Soil Leaching Tests for Use in Deriving Site-Specific Numerical Soil Standards

Version 1.0

Prepared pursuant to Section 64 of the
Environmental Management Act

Approved:	Cameron Lewis	November 1, 2017
	Director of Waste Management	Date

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1.0 Definitions

The following words, abbreviations and expressions used in this protocol are defined in Procedure 8, "Definitions and Acronyms for Contaminated Sites":

contaminant of concern (COC)	organic soil
contaminated site	Regulation
matrix numerical soil standard	site-specific numerical standard (SSS)
nonaqueous phase liquid (NAPL)	soil

2.0 Introduction

This protocol establishes procedures for using ministry approved soil leaching tests at contaminated sites for use in deriving site-specific numerical soil standards (SSSs) following procedures set out in Protocol 2 "Site-Specific Numerical Soil Standards".

3.0 Minimum requirements

The following requirements must be satisfied for using this protocol to determine site-specific numerical soil standards:

- The presence and extent of soil and groundwater contamination in each Area of Environmental Concern (AEC) to be characterized by leachate testing has been investigated in accordance with ministry guidance and procedures and standard professional practice such that maximum concentrations of contaminants of concern (COCs) in soil have been identified; and
- Substance concentrations in groundwater in or below the AEC where soil has been leachate tested are less than or equal to the concentrations measured in the soil leachate determined using the leachate testing procedure presented in this protocol.

4.0 Leachate test methods

The approved leachate test methods described below apply to specified inorganic and organic substances that have matrix numerical soil standards for the protection of groundwater use.

4.1 Saturated Paste Extraction for Soils

The Saturated Paste Extraction for Soils is provided in the British Columbia Environmental Laboratory Manual and is approved for the specific inorganic substances that have matrix numerical soil standards, as listed below.

- chloride ion
- sodium ion

4.2 Liquid-Solid Partitioning (Leachability) of VOCs – Prescriptive (BC VOC Soil Leachate Test)

The Liquid-Solid Partitioning (Leachability) of VOCs – Prescriptive (BC VOC Soil Leachate Test) is provided in the British Columbia Environmental Laboratory Manual (link). This method is approved for the following organic substances which have matrix numerical soil standards:

- benzene
- ethylbenzene
- naphthalene
- tetrachloroethylene
- trichloroethylene
- toluene
- xylenes, total

4.2 Liquid-Solid Partitioning (Leachability) as a Function of pH (Metals, Inorganics, and SVOCs) – Prescriptive" (BC Soil Leachate Test)

Liquid-Solid Partitioning (Leachability) as a Function of pH (Metals, Inorganics, and SVOCs) – Prescriptive" (BC Soil Leachate Test) is provided in the British Columbia Environmental Laboratory Manual and is a modified version of US EPA Validated Test Method 1313 [2]. This method is approved for specific organic and inorganic substances that have matrix numerical soil standards, as listed below.

The B.C. Soil Leachate Test was developed to best predict the leaching and mobility of pH sensitive substances in various soil pH settings. For these substances, the test is conducted at pH values of 5, 7 and 9; and potentially a fourth pH corresponding to the natural site soil pH. The test pH range between 5 and 9 reflects the pH range of over 90% of B.C. soils. Changes in soil pH that could occur with future changes in site conditions (e.g. the deposit of organic or alkaline fill) are expected to be captured by this range.

Organic substances

- diisopropanolamine [DIPA]
- ethylene glycol
- methanol
- nonylphenol and nonylphenol ethoxylates
- pentachlorophenol [PCP]
- perfluorooctane sulfonate [PFOS]
- phenol
- sulfolane

Inorganic substances

- arsenic*
- barium
- beryllium
- cadmium
- chromium*
- cobalt
- copper*
- lead
- manganese*
- molybdenum
- nickel
- selenium
- uranium
- vanadium*
- zinc

**redox sensitive inorganic substances*

The B.C. Soil Leachate Test is not available for cyanide due to laboratory health and safety concerns.

