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ARIZONA DEPARTMENT OF ENVIRONMENTAL QUALITY

SOIL VAPOR SAMPLING GUIDANCE

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Soil Vapor Sampling Guidance

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Disclaimer: Please note that the information is intended as general guidelines and not specific recommendations for all sites. Site-specific considerations, professional judgment, and regulatory requirements will dictate the methods and procedures used at any particular site.

Soil Vapor Sampling Guidance

1. Scope and Application

1.1 This guidance describes procedures for collection of active soil vapor samples and does not address procedures for collection of passive soil vapor samples.

1.2 This guidance is intended to detail sampling procedures to ensure delivery of soil vapor samples to the laboratory that will yield reliable and consistent results that are representative of actual conditions.

2. Definitions

2.1 Dead Volume – volume of the sampling probe and the connected sampling tubing and equipment. The boring volume is not included in the calculation of dead volume, because the probe tip sand-pack space is assumed to have been allowed to equilibrate with surrounding soil formation before soil vapor sampling occurs.

2.2 Internal Volume – dead volume plus probe tip sand-pack volume.

2.3 Probe Driving System – hydraulic or hammer system used for installation of soil vapor sampling probes.

2.4 Soil Vapor Monitoring Well – a well constructed specifically to sample soil vapor from the vadose zone.

2.5 Soil Vapor Sample – a sample of soil vapor representative of the vadose zone at the sampled location.

2.6 Soil Vapor Sampling Port – any mechanical device (usually a ball valve with a hose barb) that allows a representative soil vapor sample to be collected from a soil vapor monitoring well.

2.7 Soil Vapor Sampling Probe – any mechanical device that allows a representative sample of soil vapor to be collected from specified sampling depth.

2.8 Vapor Equilibration – the condition where vapor concentration entering a sampling probe is 95% or greater of vapor concentration in surrounding soil.

3. Considerations when Planning for Soil Vapor Sampling

The collection and analysis of soil vapor samples, along with any existing soil and groundwater data or any reasonably obtainable data (e.g., soil solids and groundwater data), is

useful for the objectives of site characterization, determination of potential pathways of exposure for health risk, optimization of remedial or mitigation systems design, and confirmation of compliance with remedial goals.

3.1 Temporal Variations in Soil Vapor Concentrations

Variations in soil vapor concentrations due to temporal effects are principally due to temperature changes, precipitation, and activities within any overlying structure. Variations will be greater the closer the samples are to the surface and are lessened with increasing depth. There are a number of available studies on the temporal variation in soil vapor concentrations and more are currently underway or planned in 2007 by the EPA and independent groups. The results of these studies have shown that short-term variations in soil vapor concentrations at depths four feet or deeper are less than a factor of two and seasonal variations in colder climates less than a factor of five.

Larger variations in soil vapor concentrations may be expected in areas of greater temperature variation and during periods of heavy precipitation as described as follows:

3.1.1 Temperature: Effects on soil vapor concentrations due to actual changes in the vadose zone temperature will be minimal.

3.1.2 Precipitation: Infiltration from rainfall can potentially impact soil vapor concentrations by displacing the soil vapor, dissolving volatile organic compounds, and by creating a “cap” above the soil vapor. In most settings, infiltration from large storms only penetrates into the uppermost vadose zone. Soil vapor samples collected at depths greater than 3 to 5 feet below ground surface (bgs) under foundations or areas with surface cover are unlikely to be significantly affected. However, soil vapor samples collected closer to the surface (<3 feet) with no surface cover may be affected. If the moisture has penetrated to the sampling zone, it typically can be recognized by difficulty in collecting soil vapor samples. If high vacuum readings are encountered when collecting a sample, or drops of moisture are evident in the sampling system or sample, measured values should be considered as minimum values. Measurement of percent moisture of the soil may also be useful if shallow sampling is performed during or shortly after significant rainfall (>1.0 inch).

3.1.3 Pressure: Barometric pressure variations are unlikely to have a significant effect on soil vapor concentrations at depths exceeding three to five feet bgs and only a minor effect (less than a factor of 2) at shallower depths unless a major storm front is passing through the area. A recent study in Wyoming (Luo et al., 2006) has shown little to no relationship between barometric pressure and soil vapor oxygen concentrations.

Human induced influences to pressure are likely to have a bigger effect upon soil vapor concentrations. For example, pressure changes resulting from the on-off cycling of an overlying building’s heating or HVAC system and the ventilation of the structure due to open doors and windows can greatly influence soil vapor concentrations at locations near the building. In colder climates, greater impacts

are most likely in the winter season. Literature suggests that temporal variations in the radon concentrations are typically less than a factor of two and seasonal effects less than a factor of five. (Vapor Intrusion Pathway: A Practical Guideline, January 2007 Interstate Technology and Regulatory Council)

3.2 Conditions Unsuitable for Collection of Soil Vapor Samples

3.2.1 Soil vapor samples should not be collected if:

- a. The groundwater is very close to the ground surface (i.e., < 3 feet);
- b. Chemical(s) of concern is/are not volatile; and
- a. Moisture or unknown material is observed in the sample stream or sample container.

