DEPARTMENT OF LABOR AND EMPLOYMENT
Division of Oil and Public Safety
Remediation Section
633 17th Street, Suite 500
Denver, Colorado 80202-3660
(303) 318-8500; Fax (303) 318-8546
Website: http://oil.cdle.state.co.us

Petroleum Hydrocarbon Vapor Intrusion Guidance Document

The Colorado Department of Labor and Employment
Division of Oil and Public Safety

December 11, 2007

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1.0 Introduction

Vapor intrusion has been defined by the U. S. Environmental Protection Agency (EPA) as the "migration of volatile chemicals from the subsurface into overlying buildings". Over the past several years, vapor intrusion has become an issue of concern at thousands of sites across the nation. Vapor intrusion can occur when a substance containing volatile organic compounds (VOCs), many of which are known carcinogens, is released into the subsurface impacting soil and possibly groundwater. Following such a release, a portion of these VOCs go into the vapor phase, whether emitted from the released material itself or from contaminated groundwater containing dissolved VOCs. These vapors can then migrate from contaminated media through subsurface soils and into overlying buildings, creating a potentially unsafe environment for building occupants.

The contaminants associated with vapor intrusion usually enter the environment as a direct result of a release to soil and groundwater from properties such as gas stations, dry cleaners and industrial facilities. As indicated by the title of this guidance document and in accordance with the general mission of the Remediation Section of the Division of Oil & Public Safety (OPS), this document only addresses the vapor intrusion problem as it relates to the release of petroleum products into the environment. This document is not intended to provide an exhaustive discussion of all aspects of the vapor intrusion problem, even as it relates to petroleum releases. Beyond providing an overview of the problem, the primary focus and intent of this document is provide guidance to the regulated community regarding the best ways to assess the vapor intrusion pathway. To that end, information is provided on the conditions which would trigger the need for a vapor intrusion assessment, the proper methods of construction and sampling soil vapor wells and sub-slab installations, the issues and challenges of indoor air evaluation and sampling, the analysis of collected vapor samples, and the evaluation of laboratory data. The subject of vapor intrusion mitigation is beyond the intended scope of this document. However, useful references are provided that address this subject in detail. This document should not be viewed as a "stand alone" text but should be referred to and used in conjunction with the Petroleum Storage Tank Owner/Operator Guidance Document.

Biodegradation of petroleum constituents and the evaluation of attenuation factors that might allow for expedited assessments of the vapor intrusion pathway have both been the subjects of recent research. However, at this time, there is no general consensus on the rates of contaminant biodegradation or the degree of contaminant attenuation one can expect in a given subsurface environment. Given the available data, OPS is not prepared to assign or accept attenuation factors. Therefore, this issue is not addressed in this document.

This document is a practical tool to assist the regulated community and their environmental consultants in the assessment of potential vapor intrusion issues at their sites of interest. A flow chart (Figure 1) is included to aid in decision-making during the characterization of the vapor intrusion pathway. Also, the Appendices include a Checklist designed to assure that the vapor intrusion pathway is properly and completely evaluated and a Building Survey form that must be used when conducting an initial screening prior to performing an indoor air sampling event.

OPS would like to thank the many environmental professionals that have given their advice and assistance in preparing this document. Special thanks to Dr. Blayne Hartman of H&P Mobile Geochemistry and David Folkes and Dr. Jeff Kurtz of EnviroGroup Limited for providing thorough and thoughtful reviews of a preliminary draft of this document.

2.0 Vapor Intrusion Program Overview

OPS requires evaluation of the soil vapor to indoor air inhalation pathway when a structure is present within the influence of hydrocarbon impacted soils or groundwater, and regular operations at that structure do not involve the dispensing of petroleum products. A structure is considered within the influence of a contaminant plume if the structure lies directly over or adjacent to the plume, i.e., where contaminant concentrations in groundwater exceed the groundwater to indoor air Risk Based Screening Levels (RBSLs). If there are potential preferential pathways (e.g. utility corridors) connected to a structure that pass through or over a contaminant plume, that structure is also considered within the influence of the plume. The steps involved in the OPS soil vapor and indoor air assessment process are illustrated in Figure 1 and are described below.

2.1 Site Characterization – Step 1

A site characterization is completed to assess potential exposure pathways. The site characterization includes gathering information and data that fully defines the type and magnitude of the contamination source and the horizontal and vertical extent of contamination in soil, groundwater, and soil vapor. All potential points of exposure (POE) are also identified, which include structures of concern and potential preferential pathways for vapor migration, as described above. **In emergency situations where impact to indoor air has been identified (i.e. petroleum odors), indoor air mitigation activities (Step 9) should be conducted immediately.**

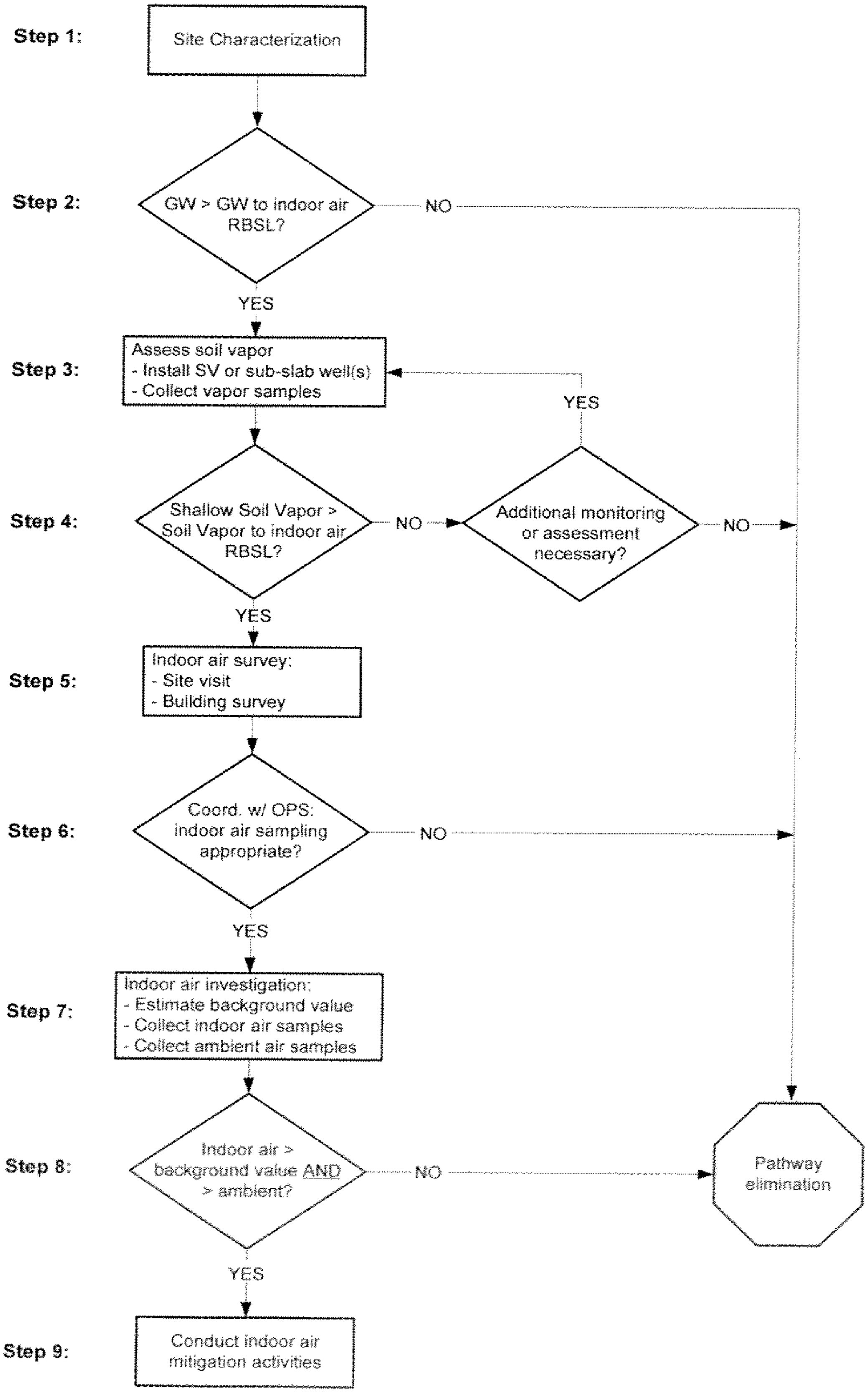
Table 1 lists the OPS RBSLs for concentrations in groundwater that would prompt an evaluation of the potential for soil vapor to impact structures within the influence of the contamination. Also in Table 1 are the RBSLs for the soil vapor to indoor air inhalation pathway. The RBSLs may be modified in the future as more empirical data is obtained. Refer to Appendix C of the OPS Petroleum Storage Tank Owner/Operator's Guidance Document for more information regarding the determination and calculation of the RBSLs.