4.2.1 Redox sensitive inorganic substances

The B.C. Soil Leachate Test must not be used for the following redox-sensitive inorganic substances, unless it can be demonstrated that oxidizing conditions are present in the soil of interest:

- arsenic
- chromium
- copper
- manganese
- vanadium

In reducing conditions, the B.C. Soil Leachate Test may under predict actual field concentrations for redox sensitive species.

Oxidizing conditions are assumed to be present in:

- Unsaturated mineral soil that is not organic soil; and
- Saturated soil, provided that:

$pH + pE \geq 13$

where: pH = pH of water;
pE (electron activity) = $E_h/59$; and
E_h = oxidation-reduction potential of groundwater or porewater expressed in mV.

Measurement of pH and E_h in the field must be carried out in accordance with the British Columbia Field Sampling Manual.

Organic soil is soil containing at least 30% organic matter by mass. This corresponds to a total organic carbon (TOC) content of approximately 17%. Reducing conditions are assumed to be present in unsaturated organic soils because of their high moisture-retention capacity, high moisture content relative to mineral soil, and lack of free water drainage at saturation.

5.0 Sampling program

The field sampling program to support the use of soil leachate testing under this protocol must include the collection and analyses of soil and groundwater samples to determine the following site-specific parameters:

- Maximum concentration(s) of the substance(s) investigated in soil for which leachate testing is to be performed;
- Maximum concentration(s) of the corresponding substance(s) in groundwater in or below the soil for which leachate tested is to be performed;
- Soil pH range, if applicable; and
- Soil redox conditions, if applicable.

Leachate testing must be performed on a minimum of three soil samples collected within each AEC of interest. Leachate testing must be performed on soil samples that have a substance concentration(s) equal to or greater than the 90th percentile of measured concentrations of the substance(s) to be tested, as confirmed by laboratory analysis.

Where an AEC is planned to be, or has been remediated (e.g. hot spot removal or risk assessment), leachate testing can be performed, as described above, on the remaining contaminated soil.

Where the area or volume of the contaminated soil to be characterized by leachate testing is greater than 300 m^2 or 900 m^3, respectively, or where soil contamination is heterogeneous and randomly distributed (e.g. contaminated fill), additional soil samples above the minimum requirement, proportionate with the larger extent of contamination or heterogeneity of the soil must be subjected to leachate testing.

5.1 Sampling procedures

The British Columbia Environmental Laboratory Manual and the British Columbia Field Sampling Manual must be consulted for sample collection, volumes, containers, hold times, and preservation instructions applicable to the approved leachate test method being used.

The B.C. Soil Leachate Test method requires a minimum of 500 g dry weight equivalent of sample. Therefore, consideration must be given to sample volume when collecting material with high moisture content, such as peat, which may contain up to 70% to 80% moisture.

Field sampling methods for volatile organic substances must be conducted to minimize losses due to volatilization.

6.0 Interpretation of leachate results

Substance concentrations in soil leachate are estimated from the results of the leachate tests performed as follows:

1. For pH sensitive substances analysed using the B.C. Soil Leachate Test, the concentration in soil leachate determined for each soil sample tested is the highest concentration measured in the test runs at pH values of 5, 7 and 9 (and potentially a fourth corresponding to the natural site soil pH). The substance concentration in soil leachate determined for each AEC of interest is the arithmetic mean of the highest leachate results measured for each soil sample tested (minimum 3).

2. For all other substances that are not pH sensitive and analysed using either the B.C. Soil Leachate Test or the B.C. VOC Soil Leachate Test and where soil leachate is obtained from a single leachate test, the substance concentration in soil leachate determined for the AEC of interest is the arithmetic mean of the leachate results measured for each soil sample tested (minimum 3).

3. For substances that are highly soluble and have a low distribution coefficient or organic carbon partitioning coefficient (Kd< 5 or a Koc <1000) a correction to the substance concentration in soil leachate determined under 1. or 2. above is required as per section 6.1.

6.1 Correction for highly soluble substances

For highly soluble substances with a low Kd or Koc, leachate concentrations measured in the ministry approved tests are not equivalent to those that would be observed under

field conditions because the relative amounts of soil and water used in the leachate tests are larger than what exists in natural soils. For this reason, a correction to the substance concentrations measured in the test leachate is required.