Please note that due to increased diffusivity, advective flow, and temperature fluctuations at near surface boundaries, the collection of a soil vapor sample in near surface soils is not useful for the purpose of calculating total soil solid VOC concentrations.

3.3 Tests to Determine if Soil Vapor Sampling is Practicable

Some soil types (i.e., clay or silty clays) may not be conducive for soil vapor collection. Tests to ascertain if soil vapor can be collected from the soils are outlined below.

3.3.1 As a qualitative test, a gas-tight syringe could be connected to the soil-vapor-sampling tubing to determine if a sample can be withdrawn. Please note that the soil-vapor-sampling tubing must have a volume of less than the gas-tight syringe for a meaningful result.

3.3.2 Another test that can be performed to determine if soil vapor sampling is practicable at a site is as follows:

- a. Install a T-connection at the end of the soil-vapor-sampling tubing;
- b. Connect a vacuum gauge to one branch of the T-connection;
- c. Connect a syringe fitting and a 60-mL or larger syringe to the remaining branch of the T-connector;
- d. With the syringe connected, pull the plunger back to the full-scale reading and hold in that position; and then
- e. Monitor the vacuum created at the full draw position and during relaxation.

If the vacuum does not relax within a few minutes to an hour, it is unlikely that soil vapor sampling is practicable at that particular location and other locations in the subsurface with similar soil characteristics.

3.4 Confirmation Sampling

Soil vapor samples used to verify completion of remedial actions must verify that residual contaminant concentrations are at or below the corrective action standard for each chemical of concern in the contaminated soil as determined under A.A.C. R18-7-201 *et seq.* (please refer to Section 6). The soil vapor samples must be collected throughout all areas previously reporting soil solid concentrations for chemicals of concern above applicable corrective action standards.

4. **Installation Methods**

This section provides useful construction information and details for installation methods.

4.1 Sample Through Rods (also known as temporary probes)

This method is advantageous if only one sampling round is required. Also, less material is placed in the ground, minimizing disturbance of the in-situ vapor and decreasing the need for collection of blanks.

The following construction details should be considered for the collection of a sample through rods:

4.1.1 Seal probes at the surface with bentonite before sampling;

4.1.2 Utilize small diameter tubing (e.g. nylon, polyethylene, copper or stainless steel) which will not react, absorb or interact with site contaminants. It is suggested to use new tubing for new field events or demonstrate that the tubing you are using is contaminant free; and

4.1.3 When using direct-push borings for the installation of soil-vapor-sampling probes, avoid lateral movement of the probes once they are in the ground to prevent atmospheric air from entering the sampling system.

4.2 Permanent Probes

4.2.1 The following construction details should be considered for the installation of permanent probes:

a. Use short discreet sampling intervals (e.g., 6 to 12 inches);

b. Color code or tag tubing of probes at the surface to be sure that the sampling depth is easily identifiable for future sampling events;

- c. Complete and seal permanent probes at the ground surface (e.g., road boxes, locked caps, vapor-tight valves).

4.3 Types of Drilling

When using auger, air rotary, or roto sonic drilling methods for the installation of soil-vapor sampling probes, the following should be considered:

4.3.1 Install sampling probes with sand-pack intervals of approximately 1 foot;

4.3.2 Seal each sampling interval with bentonite or grout above and below the sand pack in the annulus of the boring. Care should be taken to ensure that the seal material does not intrude into the sand pack;

4.3.3 If dry bentonite is placed in the boring, care should be taken to fully hydrate the bentonite. Placing the bentonite in small increments (e.g., < 6 inches) followed by water is helpful. Alternatively, the bentonite can be added using a combination of dry and hydrated bentonite, or in slurry form if the boring is of sufficient diameter; and

4.3.4 For deeper probes, down-hole support rods may be necessary during probe installation, especially for tubing sized greater than 1/8-inch OD.

4.4 Equilibration Time

During probe installation, subsurface conditions are disturbed. For probes installed with hollow stem, air rotary, or roto sonic drilling methods, purge volume test, leak test and soil vapor sampling should not be conducted for at least 48 hours (depending on site lithologic conditions and stage of investigation) following probe installation. When utilizing sample through rods, a 20 to 30 minute equilibration time is recommended.

5. **Sampling and Analysis**

5.1 Sampling Containers

The sample containers chosen for a specific site will depend on the sampling equipment and analytical requirements. The ultimate storage container should be selected prior to the initial sampling.