Table 1. RBSLs for Evaluation of the Indoor Air Exposure Pathway

Media	Units	Land Use	Benzene	Toluene	Ethyl-benzene	Xylenes
Groundwater	mg/L	Residential	0.016	10	26	2.9
		Industrial	0.41	490	>Sol	140
Soil Vapor	$\mu g/m^3$	Residential	2,900	>VP	>VP	>VP
		Industrial	37,000	>VP	>VP	>VP

>VP denotes that even at a concentration equal to the vapor pressure of the chemical, a hazard quotient of 1 is not exceeded.
>Sol denotes that even at a concentration equal to the solubility of the chemical, a hazard quotient of 1 is not exceeded.

Figure 1. OPS Soil Vapor and Indoor Air Evaluation Process



2.2 Groundwater to Indoor Air RBSL – Step 2

Based on site characterization information and data, determine whether benzene concentrations in groundwater exceed the RBSL for groundwater to indoor air (0.016 mg/L) listed in Table 1. If this RBSL is exceeded or if preferential pathways exists that could cause impact to indoor air of a structure, the soil vapor to indoor air pathway must be assessed. If the RBSL is not exceeded and OPS has not requested additional soil vapor investigation, the groundwater to indoor air pathway is eliminated.

2.3 Soil Vapor Assessment – Step 3

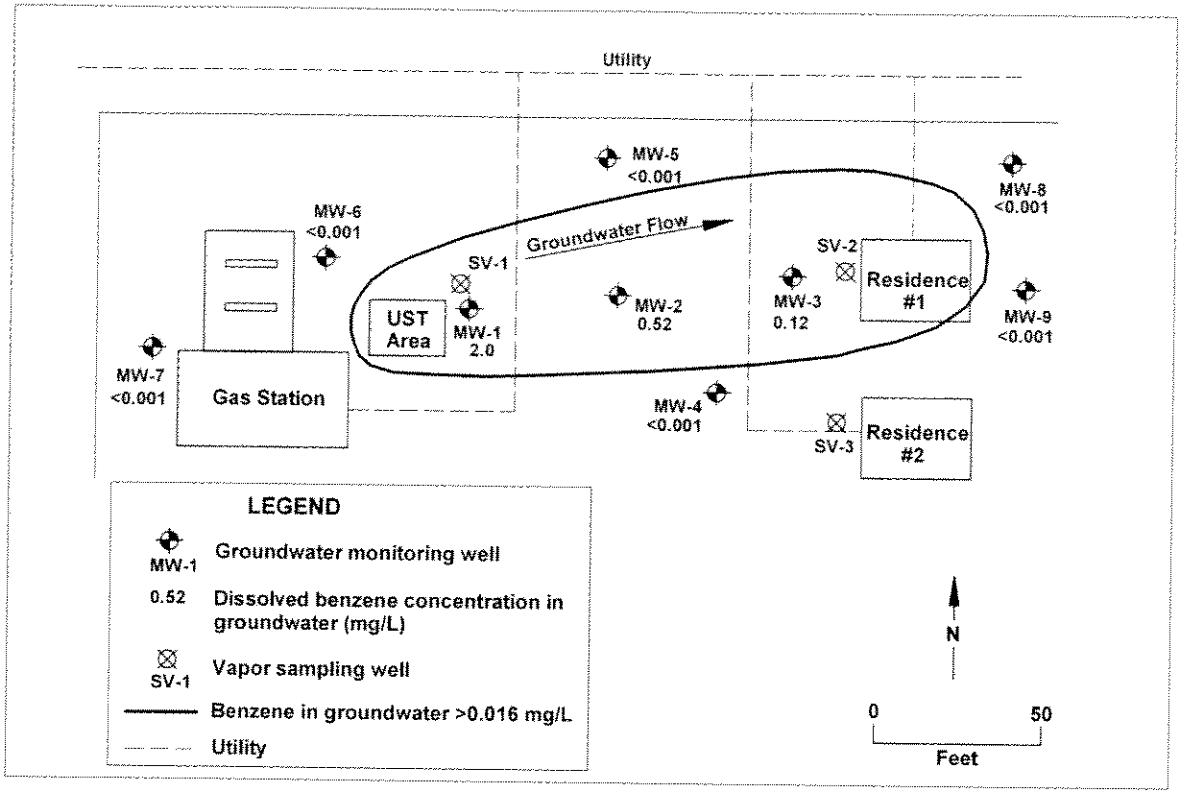
The soil vapor to indoor air pathway is assessed by installing soil vapor and/or sub-slab sampling wells. Construction of these wells is described in Section 3.0 (soil vapor wells) and Section 5.0 (sub-slab wells) of this document. A checklist that presents all components of soil vapor assessment is provided in Appendix A.

If the contamination source is not directly below a structure of concern, soil vapor monitoring wells should be installed in the source area and adjacent to the side of the structure that is closest to the source area. If the contamination source is located directly below a structure, vapor samples should be collected immediately below the structure's foundation if possible (i.e., sub-slab samples). Sufficient samples should be collected to get a representative value under the footprint of the structure, with locations selected to provide an indication of the spatial distribution of the contamination. If sub-slab samples are not possible, samples should be collected adjacent to the structure at strategic locations to determine the distribution of contaminants and thereby get an idea of possible contamination levels under the structure.

A typical scenario where a soil vapor assessment would be necessary is illustrated in Figure 2. The source area in this example is the UST area. Therefore, a soil vapor well (SV-1) is installed as close to the source area as possible. Notice that monitoring well MW-3 is located near Residence #1 and that MW-3 has a benzene concentration that exceeds the benzene groundwater to indoor air RBSL. Under this scenario, a soil vapor well or a nested set of soil vapor wells (SV-2) should be installed adjacent to the upgradient side of this structure. Also shown in Figure 2 is a utility corridor which passes through the plume and could therefore serve as a preferential pathway that allows contaminant vapors to migrate to Residence #2. To evaluate this potential impact, a soil vapor well or a nested set of soil vapor wells (SV-3) should be installed adjacent to the utility corridor near the point where the utility enters Residence #2.

Biodegradation of petroleum hydrocarbon vapor occurs at variable rates throughout migration from the source (groundwater or soil) upwards through soil, into sub-slab vapor, across the structure foundation slab and then into the structure. This biodegradation or attenuation usually occurs at a greater rate throughout the soil column than across the structure slab. Therefore, concentrations less than the soil vapor to indoor air RBSL could potentially impact indoor air.

Figure 2. Example Groundwater Contamination Plume Requiring Soil Vapor Assessment



2.4 Soil Vapor to Indoor Air RBSL – Step 4

Based on the evaluation of soil vapor sample results, determine if benzene concentrations in the shallow soil vapor interval exceed the soil vapor to indoor air RBSL of 2,900 μg/m^3 (see Table 1) in a vapor monitoring well located adjacent to a structure, or if soil vapor concentrations are present in sub-slab samples that indicate potential vapor intrusion from the contaminant plume. If one or both of these conditions exist, an indoor air evaluation (possibly including indoor air sampling) must be performed. If the soil vapor to indoor air RBSL is not exceeded in the shallow sampling interval of the vapor well (or in sub-slab samples) throughout four consecutive quarters of monitoring and preferential pathways for vapor migration still do not exist, the soil vapor to indoor air pathway can be eliminated with OPS's concurrence.

In the event that soil vapor concentrations exceed the soil vapor to indoor air RBSL in the deep and/or intermediate sampling intervals but not in the shallow sampling interval, additional monitoring may be required to ensure that the RBSL is not exceeded throughout seasonal changes in the subsurface. Conditions may exist where benzene concentrations in the shallow sampling interval exceed the soil vapor to indoor air RBSL and are significantly greater than those concentrations in the deep or intermediate sampling intervals. This situation will require additional investigation to determine the source of the shallow contamination (i.e. shallow soil source, leak in the deeper sampling point, etc.)

2.5 Indoor Air Survey – Step 5

The indoor air survey includes a site visit to interview the occupants of the structure and conduct a building survey (see Section 6.0 and Appendix B).

2.6 Is Indoor Air Sampling Appropriate? – Step 6

Information obtained from the site visit is then evaluated and, in coordination with OPS, the determination is made as to whether results of indoor air sampling will identify vapor intrusion from the subsurface contaminant source, considering any additional sources of benzene identified in the structure.