For further information regarding the correction of leachate concentrations for highly soluble substances please review Appendix C of the guidance document posted by the New Jersey Department of Environmental Protection located at:
http://www.nj.gov/dep/srp/guidance/rs/splp_guidance.pdf

Substances that require a correction to leachate concentrations measured in test leachate are:

- benzene
- diisopropanolamine [DIPA]
- ethylbenzene
- ethylene glycol
- methanol
- pentachlorophenol [PCP]
- phenol
- sulfolane
- tetrachloroethylene
- trichloroethylene
- toluene
- xylenes, total

Substance concentrations in soil leachate for these substances are corrected using one of the following methods:

1. Multiply the substance concentration in soil leachate by 20 to obtain a final estimate of the substance concentration in soil leachate; or
2. Calculate a test specific partition coefficient (*Kdtest*) for each soil sample tested as follows:

$$Kdtest = \frac{(CtMs - CtestV)/Ms}{Ctest}$$

Where:

Kdtest = is the test specific distribution coefficient (L/kg)

Ct = the total concentration of the substance in the soil sample tested (mg/kg)

Ms = the total weight of the soil sample used in the leachate test (0.05 kg)

Ctest = the substance concentration determined in soil leachate test (mg/L)

V = the volume of the eluent used in the leachate test (1 L)

For situations where the mass of contamination leached is greater than the total mass of contamination (due to sampling and experimental error) resulting in the calculation of a negative *Kdtest*, substitute 0.001 as your *Kdtest*.

After determination of *Kdtest* for each soil sample, calculate a field estimate of substance concentration in leachate (for each sample) as follows:

$$CLfield = \frac{Ct}{Kdtest + \frac{\theta w + \theta aH'}{\rho b}}$$

Where:

Kdtest = is the test specific distribution coefficient (L/kg)
θw = water-filled porosity (0.119)
θa = air-filled porosity (0.241)
H' = the dimensionless Henry's law constant (see chapter 4, Protocol 28 link)
ρb = dry bulk density of the soil (1.7 Kg/L)
CLfield = estimate of substance concentration in field leachate (mg/L)

The final estimate of substance concentration in soil leachate is the arithmetic mean of the calculated field leachate results (*CLfield*) for each soil sample tested.

7.0 Reporting requirements

Reporting under this protocol must include:

- Verification that the minimum requirements for the use of this protocol have been met (refer to Section 3.0);
- Verification that the minimum number of soil samples required for leachate testing has been met. For large or heterogeneous contamination sources, verification is needed that a sufficient number of soil samples have been tested to adequately characterize substance concentrations in leachate;
- A plan showing AECs investigated; soil sample depths and locations;
- Tabulated results for:
    - Substance concentrations in soil investigated, including maximum concentrations;

  - Substance concentrations in groundwater in or below the soil subjected to leachate testing;
  - substance concentrations in soil samples subjected to leachate testing;
  - substance concentrations in leachate; and
  - site-specific soil pH range, if applicable.
- A description and interpretation of site investigation activities, observations and the leachate soil test results including a discussion of how soil heterogeneity, redox conditions and seasonality, are expected to affect the results;
- A description of uncertainties that were identified in the course of the investigation, measures taken to mitigate the associated uncertainty, and the likely consequences of any remaining uncertainty for the site-specific numerical soil standard(s) to be derived under Protocol 2; and
- A copy of the laboratory analytical results.

8.0 References

1. USEPA. (2012). Validated Test Method 1313: Liquid-Solid Partitioning as a Function of Extract pH Using a Parallel Batch Extraction Procedure. Oct. 2012. Available at: https://www.epa.gov/hw-sw846/validated-test-method-1313-liquid-solid-partitioning-function-extract-ph-using-parallel

2. New Jersey Department of Environmental Protection. (2013). Guidance Document. Development of Site-Specific Impact to Ground Water Soil Remediation Standards Using the Synthetic Precipitation Leaching Procedure. November 2013. Available at:

   http://www.nj.gov/dep/srp/guidance/rs/splp_guidance.pdf

For more information, please direct inquiries to site@gov.bc.ca.

Revision history

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	November 1, 2017	5.0	Created for the Regulation Stage 11 amendment