5.1.1 Examples of different sample containers include:

- a Tedlar™ bags;

- b. 1.0 Liter stainless steel canisters (e.g., Summa™ canisters). The lab is responsible for certifying the cleanliness of the canister and evacuating the

canister before leaving the lab. It is strongly suggested that the lab be responsible for providing a record of the canister vacuum/pressure before and after sampling; and

c. Gas-tight syringes

All of the above listed sample containers are relatively simple to fill. Tedlar™ bags have a 72 hour holding time. Stainless steel canisters have a 30 day holding time. Syringes are typically utilized for on site analysis and the holding time should be as short as possible (less than 5 minutes for plastic syringes and less than 15 minutes for glass syringes). The transferring of samples to different container types for the purpose of extending holding times is not recommended.

5.2 Shallow Samples

Care needs to be observed when collecting shallow soil gas samples to minimize atmospheric influence from the surface. If possible, extensive purging or use of large volume sample containers (e.g. 6.0 L Summa canisters) should be avoided for collection of near-surface samples.

5.3 Storage and Shipping Considerations

- 5.3.1 Do not put sample on ice;
- 5.3.2 Do not store sample exposed to light (keep sample in dark place);
- 5.3.3 Keep sample at standard temperature and pressure as much as practicable;
- 5.3.4 Tedlar samples are not to be shipped by airplane.

5.4 Sample Collection

It is recommended to use the ADEQ QA/QC checklist for Soil Vapor Sampling when sampling (see Attachment 1).

5.4.1 Purging

Purging is utilized to obtain a sample that represents equilibrated vapor concentrations of soil surrounding the sampling probe. The initial purge testing should be conducted in an area where positive detections are most likely to occur. The purged volume selected should be consistent for all sample locations across the site. Please consider the following procedure with respect to purging:

- a. Remove three to five internal volumes of a sample system. This should ensure that vapor concentration entering a sampling container is 95% or greater representation of vapor concentration in surrounding soil; or
- b. If vapor equilibration has occurred, remove one to five dead volumes;

The number of dead volumes requiring removal may be based on procedures such as:

- c. Analyzing the purged vapor with a field vapor analyzer (PID or FID) until the concentrations of total hydrocarbons stabilize, or use field instruments to measure respiration gases (e.g., O₂, CO₂) and assess consistency across sequential purged volume samples; or
- d. Conducting a purged volume test to determine the number of dead volumes to remove that corresponds to the highest recovered vapor concentrations.

5.4.2 Purging Equipment

- a. A vacuum pump with a flow controller and flow meter can be used when sampling large (> than 200 cubic inch probe volume) or middle size probe. Another device (e.g. syringe) should be used for small size probes (less than 3 cubic inch probe volume).
- b. To evaluate lithologic conditions adjacent to the soil gas probe (such as no flow conditions due to clayey lithology), a vacuum gauge or similar device should be used between the soil gas sample tubing and the soil gas extraction devices (e.g. vacuum pump).

The whole purging device should be used at the end of the sampling train (after the T-valve and canister) to avoid field cross contamination from the device.

5.4.3 Purging flow rate

- a. 200 ml/min is the default rate.
- b. The purge rate may be modified based on conditions encountered in individual soil gas probes, such as:

*The probe vacuum reading > 5 inches Hg (full vacuum reading is 29.9 inch Hg)

*Condensation is present in the sampling train, or

*The internal volume of the sampling train is very large (i.e., the purging time would be over one hour at 200 ml/min flow rate)

These modified rates should be documented.

5.4.4 Purging time

- a. Determine the dead volume - the internal volume of the probe plus the internal volume of the tubing used to connect the probe and the sampling train.
- b. The dead volume divided by 200 ml/min or the appropriate purging flow rate is the purging time.

Please note that care should be taken not to collect a sample under non-equilibrium conditions generated by high purge rates. Overpurging is a common mistake of soil vapor sampling

5.5. Leak Testing

Consider conducting a leak test where leakage may be a concern (i.e. at fitting junctures and anywhere leakage may occur).

The following is a procedure for checking belowground sampling equipment for leaks:

5.5.1 Use oxygen as a qualitative test for a high-end indicator of short-circuiting. Elevated oxygen measurements in soil vapor analytical results may indicate significant short-circuiting. This, though, may not be true for shallow depths or in areas where there is only halogenated VOC contamination); and

5.5.2 Use tracer compounds (e.g., difluorethane, butane, propane, isopropanol) to conduct leak tests (helium is recommended as a leak tracer for projects using TO-15 (fixed lab) analysis). For example, the tracer is applied at the surface where air could enter the soil vapor probes. When using a tracer gas, a shroud is needed to keep the tracer gas in contact with the probe during the testing. Please note that helium is a common carrier gas during sample analysis. So it is not recommended for use as a tracer compound. **NOTE** – Contact the lab with any specific questions regarding any further information on tracer compound and techniques.

5.5.3 Gently apply the tracer compound at the surface where air could enter the soil vapor probes (i.e. at the top of the probe) and at all the connections of the sampling train when the sampling starts. Never over apply. Over application of the tracer compound may cause cross contamination and failure to obtain usable results.