2.7 Indoor Air Investigation – Step 7

If it is determined that indoor air sampling may provide an accurate assessment of vapor intrusion (i.e., the building survey did not identify complications from other possible sources within the structure), indoor air sampling should proceed (see Section 6.3). An outdoor ambient air sample must also be collected during the indoor air sampling event. Background indoor air concentrations are site specific. Therefore, in some cases, it may be necessary to sample background indoor air in nearby structures of similar construction to the one where indoor air is being evaluated.

2.8 Indoor Air Quality Evaluation – Step 8

Based on the evaluation of indoor air and ambient outdoor air sample results, determine if benzene concentrations in indoor air exceed the estimated background value and are greater than the ambient outdoor value. If the benzene concentrations in indoor air do not exceed the background value throughout four consecutive quarters, the indoor air exposure pathway is eliminated.

2.9 Indoor Air Mitigation – Step 9

If benzene concentrations in indoor air exceed the ambient and estimated background values, contamination has been identified in indoor air and must be mitigated. Mitigation of indoor air contamination is addressed in Section 9.0.

OPS should be contacted at any time during the investigation if the next appropriate step is unclear.

3.0 Soil Vapor Well Construction

3.1 Permanent Soil Vapor Well Construction

Depending upon the depth to groundwater, from one to three soil vapor wells with discrete sampling intervals will be required. These wells may be nested within the same borehole or installed in separate borings located adjacent to one another (see Figure 3).

3.1.1 Depth to groundwater < 10 feet

If depth to groundwater (or to the contamination if in the vadose zone) is less than ten feet below ground surface (bgs), only one sampling interval located a minimum of three feet below the base of the at-grade or below-grade slab or foundation of the potentially impacted structure (and preferably at least five feet bgs) is required. This depth restriction is necessary to minimize the effects of changes in barometric pressure and surface temperatures, as well as limiting the breakthrough of ambient air from the surface.

3.1.2 Depth to groundwater between 10 and 20 feet

If depth to groundwater (or a vadose contaminated zone) is between ten and twenty feet bgs, two discrete sampling intervals are required: one located as described above and a second located above the seasonal high water table (or the vadose zone contamination). The groundwater seasonal high can be determined by review of existing historical data or estimated by utilizing the typical capillary rise based on soil type.

If contaminated groundwater is the vapor source, a third well may be installed and screened across the groundwater surface to facilitate groundwater sample collection. Soil vapor may also be sampled from this well to get an indication of vapor concentrations partitioning from the groundwater, but the collected sample probably will not accurately reflect soil gas concentrations. A groundwater monitoring well, as described above, must be installed in a separate borehole than the soil vapor wells to avoid interfering with the deep soil vapor sampling interval.

3.1.3 Depth to groundwater > 20 feet

If depth to groundwater (or a vadose contaminated zone) is greater than twenty feet bgs, a third well should be installed to enable sampling at an intermediate depth.

3.2 Installation of Soil Vapor Wells

Soil vapor wells should be constructed in the same manner at all sampling locations to minimize data variations. The following procedures should be followed when constructing a permanent soil vapor well, unless otherwise instructed or approved by OPS.

3.2.1 Drilling method

Vapor wells can be installed using an auger drill rig, direct-push rig, or hand auger. Please note that depending on the drilling method used, sample collection may need to be delayed to allow subsurface conditions to equilibrate (see Section 4.0). Schematic drawings of auger and direct-push well constructions are shown in Figure 3. The presence of cobbles or highly compacted, fine-grained soils may preclude the use of direct-push technologies. In addition, direct-push samplers sometimes have difficulty collecting soil gas samples in finer-grained units (relative to augured installations with a more significant volume of permeable backfill). Detailed lithologic logs and construction diagrams should be prepared for all well installations.

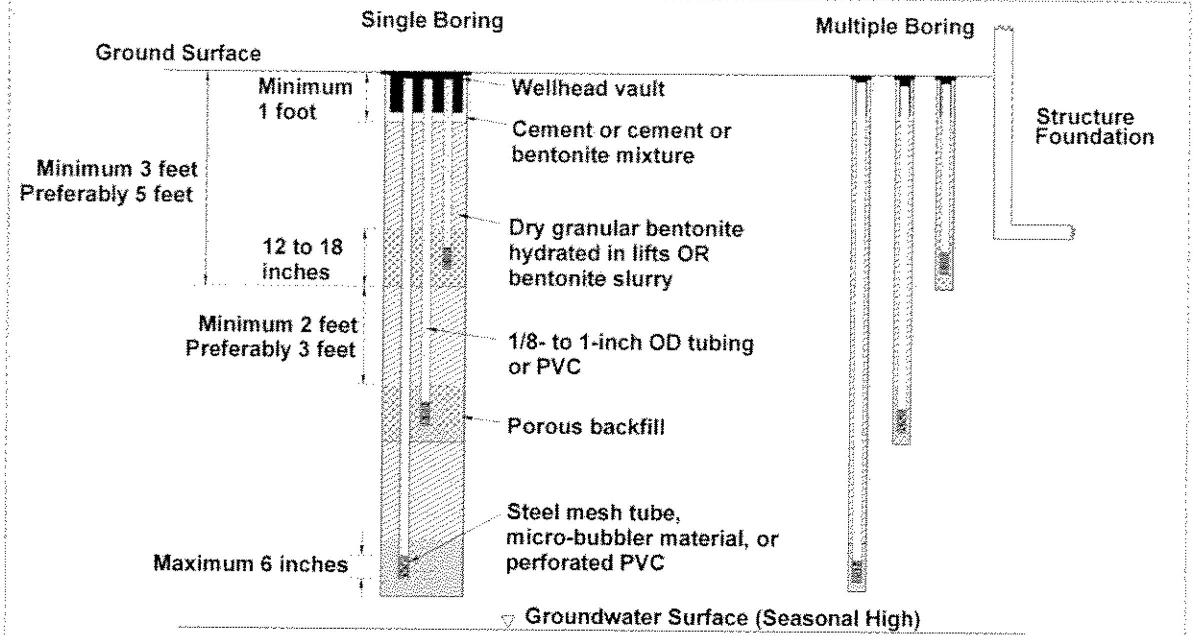
3.2.2 Soil samples

Soil samples should be collected and submitted for laboratory analysis for contaminants of concern (COC) from depths showing elevated field instrument readings or from just above the water table if no elevated readings are noted.

3.2.3 Sampling interval (screen length)

Unless installing a well designed to intersect the water table for groundwater sampling purposes, screen intervals of six inches or less should be used.

Figure 3. Soil Vapor Sampling Wells



Notes: 1. If bentonite slurry is used, at least one foot of unhydrated granular bentonite must be placed between the porous backfill and the slurry seal.
2. Another interval screened across the water table is optional.

3.2.4 Soil vapor well casing and sampling point materials

A vapor sampling well is generally comprised of a solid section of small diameter (1/8- to 1/2-inch) rigid, inert tubing (e.g., high-density polyethylene, nylon, stainless steel or Teflon®) that is connected to a sampling point through which the sampled vapor is drawn from the subsurface. Alternatively, PVC pipe up to one inch in diameter can be used for the soil vapor well casing, with a six-inch section of slotted screen at the target sampling depth. Soil vapor well casing diameters of less than one inch are advised to minimize the dead volume that must be purged prior to sampling. Sample tubing should be color coded, labeled, or cut to various lengths at the surface to clearly differentiate sample intervals.

When using rigid tubing, a variety of sampling points or tips can be used. These points can include 6-inch lengths of 1/8- to 1/2-inch diameter stainless steel mesh tubing, 1/4-inch diameter micro-bubbler material commonly used in fish tanks, or perforated, stainless-steel anchors placed by direct-push rods.

3.2.5 Sand or filter pack

A layer of the porous backfill (e.g., sand that is coarser grained that the native formation materials) should be added to the bottom of the borehole below the sampling screen and placed around the screen to create a sampling zone of 12- to 18-inches in length. The screen should be located in the middle of the interval of porous backfill.

3.2.6 Sampling interval seal

The borehole seal above the sand pack consists of granular bentonite installed by one of the following methods:

- At least one foot of dry granular bentonite should be placed on top of the sand pack to prevent bentonite slurry, which is placed on top of the dry granular bentonite, from infiltrating into the sand pack, or
- Dry granular bentonite can be placed in 6-inch lifts (layers) and hydrated following each lift. The initial lift above the sand pack must be at least 6 inches (preferably one foot) thick, with minimal water used for hydration so that hydration water does not infiltrate into the sand pack.