The Detection Limit for leak check compounds should be 10 ppbv or less. The soil vapor sample is analyzed for the tracer compound using a method that can detect it as a calibrated analyte or as a Tentatively Identified Compound (TIC).

Care should be taken that the tracer compound of interest and other co-existing volatile compounds in the tracer media are not target compounds of interest in soil vapors investigated at the site. A discussion of advantages and disadvantages

regarding different tracers can be found in Appendix D (pages D-9 and 10) of the January 2007 ITRC Vapor Intrusion Pathway: A Practical Guideline.

5.6 Sample Collection Flow Rates

Flow rates should not exceed approximately 200 ml/min and vacuums should be maintained to below 10 inches of water, if practical. Also, consider the following:

5.6.1 Minimize the sample collection flow rate for near groundwater situations to prevent groundwater from entering the sample container;

5.6.2 Measure and recording the vacuum at which the samples were collected for each sampling probe;

5.6.3 Monitoring the vacuum during sampling with an in-line gauge; and

5.6.4 Use of a calibrated flow controller supplied by the lab to provide a consistent flow rate for each sample collected. One flow controller should be used for each sample collected.

5.7 Sample Collection Procedure

The following are examples of sample collection procedures utilizing different types of sample containers:

5.7.1 Collection using Tedlar™ bags:

a. A “T-coupling” should be used to place the Tedlar™ bag in the sampling system ahead of the purging equipment used to purge vapor from the system. Appropriate compatible connecting threads will be required in order to use the Tedlar™ bag;

b. Attach sample tubing to a vacuum box and pump;

c. Label the bag accordingly and keep it in a dark area with the temperature as near as possible to the soil temperature at the time sampled (to avoid condensation) as much as practicable until analysis occurs. The sample collected in a Tedlar™ bag should be analyzed as soon as possible after collection;

d. Open the valve on a clean dry Tedlar™ bag and attach it to the inside of the vacuum box;

e. Close the vacuum box, close stopcock (3-way valve) between vacuum box and pump, then turn the pump on; and

f. Allow Tedlar™ bag to fill to 50 – 70% of capacity (do not overfill), shut off the pump, close the toggle switch (to prevent loss of sample), open the stopcock, and remove Tedlar™ bag from the vacuum box.

5.7.2 Collection using stainless steel canisters (e.g., Summa™ canisters):

a. The lab should provide a Flow Controller with every canister to control the sampling flow rate equivalent to 200 ml/min or appropriate rate. The Flow Controller should be pre-cleaned and certified for cleanliness before being issued for field use.

b. A “T-coupling” should be used to place the stainless steel canister in the sampling system ahead of the purging equipment used to purge vapor from the system. Appropriate compatible connecting threads will be required in order to use the stainless steel canisters;

c. If necessary, a vacuum gauge can be used to verify the pressure inside the stainless steel canister prior to sampling to ensure the can has arrived from the laboratory with the proper vacuum. Please note, any kind of vacuum gauge may have potential field cross contamination risk if not used properly. It is recommended to check the clean canister with vacuum gauge just prior to sampling in the field. Do not use the same vacuum gauge after sample collection.

The field vacuum gauge may become contaminated if it is used on a sample that contains contaminants, and could then cause cross contamination. Therefore, the use of mechanical vacuum gauges is not recommended. Use of a digital gauge is recommended.

d. Empty stainless steel canisters may not be stored for more than 30 days prior to sample collection. Once filled, the stainless steel canisters should be properly labeled and packaged for transport to the off-site laboratory. (Note: Only stainless steel canisters can be shipped by air freight to an analytical laboratory for analysis and should be analyzed within 30 days after sample collection.);

e. Connect all parts of the sampling train in the following order:

- *top of the probe
- *tubing
- *“T-coupling”
- *purging pump

Place the Flow controller on the site of “T-coupling”.

For permanently installed probes, check the tightness of the probe, the valve on the top of the probe, and the presence of glue applied at the probe

junctures. Fix any problems if possible before purging, and record on the SWSP form.

5.7.3 Open all the valves; turn on the pump at the appropriate flow rate for the calculated purging time. During the purge, action should be taken if any of the following conditions are noted:

- a. The probe vacuum is > 5 inches Hg, or
- b. Condensate is present in the sampling train

To address condition “a”, close the T-coupling valve, turn off the pump, extend the sampling time (e.g. from 5 minutes to 10 or 15 minutes). To address condition “b”, raise the canister as high as possible until the water evacuates the line. Record all observations and actions.

If the probe vacuum is < 5 inches Hg, finish within the purging time, close the T-coupling valve, turn off the pump.

Connect the canister to the Flow Controller, open the canister valve. If a canister with a bayonet style quick connector is used, simply push the canister fitting into the flow controller until it is securely seated. Apply the leak test tracer compound (as described in 5.5) immediately after the canister is connected or opened.

Allow the canister to fill for the appropriate time.

5.7.4 Disconnect the canister from the sampling train, replace the canister valve cap and complete the sample label (Note: Labeling should be done on the tag attached to the canister), do not write on the outside of the stainless steel canister itself.

5.7.5 The equipment blank is used to monitor any cross contamination from the sampling train. Use the same setup as outlined above, but using clean cylinder air/nitrogen as source gas.

5.7.6 The background blank will monitor any cross contamination from the surrounding ambient air. Take the background blank sample from upwind and as close as possible to the probe location.

5.7.7 A duplicate or split sample should be collected every 20 samples or field sampling event. Please note that it is very difficult to have reasonable precision for sample duplicates if a T-manifold splitter is not used, especially for medium or shallow probes.

5.8 Analysis

Analysis of vapor samples can occur in the field (mobile laboratory) or at a fixed laboratory setting. Use of a mobile laboratory for vapor analyses can be practical in terms of data collection when field decisions need to be made, especially during the

investigative process. The intention of analyses in the field is to ensure a good data set that provides results in real time that adequately represents conditions at the site. A good field data set should result in less time spent during the site investigation process.

The following analytical methods are acceptable for soil vapor analysis:

For VOCs:

5.8.1 8260BAZ (Modified for Vapor)

5.8.2 8021B (Modified for Vapor)

5.8.3 TO-15

5.8.4 TO-14A

NOTE: Please contact the regulating program for the appropriate analytical method. All COCs may not be included in the method target compound list.

5.9 Data Quality Objectives (DQOs)

Data quality objectives (DQOs) will vary with both the stage of investigation and the intended use of the data collected from soil vapor sampling. During screening or the initial stages of investigation, DQOs will be less stringent than those for confirmation of remediation or risk assessment for indoor air vapor intrusion. DQOs will determine the sampling method, the type of sample collected, the frequency of sample collection, sampling location, the number of samples to be collected, and the specific quality assurance (QA) and quality control (QC) necessary, both in the field as well as in the laboratory. Following DQOs will ensure that the data is useable for the intended purpose.

The most important QA/QC activities and parameters include:

5.9.1 Sampling method

5.9.2. Sampling equipment maintenance and calibration

5.9.3 Control samples, i.e., trip blanks, field blanks, method blanks

5.9.4 Standard Operation Procedures (SOPs)

5.9.5 Analyses method appropriate for target compounds

5.9.6 Sample holding times and transportation conditions

5.9.7 Analyses method with required practical quantitation level

5.9.8 Laboratory QC samples

5.10 Quality Assurance/Quality Control

5.10.1 Sampling QA/QC

Solid quality assurance and quality control procedures start with organized planning. A well thought out work plan will help to ensure that soil vapor samples are collected in a manner resulting in data of known quality. Stated data objectives and quality control techniques are essential to the work plan. There are several quality control procedures to ensure collection of representative samples. The following are some of those quality control procedures that should be considered:

- a. Purging (see Section 5.4.1)
- b. Leak Testing (see Section 5.5)

5.10.2 Analysis QA/QC

All soil vapor analysis should be performed by a laboratory that is certified by Arizona Department of Health Services (ADHS) and maintains a Quality Assurance Plan. Quality Control Procedures for analysis performed with soil vapor sampling should follow good laboratory practices and criteria within the specified methods and at a minimum include the following quality control criteria:

- a. Detection Limit Study
- b. Method Blank
- c. Calibration
- d. Calibration Verification
- e. Surrogates
- f. Duplicate (1 per 20 sample/field sampling event)
- g. Second Source Standard

When QC criteria fall outside specified control limits, the analysis should be qualified using Arizona data qualifiers. Any event that cannot be described by the data qualifiers must be documented in a case narrative which must be included with the final report. Using the Arizona data qualifiers does not automatically qualify the data as acceptable to ADEQ. ADEQ expects that data reported utilizing these qualifiers, unless stated otherwise, is useable, scientifically valid and defensible.

5.10.3 Other Soil Vapor Analytes

Chemicals of interest for soil vapor sampling are specific for the type of contaminant release and breakdown products. They include both volatile organic and inorganic compounds, as well as some semi-volatile organic compounds. The method selected for laboratory analysis should be consistent with the stage of investigation and remediation, the volume of sample that is practical to collect, and the DQO's. Analysis of all samples collected to demonstrate compliance with regulatory requirements should be conducted by a laboratory licensed by the ADHS using an ADHS approved method.

The following table lists the types of compounds, methods, and ADHS approval status. The laboratory should be consulted for specific target list compounds, as well as detection limits. If a particular method is desired for compliance sampling which is not currently approved by ADHS, please contact ADEQ to begin approval for the method using A.A.C. R9-14-610(C).