The bentonite seal should be a minimum of three feet (preferably five feet) thick to prevent ambient air infiltration to the sampling point. The boring can be filled with a clean backfill material (or bentonite) to approximately (but no less than) one foot from the ground surface.

3.2.7 Protective surface seal

A protective surface seal (cement or a cement/bentonite mixture) should be set around the top of the well tubing to prevent infiltration of water and ambient air into the completed borehole. It is recommended that the surface seal is at least one foot thick and extends horizontally from the vapor well for a distance of at least six inches in all directions.

3.2.8 Vapor-tight connections in the sampling apparatus

When using the preferred rigid nylon tubing, leakage is less likely if self-sealing, quick-connect, brass or stainless steel, threaded or compression fittings are used as opposed to barbed fittings. If barbed fittings are used, some other means of ensuring a leak-proof cap to the tubing is required.

3.2.9 Locking vault

Install a locking utility vault or meter box with ventilation holes to prevent accidental damage or vandalism. If the completion is not flush with the ground surface, consider installing guard posts or bollards to protect the well.

3.3 Single Event Sampling

Temporary wells may be acceptable with prior approval from OPS. In general, a temporary soil vapor well is installed by driving the direct-push rod to a predetermined depth and then pulling it back to expose the inlets of the perforated tip of the vapor well, usually made of stainless steel. After sample collection, both the drive rod and tubing are removed and the hole is properly abandoned. For shallow depths (3-5 feet) and finer grained soils which do not readily collapse around the driving rod, the wells should be carefully installed with minimal lateral movement to prevent leakage of ambient air down along the outside of the well. In addition, hydrated granular bentonite or bentonite slurry should be used to seal around the drive rod at the ground surface, and a rubber seal should be placed between the sample tubing and the inside wall of the rod to further prevent ambient air intrusion from occurring.

4.0 Soil Vapor Sampling Methodology

Refer to the Checklist included in Appendix A to assure that the vapor intrusion pathway is adequately evaluated and that proper sampling procedures are followed. OPS requires that the following practices be followed in association with soil vapor sampling.

4.1 Subsurface Equilibration

During well installation, subsurface conditions are disturbed to varying degrees depending upon the installation method. Therefore, prior to sampling, allow subsurface conditions to equilibrate. Otherwise, the soil gas samples may not be representative of subsurface conditions. For wells installed by direct-push methods, sampling should not occur for at least 20-30 minutes after well installation. If utilities are nearby and it is necessary to clear a borehole by a method that disturbs the soil gas, such as with an air knife or hydro-knife, or if wells are installed using hollow-stem drilling methods, sampling should not be performed on the same day as well installation.

4.2 Feasibility Testing

After the vapor well has been installed, testing should be performed to determine if a representative soil vapor sample can be collected. Excessive vacuum may cause the transfer of sorbed contaminants into the vapor phase or a breach in the bentonite seal which would allow ambient air to infiltrate into the sample. Feasibility testing can be accomplished by applying a vacuum to the vapor well using a 20-100 cubic centimeter (cc) syringe connected to the end of the sampling tubing and pulling the syringe's plunger. If the plunger does not hold its position, collection of a soil vapor sample at that location is not feasible. In this case, a new well may need to be installed at a different depth or location.

4.3 Leak Testing

Leakage during soil vapor sampling may dilute samples with ambient air and produce results that underestimate actual site concentrations. Therefore, leak testing must be performed to determine whether leakage is occurring. Leak testing is crucial for identifying leaks from the surface to the shallow soil vapor sample interval or around the sample train (fittings, etc.). With deeper sampling intervals, it is unlikely that surface air will be drawn down the full depth of the well to the sampling interval.

During the initial stages of a soil vapor sampling program, leak testing should be conducted at each of the sampling wells. When using permanent soil vapor wells as part of a long-term monitoring program, annual testing of well integrity is recommended. If leakage is confirmed and the problem cannot be corrected by enhancing the annular seal, the soil vapor well should be properly abandoned, and a replacement well should be installed at least five feet from the decommissioned well. Discussion regarding liquid and gas tracers is included in the following sub-sections.

4.3.1 Gas Tracers

Gas tracers can be used for leak testing by enriching the atmosphere in the area where the well intersects the ground surface with helium, difluoroethane, or sulfur hexafluoride. Difluoroethane (a component of air dusters) is widely used as a leak detection chemical and is much less expensive than sulfur hexafluoride. Place a shroud (e.g., plastic pail, cardboard box, or a garbage bag) over the area to keep the tracer in contact with the well. Purge the sample point using a sampling pump or a syringe.

Helium or sulfur hexafluoride is preferred by many professionals as a tracer gas because you can utilize a portable monitoring device to measure their concentrations. However, because of the small molecular size of helium, it may permeate sampling materials and be detected in the sample at low concentrations. One disadvantage of using difluoroethane is that it must be analyzed by a laboratory.

One should measure a vapor sample from the well for the presence of the tracer gas before and after sampling for the chemicals of concern. If measured concentrations in the sample exceed 10% of the concentration under the shroud, the well seal should be enhanced to reduce infiltration of ambient air prior to collecting analytical sample.

4.3.2 Liquid Tracers

An alternative method of leak testing is to use a liquid tracer by applying the liquid to a clean towel wrapped around the sample tubing and fittings at the surface of a well. This method is particularly well suited for sampling temporary soil vapor points (sampling through probe rod) since it can be applied where the rod meets the ground surface and at the top of the rod. Common liquid tracers include isopropyl alcohol and butane (found in shaving cream). If the tracer is detected at a high concentrations (i.e., >100 µg/L) in the soil vapor sample, it is likely that there is a leak.

Liquid tracers, while easier to use than gas tracers, may leave residue on the sampling apparatus and must be analyzed in the laboratory. If the tracer will be analyzed in the laboratory (i.e. difluorethane, isopropanol, and butane), these compounds must be included in the list of analytes reported by the laboratory.

4.4 Purging

To ensure that ambient or stagnant air is removed from the sampling system and samples collected are representative of subsurface conditions, purging must be performed.

4.4.1 Purging equipment

Purging equipment may consist of an electric- or hand-powered vacuum pump, syringe, or a peristaltic pump. All equipment, including associated valves and fittings, should be checked for leaks before purging the sampling system.

4.4.2 Purge volume

Purging requires the removal of at least three sample tubing volumes. Before purging, calculate the purge volume (or "dead space volume") based on the length and diameter of the sampling tubing and the connected sampling tubing and equipment. Do not include the volumes of the syringe and sample container (e.g., Tedlar® bags, summa canisters) when calculating purge volume. You can assume the following approximate quantities to calculate three purge volumes:

- 5 cc per linear foot of 1/8-inch diameter tubing
- 20 cc per linear foot of 1/4-inch diameter tubing
- 40 cc per linear foot for 1/2-inch diameter tubing (sch 40 PVC)
- 85 cc per linear foot for 3/4-inch diameter tubing (sch 40 PVC)
- 310 cc per linear foot for 1-inch diameter tubing (sch 40 PVC)

If sampling must be performed within 48 hours of well installation using a hollow-stem auger, approximately two to three dead volumes of the sand pack should also be purged prior to collecting a sample. In order to minimize surface leakage, excessive purging should be avoided for collection of near surface samples (e.g., less than 5 feet).

4.4.3 Flow rates

Flow rates for purging (as well as sampling) should generally not exceed 0.2 liters per minute (L/min) to minimize air infiltration (short-circuiting) and to limit stripping or partitioning of chemicals of concern from soil. However, a recent study has indicated that no significant difference was detected in soil vapor concentrations for flow rates ranging from 0.1 L/min to 100 L/min in relatively coarse-grained soils.

4.5 Additional Required Measurements

OPS requires the field measurement or laboratory analysis of oxygen and carbon dioxide during the sampling procedure. This data can assist in determining the soil vapor profile at the site and in assessing data quality of the samples (consistency across purge volumes). In general, carbon dioxide concentrations increase with depth while oxygen concentrations decrease with depth and approach zero directly above the soil or groundwater source. Analysis for methane is required in situations where light non-aqueous phase liquid (LNAPL) is present or oxygen content is less than 10%; otherwise, it is optional. High concentrations of total petroleum hydrocarbons in vapor may require the use of a filter on the analyzer sampling probe to allow for accurate measurement of methane concentrations. These additional required measurements are summarized in Table 2.