Table 5.1 Analytical Methods

Compounds	Method	ADHS Certified
Chlorinated VOCs and Petroleum VOCs BTEX/MTBE	TO-14A	Yes
Chlorinated VOCs and Petroleum VOCs	TO-15	Yes
VOCs	8260BAZ	Yes
VOCs	8021	No

***ADHS has begun working on the process for certifying Method 8260**

6. Relating Soil Vapor Concentration to Total Soil Concentration

Calculation of total soil concentrations using the method outlined below will vary depending on the input choice of chemical and physical values, such as soil adsorption coefficients (K_{oc}) and soil organic carbon fractions (f_{oc}). In this section, ADEQ provides a list of default values and methods to derive alternative values to be utilized in the three-phase partitioning equation outlined in Section 6.1. The listed default values are appropriate for use throughout much of Arizona and are conservative values so as to be protective of public health and the environment.

6.1 Three-phase Partitioning Equation

The following three-phase partitioning equation is accepted by ADEQ for the calculation of total soil concentrations which may occur in situ for a chemical. The equation is based on a standard soil partitioning equilibrium model which assumes that a fourth phase, non-aqueous phase liquid (NAPL) is not present. Therefore, at soil concentrations exceeding the 3-phase saturation limit, measured soil vapor concentrations are inapplicable for calculating total soil concentrations using this equation. The equations used that govern the equilibrium partitioning between phases are the linear

sorption partitioning equation normalized with respect to organic carbon (Karichoff et al., 1979) and Henry's Law:

$$C_t = \frac{C_g [K_{oc}f_{oc}\rho_b/H_o + \theta_w/H_o + (\theta_t - \theta_w)]}{\rho_b}$$

where,

C_t – Total concentration in soil ($\mu\text{g}/\text{kg}$)

C_g – Concentration in soil vapor ($\mu\text{g}/\text{L}$)

f_{oc} – Mass fraction of natural soil organic carbon content (g-organic carbon/g-soil)

K_{oc} – Soil organic carbon-water partitioning coefficient (ml/g)

ρ_b – Dry Bulk Density (kg/L)

H_o – Henry's Law Constant (dimensionless)

θ_t – Total soil porosity (volume of voids/volume total)

θ_w – Volumetric Water Content (volume of water/volume of soil)

6.2 List of Default Values for the Soil Matrix

6.2.1. Fraction of Organic Carbon in Soil (f_{oc}). A default input for fraction of organic carbon in soil of 0.006 (0.6%) is selected for use in the equation.

6.2.2 Soil Dry Bulk Density (ρ_b). A default input for dry bulk soil density of 1.5 kg/L is selected for use in the equation. Dry bulk-densities for basin-fill deposits typically range from 1.3 to 1.8 kg/L. The 1.5 kg/L value is within this range.

6.2.3 Total Soil Porosity (θ_t). A total soil porosity of 0.43 (43%) is selected is selected for use in the equation and was based on a default soil particle density (ρ_s) of 2.65 kg/L [$\theta_t = 1 - \rho_b/\rho_s = 0.43$].

6.2.4 Soil Volumetric Water Content (θ_w). A default volumetric water content of 15% (0.15) is selected for use in the equation. Volumetric water content in basin-fill deposits typically range from 5 to 25 percent. The 15% value is within this range.

6.3 Test Methods Required to Change Soil Matrix Default Values

This section specifies procedures and requirements to derive site-specific input parameters for use in the three-phase partitioning equation. Site-specific values may be

substituted for one or more of the following four input parameters: soil dry bulk density, soil organic carbon content, total soil porosity, and soil volumetric water content.

6.3.1 Deriving soil organic carbon fraction (f_{oc}). ASTM Method D2974 or other methods approved by ADEQ may be used to derive site-specific soil organic carbon fraction values. Soil samples used to measure site-specific soil organic carbon content must be collected from uncontaminated soil in lithologic zones that are representative of where the soil-vapor contamination is present. All laboratory measurements shall be based on methods that do not include inorganic carbon in the measurements.

6.3.2 Deriving soil dry bulk density (ρ_b). ASTM Method D2049 or D2937 or other methods approved by ADEQ may be used to derive site-specific soil bulk density values.

6.3.3 Deriving total soil porosity (θ_t). ASTM Method D4404 or other methods approved by ADEQ may be used to derive site-specific total soil porosity values.

6.3.4 Deriving soil volumetric water content (θ_w). ASTM Method D2216 or other methods approved by ADEQ may be used to derive soil volumetric water content values.

6.4 List of Chemical Default Values (K_{oc} and H_o) for Selected VOCs

Soil organic carbon-water partitioning coefficients (K_{oc}) and dimensionless Henry's Law constants (H_o) are provided for the following VOCs (see table below). These values, taken from *Soil Screening Guidance* (US EPA, 1996), are accepted by ADEQ for use in the three-phase partitioning equation. The chemicals shown are not a complete list of all potential VOCs encountered in contaminant releases, but represent those commonly encountered, those with greater potential to exist in the vapor phase, or those with greater toxicity relative to other VOCs.