Oxygen, carbon dioxide, and methane data can also indicate that biodegradation is occurring and, if so, what type of biodegradation (aerobic or anaerobic). Besides indicating biodegradation, a decrease in oxygen concentration may also be partially due to background oxygen demand (e.g. in soils with high natural organic matter). Background oxygen demand can be assessed in areas with no contamination.

When aerobic biodegradation results in the depletion of oxygen from soil gas, an equivalent amount of carbon dioxide should be generated, resulting in the sum of oxygen and carbon dioxide concentrations being approximately 21% (i.e., atmospheric oxygen concentration). Soil gas analytical results where the sum of oxygen and carbon dioxide is less than 18% may suggest sample collection or analysis problems. However, under anaerobic conditions, high levels of methane may be generated, potentially displacing other gasses. High concentrations of carbon dioxide are also typically present under anaerobic conditions.

Table 2. Additional Required Measurements

Compound	Required by OPS?	Field Instrument	Laboratory Analytical Method	General Trend
Oxygen	Yes	Field meter w/ electrochemical cell	3810M/D1946	Usual decrease closer to source
Carbon Dioxide	Yes	Field meter w/ infrared analyzer	3810M/D1946	Usual increase closer to source
Methane	Yes*	Field meter	3810M/D1946	Possible increase closer to source

*Only required if LNAPL is present or O_2 is <10%

4.6 Other Measurements

Radon gas is present in all soils. Therefore, radon data can be useful in assessing the potential for vapor intrusion in a given structure. However, OPS does not require the analysis of indoor air samples for radon as part of a hydrocarbon vapor intrusion investigation.

OPS does not require measurement of the air pressure differential between the interior of a structure and beneath the foundation slab. However, doing so may help determine whether or not "barometric pumping" is occurring. This measurement can be performed by utilizing pressure transducers. If a significantly higher pressure exists in the sub-slab compared to the interior of the building, the potential exists for vapors to be drawn into the structure by advection due to the lower air pressure inside compared to outside the structure.

4.7 Sample collection and sample containers

Use fresh tubing between the soil vapor sampling tubing and the sample container at each sampling location. Sample containers chosen for a specific site will depend on site conditions, sample depth, and analytical requirements (see Section 7.0). OPS recommends that soil vapor samples be collected in a 1-liter summa canister, 400cc mini-can, or glass bulb if the sample will be shipped. If the samples will be analyzed at a local laboratory, samples may be collected in a Tedlar® bag or canister. Tedlar® bag samples are generally not considered reliable if more than 48 hours have passed since sample collection. If analyses will be performed onsite, collection into a syringe or Tedlar® bag is acceptable. Sample containers with volumes greater than 1-liter should be avoided for collection of near surface samples (e.g., less than 5 feet bgs). Section 7.0 includes information on sample containers and associated holding times.

Regardless of which sample collection device is used, the soil vapor well must be appropriately purged before collecting a vapor sample (see Section 4.4 above). When using 1-liter summa canisters, 400 cc mini-cans, or any container under vacuum, the container is connected to the tubing from the soil vapor well and then the container is opened. A syringe, a vacuum box with Tedlar® bags, or a peristaltic pump may also be used to obtain vapor samples. The use of other types of pumps that do not have dedicated tubing is discouraged, due to probable cross-contamination of the collected sample. A glass bulb with a pit-cock on both ends to seal the bulb after sample collection can also be utilized for vapor sample collection. The tubing from the soil vapor well is connected to one end of the bulb, and the other end of the bulb is connected to tubing from a vacuum pump which draws the sample into the glass bulb. When using the sample containers discussed above, always follow the instructions provided by the manufacturer.

4.8 Sample shipment

Soil vapor samples should not be chilled during sample shipping to a laboratory because the volatiles may condense out of the vapor phase at the lower temperature. Tedlar® bags should not be shipped due to pressure differentials (causing the bag to explode or deflate) and the potential for diffusion through the bag wall, puncturing of the bag, or valve leakage. Exposure of the Tedlar® bag sample to direct sunlight or excessive heat should be minimized.

5.0 Sub-Slab Soil Vapor Well Construction and Sampling

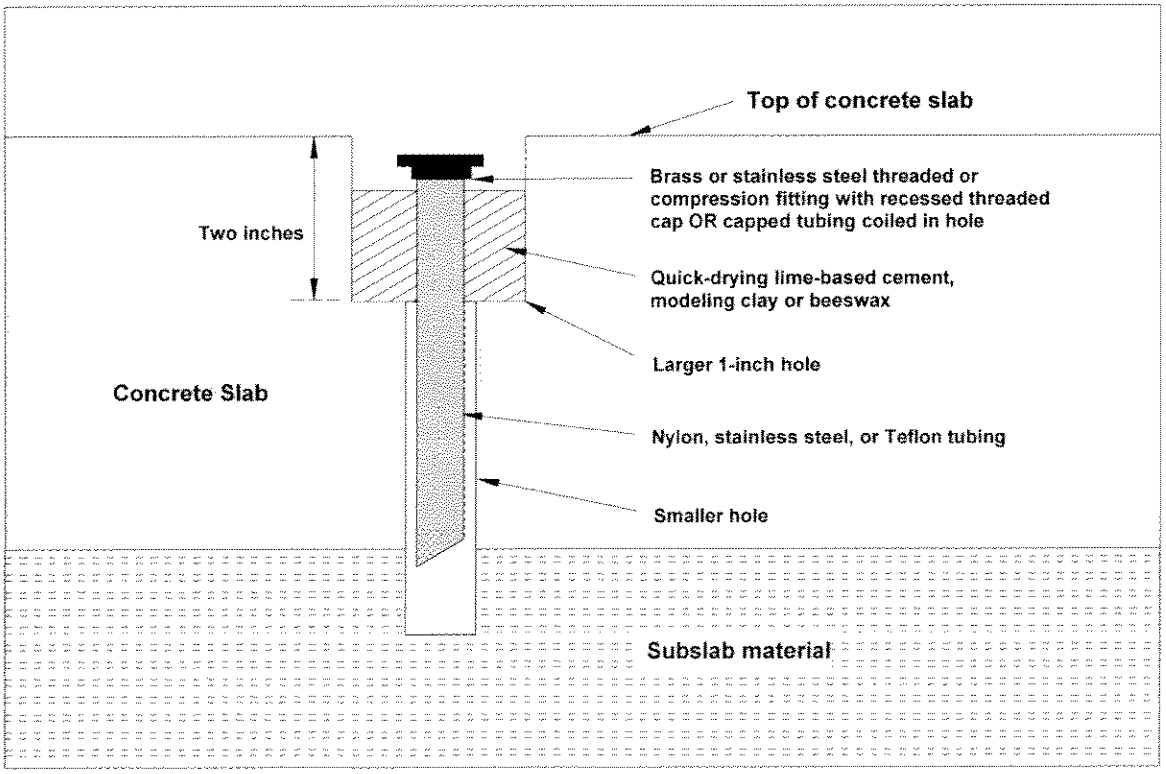
If a structure is located directly over a source of contamination, vapor samples should be collected immediately below the structure's foundation slab. The installation and sampling of a sub-slab soil vapor sampling point can determine whether vapors are present beneath the structure slab that could be drawn into the indoor air by advection. However, sub-slab vapor sampling may not be possible because of its intrusive nature and related access issues.

Methods of construction of a sub-slab sampling point are similar to those described for vapor wells in Section 3.0 of this document (Soil Vapor Well Construction), although the sampling point is installed through the structure's slab and extends only into the engineered fill directly beneath the foundation. A schematic of a sub-slab sample point is shown in Figure 4. Key components in sub-slab sample point installation and special considerations for sub-slab sampling are listed below.

5.1 Sub-slab well location

Sample points should be installed in central locations away from foundation footings and utilities. For a typical single-family residence, the installation and sampling of one sub-slab vapor point should be adequate to evaluate sub-slab conditions.

Figure 4. Sub-slab Soil Vapor Sampling Well



5.2 Sample point construction

Water should not be used when drilling through the concrete slab. If dust prevention is necessary when drilling through the slab, cover the location with a towel and drill through a pre-cut hole in the cloth. If a flush or recessed surface termination with a permanent point is required, a 1-inch diameter hole in the upper two inches of the slab will leave space for installation of a brass or stainless steel threaded or compression fitting. A hole slightly larger than the sample tubing is then drilled in the center of the 1-inch hole. Cut tubing (nylon, stainless steel, or Teflon®) to an appropriate length to reach the base of the slab. Sand can be added to fill the void in the sub-slab material to the base of the sample tubing and, if necessary, in the void between the sample tubing and small hole. A quick-drying, lime-based cement may be placed within the 1-inch hole (and on top of the sand, if present) to seal the well. As an alternative, modeling clay or beeswax may be placed above the sandpack to form an air-tight seal.

5.3 Leak testing

Leak testing should be conducted during purging as described in Section 4.3 of this document. If cement is used to seal the well, be sure that the cement is allowed to dry and set up before testing the wellhead for leaks.

5.4 Purging

If cement was used to seal the sub-slab installation, wait an adequate amount of time for the seal to set up before purging the sample point. If clay or beeswax is used to seal the installation, the sample point can be purged and sampled immediately after construction. The purge volume should include the total internal volume of all sampling tubing and fittings, the open hole in the slab below the tubing, and the cavity created in the sub-slab material during drilling. Refer to Section 4.4 for information on purging equipment, purge volumes, and vacuum and flow rates.

5.5 Sample collection

If the sample will be submitted for laboratory analysis, it should be collected using a 1-liter summa canister, 400cc mini-can, glass vial, Tedlar® bag, or an equivalent collection vessel. For onsite analysis, a syringe may be used for sample collection. Refer to Section 4.7 of this document for sampling procedures.

5.6 Sample shipment

Refer to Section 4.8 for information on shipping samples. Always follow laboratory instructions for sample shipping of canisters or other collection vessels.

5.7 Additional considerations

Sub-slab samples should be avoided in areas where groundwater might intersect the slab. Also, if a vapor barrier exists under the slab, a sub-slab sample point should not be installed, since doing so might result in damage to the barrier.

6.0 Indoor Air Evaluation and Sampling

In the event that the soil vapor and/or groundwater concentrations are greater than the appropriate RBSLs, or if other conditions (such as the presence of hydrocarbon odors) suggest that vapor intrusion is occurring, OPS will require a site-specific indoor air evaluation. This evaluation will include the following components.

6.1 Site visit

A site visit should be conducted to confirm the location, use, and occupancy of all potentially impacted structures.

6.2 Building Survey

Before performing an indoor air sampling event, a survey of all potentially impacted structures, including interviews with the occupants, owners, and landlords (if applicable) must be conducted and must include gathering information on the following topics:

- Type of building construction
- Foundation characteristics
- HVAC system layout
- Potential indoor sources of contaminant vapor
- Inventory of household chemical products
- Water and sewage systems; utility corridors leading to the structure; types of drains, etc.
- Locations of sub-slab utilities in the event that sub-slab sampling is necessary

An example of a building survey form which covers the above topics is included in Appendix B.

In addition, a walkthrough of all potentially impacted structures should be conducted to identify potential "background" sources, eliminate them, and educate the occupants on those activities that should be avoided immediately before and during the sample collection. It is extremely important to identify all consumer products, household cleaners, supplies used for personal hobbies, or building supplies that may be used in the structures, many of which contain volatile chemicals. If practical, all background sources (or at least gas tanks, lawn mowers and vehicles) should be removed from the structures and attached garages prior to indoor air sampling. If applicable, these products should not be used inside the buildings within 24 hours of the sampling event or, depending on the impacts to carpeting, drapes, etc., within two weeks of the sampling event. The occurrence of smoking (a source of benzene) in the building should clearly be noted during the interview. Although not comprehensive, the National Institutes of Health Household Products Database (http://householdproducts.nlm.nih.gov/) contains information on common household products that cause measurable levels of volatile chemicals in indoor air.

6.3 Indoor air sampling

If information from the building survey indicates that indoor air sampling will provide an accurate assessment of vapor intrusion, indoor air sampling must be conducted. The sampling protocol is described below.

6.3.1 Access agreement

Because of the intrusive nature of indoor air sampling, it is always necessary to execute an access agreement for each structure before proceeding with the sampling.

6.3.2 Sample container

Because of the low detection limits required for indoor air samples, a summa canister is the preferred sample container for laboratory analysis. If real-time onsite analyses will be conducted, other sample containers could include gas-tight glass or stainless steel vials, syringes, or glass-lined canisters (other than summa canister).

6.3.3 Sample locations

The sample canisters should be placed in the occupied living areas and the basement. Canisters should be placed in the breathing zone, usually 3-5 feet off the floor, and in high use areas. If small children occupy a particular area or room within the structure, a sample canister should be placed on the floor. If there is concern for damage or disturbance of the canister in high use areas, the canister may be moved from these areas but away from doors, windows, and vents. For multi-storied residential buildings, one sample should be collected in the basement level or first floor (if slab-on-grade construction). Crawl spaces that are not ventilated can be sampled to determine if contaminant vapors are present that could potentially impact indoor air.

6.3.4 Sample collection period

Residential indoor air samples are typically collected over a 24-hour period. However, in certain situations (e.g., commercial or industrial settings), it may be more appropriate to sample over an 8-hour period. During the sampling period, exterior doors and windows should generally be kept closed. Heating/ventilation/air conditioning (HVAC) systems should be operated normally to be representative of actual living conditions. HVAC operation should be noted and considered when evaluating whether additional tests are required (e.g. during different seasons). Indoor air concentrations due to vapor intrusion will vary over time and are likely to be (but not necessarily) higher during winter season.

6.3.5 Ambient air sampling

An outdoor ambient sample must be collected simultaneously with the indoor air samples to provide a baseline against which the indoor air sample concentrations can be compared. Outdoor ambient air samples should be collected from a representative location, preferably upwind and away from any wind obstructions such as trees or buildings.

6.3.6 Background air sampling

In some situations, it may be necessary to collect background indoor air samples. Such samples should be collected inside a non-impacted structure located away from the contaminant plume that is similar in construction to the structure where indoor air is being evaluated. OPS does not have an RBSL for indoor air. However, OPS does consider benzene concentrations that are greater than background levels to be an indicator of possible vapor intrusion.

6.3.7 Additional measurements

As stated in Section 4.6, radon and/or air pressure may be measured for comparison with sub-slab measurements to assist in the determination of the presence of vapor intrusion.

6.3.8 Sample shipment

Refer to Section 4.8 for information on shipping samples. Always follow laboratory instructions for shipping of sample canisters.

7.0 Laboratory Analysis

OPS requires that all soil vapor, sub-slab vapor, and indoor air samples be analyzed for BTEX. Several analytical methods are available to measure soil gas samples, all of which can give accurate results when followed with appropriate Quality Assurance and Quality Control (QA/QC) measures. Table 3 includes laboratory methods and associated collection methods for analysis of petroleum-based contaminants and other analytes in soil vapor and indoor air samples.

Table 3. Soil Vapor and Indoor Air Analytical Methods

Analytes	Method Reference	Description	Sample Container	Container Holding Time	Detection Limit
Soil Vapor Sample Analysis					
BTEX	8021B [1,2]	GC/PID analysis	G, MC, SC	30 days	10-100 µg/m^3
			T	48 hours	
			SY	Onsite analysis	
BTEX	8260B [1,2]	GC/MS analysis	G, MC, SC	30 days	50-200 µg/m^3
			T	48 hours	
			SY	Onsite analysis	
BTEX	TO-1	Tenax® adsorption, GC/FID, although sometimes equipped with GC/MS analysis	SC	30 days	1-3 µg/m^3
			T	48 hours	
BTEX	TO-3	Cryogenic pre-concentration, GC/FID analysis	SC	30 days	1-3 µg/m^3
			T	48 hours	
			T	48 hours	
Sub-slab Vapor and Indoor Air Sample Analysis					
BTEX	TO-15 [1]	GC/MS analysis	SC	30 days	1-3 µg/m^3
BTEX	TO-14A	GC/FID/ECD or GC/MS analysis	SC	30 days	1-3 µg/m^3
BTEX	TO-15 SIM	GC/MS (SIM mode) analysis (5 to 10 compound subset of TO-15)	SC	30 days	0.1-0.5 µg/m^3
BTEX	TO-17	Air pump drawing air through adsorbent tube, thermal desorption & GC/MS with FID analysis	AT	30 days	1-3 µg/m^3

1 - OPS preferred method
2 - Must be calibrated with a vapor standard

T = Tedlar Bag   SC = Summa canister   G = glass bulb   SY = Syringe
MC = stainless steel vial (400 ml mini-can)   AT = Multi-bed adsorbent tube

Note: Detection limits listed in Table 3 are realistic or practical detection limits, which are dependent upon sample volume.

There are several websites that provide a wide range of unit conversions. Listed below are useful conversions for commonly reported laboratory units to the OPS-required unit of µg/m^3 for soil vapor and indoor air analytical results.