Alternative K_{oc} and H_o values can be substituted for the values listed in the table on the next page if those alternative values more accurately represent conditions encountered at a site. Sources for these values may be obtained from the *Superfund Chemical Data Matrix* (US EPA, most current editions) and the most recent version of Estimation Programs Interface Suite™ (US EPA, 2007) available at <http://www.epa.gov/opptintr/exposure/pubs/episuite.htm>.

Alternative K_{oc} and H_o values based on scientific literature are subject to ADEQ approval.

Compound	K_{oc} (L/kg) ¹	H_o (dimensionless) ²
Benzene	5.89E+01	2.28E-01
Bromodichloromethane	5.50E+01	6.56E-02
Bromoform	8.71E+01	2.19E-02
Carbon disulfide	4.57E+01	1.24E+00
Carbon tetrachloride	1.74E+02	1.25E+00
Chlorobenzene	2.19E+02	1.52E-01
Chloroform	3.98E+01	1.50E-01
1,2-Dibromoethane (EDB)	2.81E+01	2.90E-02
1,1-Dichloroethane	3.16E+01	2.30E-01
1,2-Dichloroethane (DCA)	1.74E+01	4.01E-02
1,1-Dichloroethene	5.89E+01	1.07E+00
<i>cis</i> -1,2Dichloroethene	3.55E+01	1.67E-01
<i>Trans</i> - 1,2=Dichloroethene	5.25E+01	3.85E-01
1,2-Dichloropropane	4.37E+01	1.15E-01
1,3-Dichloropropene	4.57E+01	7.26E-01
Ethyl benzene	3.63E+02	3.23E-01
Methyl bromide	1.05E+01	2.56E-01
Methylene chloride	1.17E+01	8.98E-02
Styrene	7.76E+02	1.13E-01
1,1,2,2- Tetrachloroethane	9.33E+01	1.41E-02
Tetrachloroethene (PCE)	1.55E+02	7.54E-01
Toluene	1.82E+02	2.72E-01
1,1,1-Trichloroethane	1.10E+02	7.05E-01
1,1,2-Trichloroethane	5.01E+01	3.74E-02
Trichloroethene (TCE)	1.66E+02	4.22E-01
1,2,4-Trimethylbenzene	3.72E+03	2.30E-01
1,3,5-Trimethylbenzene	8.19E+02	3.20E-01
Vinyl acetate	5.25E+00	2.10E-02
Vinyl chloride	1.86E+01	1.11E+00
Xylenes (total) ³	3.86E+02	2.76E-01

Ref: U.S. EPA Soil Screening Guidance: User's Guide, 2nd Edition (July 1996)

¹ - K_{oc} = organic carbon partition coefficient

² - H_o = Dimensionless Henry's Law Constant (HLC[atm-m]*41(25°C))

³ - K_{oc} and F_{oc} values for total Xylenes represent average of values for *ortho*-, *meta*-, and *para*-Xylenes.

A soil vapor unit conversion table is supplied below.

Soil Vapor Unit Conversion Factors*		
Unit	To Convert To:	Multiply by:
µg/L	mg/m ³	1
µg/m ³	mg/m ³	0.001
ppbv	µg/m ³	MW/24
µg/m ³	ppbv	24/MW
ppmv	mg/m ³	MW/24
ppbv	mg/m ³	MW/24,000
µg/L	µg/m ³	1000
µg/m ³	µg/L	0.001
µg/L	ppbv	24,000/MW
µg/L	ppmv	24/MW
ppbv	ppmv	0.001
ppmv	ppbv	1000

*At standard temperature and pressure.

µg/L	micrograms per liter
mg/m ³	milligrams per cubic meter
µg/m ³	micrograms per cubic meter
ppbv	parts per billion by volume
MW	molecular weight
ppmv	parts per million by volume

7. Procedure References

7.1 Atlantic RBCA Version 2.0 for Petroleum Impacted Sites in Atlantic Canada, User Guidance, Appendix 9 – Guidance for Soil Vapor and Indoor Air Monitoring Assessments

7.2 California Regional Water Quality Control Board, California Department of Toxic Substances Control. Advisory – Active Soil Gas Investigations January 28, 2003. Hartman, Blayne (2006). Part 4 – “How to Collect Reliable Soil-Gas Data for Risk-Based Applications, Specifically Vapor Intrusion: Updates on Soil-Gas Collection and Analytical Procedures.” LUSTLine Bulletin 53 September 2006

7.3 Karichoff, S.W., D.S. Brown, and T.A. Scott. 1979. Sorption of hydrophobic pollutants on natural sediments. Water Resources Research 13, no. 3: 241–248.