Parts per billion by volume (ppbv) x 3.25 = µg/m^3 (for benzene only)
Parts per million by volume (ppmv) x 3,250 = µg/m^3 (for benzene only)
Micrograms per liter (µg/L) x 1,000 = µg/m^3
Milligrams per liter (mg/L) x 1,000,000 = µg/m^3
Milligrams per cubic meter (mg/m^3) x 1,000 = µg/m^3

For any compound, the conversion of ppbv to μg/m^3 is obtained by use of the Ideal Gas Law as follows:

$$C(ppbv)\frac{MW_v Pv}{1000RT} = C\left(\frac{\mu g}{m^3}\right)$$

Where: MW_v = molecular weight (g/mole)
Pv = vapor pressure (atm)
T = temperature (°K)
R = the universal gas constant (8.204E-05 atm m^3/°K mole)

8.0 Data Validation

The following equations can be used to estimate the maximum benzene concentration expected in soil vapor ($C_{max,vapor}$) adjacent to dissolved contamination in groundwater or free-product (light non-aqueous phase liquid [LNAPL]). If benzene concentrations in soil vapor are significantly higher than the estimated maximum concentrations, the data should be further evaluated for potential errors or unknown source(s).

Expected maximum benzene in soil vapor ($C_{max,vapor}$) adjacent to **contaminated groundwater**:

$$C_{\max vapor}\left(\frac{ug}{m^3}\right) = H * C_{\max GW}\left(\frac{ug}{L}\right)\left(\frac{L}{10^3 ml}\right)\left(\frac{ml}{cm^3}\right)\left(\frac{10^6 cm^3}{m^3}\right)$$

Where: H = Henry's Constant for benzene = 0.23 (dimensionless)
$C_{max,GW}$ = maximum benzene concentration in groundwater

For example, a concentration of 100 μg/L benzene in groundwater could yield a benzene soil vapor concentration of:

$$C_{\max vapor}\left(\frac{ug}{m^3}\right) = 0.23 * 100\left(\frac{ug}{L}\right) * 10^3 = 23{,}000\ \mu g/m^3$$

Expected maximum benzene in soil vapor ($C_{max,vapor}$) adjacent to **LNAPL**:

$$C_{\max vapor}\left(\frac{ug}{m^3}\right) = NMF_{benzene} * \left(\frac{Pv(atm) * MW_{benzene}\left(\frac{g}{mole}\right) * 10^6\left(\frac{ug}{g}\right)}{R\left(\frac{atm - m^3}{mole\text{-}^\circ K}\right)T(^\circ K)}\right) = 6.9E + 06$$

Where: Pv = vapor pressure of benzene = 0.1 atm
$MW_{benzene}$ = molecular weight of benzene = 78.1 g/mole
R = universal gas constant = 8.204E-05 atm m^3/°K mole
T = Standard temperature = 298 °K
$NMF_{benzene}$ = estimated mole fraction of benzene in LNAPL = 0.02 (dimensionless)

$$NMF_{benzene} = \frac{(MF_{benzene} * MW_{benzene})}{MW_{LNAPL}}$$

Where:

$MF_{benzene}$ = mass fraction of benzene in LNAPL = 0.025 g/g
$MW_{benzene}$ = molecular weight of benzene = 78.1 g/mole
MW_{LNAPL} = molecular weight of LNAPL (all components) = 103 moles

9.0 Mitigation Measures

Remediation of petroleum hydrocarbon contamination sources in soil and groundwater is the most effective way to mitigate soil vapor intrusion into indoor air. If source remediation (i.e. soil excavation, soil vapor extraction, etc.) does not immediately mitigate the vapor intrusion problem, additional mitigation methodologies must be implemented. As in the case of petroleum hydrocarbon source remediation systems, it is also necessary in vapor mitigation systems to include intrinsically safe equipment when potentially explosive situations are present. An example of this situation is when LNAPL is very close to the building and vapor concentrations exceed 10% of the Lower Explosive Limit (LEL).

Below are selected references associated with indoor air mitigation. Since most vapor intrusion mitigation design has been based on radon control systems, many of the references below pertain to the control of radon.

9.1 Existing buildings

Passive or active venting systems, and sub-slab depressurization and pressurization systems.

References:

Massachusetts DEP. 1995. *Guidelines for the Design, Installation, and Operation of Sub-slab Depressurization Systems.*

New Jersey Dept of Environmental Protection. 2005. *Vapor Intrusion Guidance.* www.state.nj.us/dep/srp/guidance/vaporintrusion/vig.htm

USEPA. 1991. *Sub-slab Depressurization Handbook for Low-permeability Fill Material* (for home radon reduction). EPA /625/6-91/029.

USEPA. 1993. *Radon Reduction Techniques for Existing Detached Houses, technical guidance for active soil depressurization systems.* EPA 625/R-93/011.

USEPA. Revised April 1994. *Radon Mitigation Standards.* EPA 402-R-93-078. Accessible at http://www.epa.gov/iaq/radon/pubs/index.html

USEPA. Revised February 2003. *A Consumer's Guide to Radon Reduction.* EPA 402-K-03-002. Accessible at http://www.epa.gov/iaq/radon/pubs/index.html

9.2 Future buildings

Passive and active venting systems using gas barrier/membrane technology.

References:

ASTM. 1992. *Radon Control Options for the Design and Construction of New Low-Rise Residential Buildings.* ASTM Standard Guide, E14655-92.

USEPA. March 1994. *Model Standards and Techniques for Control of Radon in New Residential Buildings.* EPA 402-R-94-009. Air and Radiation (6604-J). Accessible at http://www.epa.gov/iaq/radon/pubs/newconst.html

USEPA. January 1993. *Radon Prevention in the Design and Construction of Schools and Other Large Buildings.* Office of Research and Development. EPA 625-R-92-016.

USEPA. May 1995. *Passive Radon Control System for New Construction.* Indoor Environmental Division, Office of Radiation and Indoor Air. EPA 402-95012.

Also, the Interstate Technology and Regulatory Council (ITRC) published a document in January 2007 titled "Vapor Intrusion Pathway: A Practical Guide". The ITRC document can be found at (http://www.itrcweb.org/teamresources_vapor.asp). This reference provides valuable information on the topic of vapor intrusion mitigation. An extensive list of references covering most issues related to vapor intrusion is included in this document.

Appendix A
Soil Vapor and Indoor Air Sampling Checklist

SOIL VAPOR AND INDOOR AIR SAMPLING CHECKLIST

Vapor Well Location		**Response**		**Comment**
Is the contaminant volatile?			Yes	
			No	
Are there occupied structures within the influence of the plume which do not dispense petroleum products?			Yes	
			No	
What is the construction of the structure?			Slab-on-grade	
			Basement	
			Crawlspace	
What is the use of the structure?			Commercial	
			Residential SFH	
			Residential MFH	
			School/daycare	
			Other	
Is a nested vapor point located within the source?			Yes	
			No	
Are nested vapor point(s) planned or located at all qualifying structures within the influence of the plume?			Yes	
			No	
Are sub-slab vapor points planned or located in any structure?			Yes	
			No	
Permanent Vapor Well Installation		**Response**		**Comment**
Soil vapor well installation method.			Direct push	
			HSA	
			Hand auger	
			Other	
Was a soil sample collected from the well boring?			Yes	
			No	
At what depth was the soil sample collected?				
What material was used to construct the sample collection point?			Steel mesh	
			Micro-bubbler	
			Perforated stainless steel	
			Other	
What material was used to connect the well sample collection point to the surface?			Stainless steel	
			Nylon	
			Teflon	
			PVC	
			Other	
What is the diameter of the soil vapor sample point?				
What is the screened interval of each sample port?	Shallow			
	Intermediate			
	Deep			
Is the depths of nested sample collection points clearly identified on each tube?			Yes	
Was is the depth interval of the porous backfill? (12 to 18 inches thick)	Shallow			
	Intermediate			
	Deep			
What is the depth interval of the annular seal? (minimum 2 feet & preferably 3 feet thick)	Shallow			
	Intermediate			
	Deep			
What is the material of the annular seal?			Granular bentonite	
			Bentonite slurry	
			Other	