7.4 Luo, H., P. Dahlen, P. Johnson, T. Creamer, T. Peargin, P. Lundegard, B. Hartman, L. Abreau, and T. McAlary. 2006. “Spatial and Temporal Variability in Hydrocarbon and Oxygen Concentrations Beneath a Building Above a Shallow NAPL Source.” Presented at Remediation of Chlorinated and Recalcitrant Compounds, Monterey, Calif.

- 7.5 U.S. EPA Soil Screening Guidance: User's Guide, 2nd Edition (July 1996)
- 7.6 Vapor Intrusion Pathway: A Practical Guideline, January 2007, Interstate Technology and Regulatory Council.
- 7.8 Wilson, L. H., P. C. Johnson, and J.R. Rocco (2005). Collecting and Interpreting Soil Gas Samples from the Vadose Zone: A Practical Strategy for Assessing the Subsurface-Vapor-to-Indoor-Air Migration Pathway at Petroleum Hydrocarbon Sites. API Soil Gas Sampling May 2005 Pre-Publication Version.

8. [Attachment 1](#)

Arizona Department of Environmental Quality QA/QC checklist for Soil Vapor Sampling

Sampling Company

1 Date: _____ Start time: _____

2 Company Name: _____ Sampler's Name: _____

Consulting Firm:

3 Company Name: _____ Project Name: _____

4 Project Manager: _____ Project Number: _____

Well's Information

5 Location: _____ Client ID: _____ Permanent Temporary

6 Address: _____

7 ADEQ File Identification #(s) _____

8 Describe the probe location: _____

9 Probe Depth: _____ inch Probe ID: _____ inch **Probe volume: 0 inch³ (0) mls**

10 Probe type: Tygon Teflon Vinyl PVC Metal Other: _____

11 Is probe tested in the lab before installed? Y N NA Don't know

12 Comments: _____

Weather Conditions

13 Temperature: _____ C° F°

14 Has there been significant rain or snow recent to the sampling event? Y N

15 If Yes to Question 14 Date _____ Amount of Precipitate _____ inches

Soil Conditions Information

16 Was a soil sample collected and analyzed for volumetric moisture content? Y N attach results if yes

If yes, attach results

If no, is the apparent moisture content dry moist saturated

17 What is soil type encountered at sample location? _____

18 Was sample collected beneath a surface cover (e.g. parking lot, sidewalk, road, building, other)? Y N

19 Describe the surface cover, if any _____

20 Was the sample collected near a subsurface conduit? Y N

Describe subsurface conduit, if any _____

Sampling Train

21 Sample container: Canister : 1.0 L 6.0 L Silanized: Y N

Other: _____

Tedlar bag: Y N Gas tight syringe Y N

22 Flow restrictor: On: 1000 mL/min 500 mL/min 200 mL/min Other: _____

One min = Taking one minute to fill one liter canister.

23 Tubing type: Tygon Teflon Vinyl PVC Other: _____

24 Tubing used from probe top to canister: Length: _____ inch ID _____ inch

25 **Tubing volume: 0 inch³ (0) mls**

26 Are all parts of Sampling Train tested in the lab before sampling? Y N

Probe Purging Before Sampling

- 27 Total volume: probe(v) + tubing(v) = Probe volume 0 + Tubing volume 0 = 0 mls
- 28 Total volume to be purged (mls): 1x 0 1.5x 0 2x 0 3x 0
- 29 Purging pump #: _____ Purging flow rate: _____ ml/min Purging time: _____ mins _____ seconds
- 30 Gauge reading: < 5 inHg Other: _____ Comments: _____
- 31 Syringe Purging: NA Dedicated Syringe Re-used Suringe Volume _____
- 32 Is there condensation evident in the sampling train? Y N
- 33 Post sample collection - Is there condensation evident in the sampling container? Y N
- 34 **Leak Test** Y N If Yes, fill in the blanks blow: _____
- 35 Tracer compound: _____ Trade name: _____ Tested before use: Y N
- 36 Locations applied: Probe top Sampling train: Other: _____
- 37 **Field Duplicate** Y N If Yes, fill in the blanks blow: _____
- 38 Used the Duplicate Splitter? Y N If no, describe the procedure: _____

Other Information

- 39 Identify the equipment and method used to install probe and collect sample _____
- 40 What was the equilibration time between probe installation and withdrawal of any soil vapor? _____
- 41 Sample storage /shipping temperature _____
- 42 Sample storage /shipping container _____
- 43 Sample transportation mode(s) _____
- 44 Was an equipment blank taken? Y N Was Tank air or Nitrogen used? _____
Note: Ambient air should not be used
- 45 Was a field blank taken? Y N
- 46 Was a background (upwind ambient) sar Y N
- 47 Are there any potential VOC sources other than the identified release nearby?
 Groundwater/active fueling station/ dry cleaners/ dry wells/ other - please describe _____
- 48 **Well (Probe) Inspection Note:** _____