If the well is a subslab well, what is the material of the annular seal?		Cement	
		Modeling clay	
		beeswax	
What is the material of the protective seal at the surface?		Cement	
		Native soil	
		Other	
What is the thickness of the protective seal? (min 1 foot)			
Were vapor tight connections applied to sampling ports?		Yes	
Was a protective vault installed at ground surface?		Yes	
		No	
Soil Vapor Sample Collection	**Response**		**Comment**
Did it rain shortly before the sampling event?		Yes	
		No	
Was a sampling feasibility test conducted?		Yes	
		No	
Was leak testing conducted prior to sampling?		Yes	
		No	
What was the leak testing tracer chemical used?		Helium	
		difluoroethane	
		sulfur hexafluoride	
		Other	
What method was used to purge well?		Electric pump	
		Peristaltic pump	
		Hand pump	
		Syringe	
		Other	
Was the flow rate for purging and sampling $\leq$ 0.2 L/min?		Yes	
		No	
Were at least three dead volumes of the well purged?		Yes	
		No	
Sample collection container		Summa canister	
		Tedlar bag	
		Syringe	
		Glass bulb	
		Other	
Were O_2 and CO_2 measurements collected?		Yes	
		No	
Was methane measured? (O^2 < 10% or LNAPL present)		Yes	
		No	
What method was used to analyze for BTEX/TVPH		8021B	
		8260B	
		TO-1	
		TO-3	
		TO-15 (subslab)	
		TO-17 (subslab)	
		18M	
		Other	

Indoor Air Sampling	Response		Comment
Is the indoor air sampling location in an occupied structure within the influence of the plume that does not dispense petroleum products?		Yes	
		No	
Was an access agreement executed with the building occupant(s)?		Yes	
		No	
Was the OPS Indoor Air Quality Building Survey form completed prior to sampling?		Yes	
		No	
Location and number of indoor living areas where an indoor air sample was collected?		Main floor	
		Upper floor	
		Basement	
		Crawlspace	
		Other	
What was the sample collection period for the summa canister?		Instantaneous	
		8 hours	
		24 hours	
		Other	
What method was used to analyze for BTEX/TVPH?		TO-14A	
		TO-15	
		TO-15 SIM	
		TO-17	
		18M	
		Other	
Was an ambient air sample collected from a location outside the structure?		Yes	
		No	

Acronyms:
SFH = single family home
MFH = multi-family home
HSA - hollow-stem auger

Appendix B
Building Survey Form

COLORADO DIVISION OF OIL AND PUBLIC SAFETY
INDOOR AIR QUALITY BUILDING SURVEY FORM

This form must be completed for each residence involved in indoor air testing.

Based on the New York State Department of Health's Guidance for Evaluating Vapor Intrusion (2005)

Preparer's Name ______________________________ Date/Time Prepared ____________
Preparer's Affiliation ____________________________ Phone No.____________
Purpose of Investigation ____

1. OCCUPANT:

Interviewed: Y / N
Last Name: _________________________ First Name: __________________________
Address: ____
County: ______________
Home Phone: ________________ Office Phone: ________________
Number of Occupants/persons at this location ______ Age of Occupants ______________

2. OWNER OR LANDLORD: (Check if same as occupant ___)

Interviewed: Y / N
Last Name: ________________________First Name: ____________________________
Address: ____
County: ______________
Home Phone: ________________ Office Phone: ________________

3. BUILDING CHARACTERISTICS

Type of Building: (Check appropriate response)

☐ Residential
☐ Industrial
☐ School
☐ Church
☐ Commercial/Multi-use
☐ Other: ______________

If the property is residential, type? (Check appropriate response)

☐ Ranch
☐ Split Level
☐ Contemporary
☐ Apartment House
☐ Log Home
☐ Multi-family
☐ Colonial
☐ Mobile Home
☐ Townhouses/Condos
☐ Other:____________
☐ Raised Ranch
☐ Cape Cod
☐ Duplex
☐ Modular

If multiple units, how many? __________________________

If the property is commercial, type?

Business Type(s) ______________________________

Does it include residences (i.e., multi-use)? ☐ Yes ☐ No If yes, how many? ______

Other characteristics:

Number of floors______ Building age______

Is the building insulated? ☐ Yes ☐ No

How air tight? ☐ Tight ☐ Average ☐ Not Tight

4. AIRFLOW

Use air current tubes or tracer smoke to evaluate airflow patterns and qualitatively describe airflow between floors, airflow near source, outdoor air infiltration, and infiltration into air ducts.

____

____

____

5. BASEMENT AND CONSTRUCTION CHARACTERISTICS

Check all that apply

a. Above grade construction: ☐ wood frame ☐ concrete ☐ stone ☐ brick

b. Basement type: ☐ full ☐ crawlspace ☐ slab ☐ other ____________

c. Basement floor: ☐ concrete ☐ dirt ☐ stone ☐ other ____________

d. Basement floor: ☐ uncovered ☐ covered ☐ covered with ______________

e. Concrete floor: ☐ unsealed ☐ sealed ☐ sealed with ______________

f. Foundation walls: ☐ poured ☐ block ☐ stone ☐ other ____________

g. Foundation walls: ☐ unsealed ☐ sealed ☐ sealed with ______________

h. The basement is: ☐ wet ☐ damp ☐ dry ☐ moldy

i. The basement is: ☐ finished ☐ unfinished ☐ partially finished

j. Sump present? ☐ Yes ☐ No

k. Water in sump? ☐ Yes ☐ No ☐ Not applicable

l. Basement/Lowest level depth below grade: ________ feet

Identify potential soil vapor entry points and approximate size (e.g., cracks, utility ports, drains)

____

____

____

6. HEATING, VENTING and AIR CONDITIONING

Type of heating system(s) used in this building: (check all that apply – note primary)

☐ Hot air circulation ☐ Heat pump ☐ Hot water baseboard
☐ Space Heaters ☐ Stream radiation ☐ Radiant floor
☐ Electric baseboard ☐ Wood stove ☐ Outdoor wood boiler
☐ Other ______________________

The primary type of fuel used is:

☐ Natural Gas ☐ Fuel Oil ☐ Kerosene
☐ Electric ☐ Propane ☐ Solar
☐ Wood ☐ Coal

Domestic hot water tank fueled by: ______________________________

Boiler/furnace located in: ☐ Basement ☐ Outdoors ☐ Main Floor
☐ Other________________________

Air conditioning: ☐ Central Air ☐ Window units ☐ Swamp cooler ☐ None

Are there air distribution ducts present? ☐ Yes ☐ No

Describe the supply and cold air return ductwork, and its condition where visible, including whether there is a cold air return and the tightness of duct joints. Indicate the locations on the floor plan diagram.

____

____

____

7. OCCUPANCY

Is basement (or lowest level) occupied?

☐ Full-time ☐ Occasionally ☐ Seldom ☐ Almost Never

General use of each floor (e.g., family room, bedroom, laundry, workshop, storage)

Basement ____

1st Floor ____

2nd Floor ____

3rd Floor ____

4th Floor ____

8. FACTORS THAT MAY INFLUENCE INDOOR AIR QUALITY

a. Is there an attached garage? ☐ Yes ☐ No
b. Does the garage have a separate heating unit? ☐ Yes ☐ No
c. Are petroleum-powered machines or vehicles stored in the garage (e.g., lawnmower, ATV, car)
☐ Yes ☐ No
Describe:____
d. Has the building ever had a fire? ☐ Yes ☐ No When?_________________________

e. Is a kerosene or non-vented gas space heater present? ☐ Yes ☐ No
Where?____________________
f. Is there a workshop or hobby/craft area? ☐ Yes ☐ No
Where & Type?____
g. Is there smoking in the building? ☐ Yes ☐ No
How frequently?____
h. Have cleaning products been used recently? ☐ Yes ☐ No If yes, list on table in Sect 13
i. Have cosmetic products been used recently? ☐ Yes ☐ No If yes, list on table in Sect 13
j. Has painting/staining been done in the last 6 months? ☐ Yes ☐ No If yes, list on table in Sect 13
k. Is there new carpet, drapes or other textiles? ☐ Yes ☐ No If yes, list on table in Sect 13
l. Have air fresheners been used recently? ☐ Yes ☐ No If yes, list on table in Sect 13
m. Is there a kitchen exhaust fan? ☐ Yes ☐ No
If yes, where vented?____
n. Is there a bathroom exhaust fan? ☐ Yes ☐ No
If yes, where vented?____
o. Is there a clothes dryer? ☐ Yes ☐ No If yes, is it vented outside? ☐ Yes ☐ No
p. Has there been a pesticide application? ☐ Yes ☐ No
When & Type? ____
q. Are there odors in the building? ☐ Yes ☐ No
If yes, describe: ____
r. Do any of the building occupants use solvents at work? ☐ Yes ☐ No
(e.g., chemical manufacturing or laboratory, auto mechanic or auto body shop, painting, fuel oil delivery, boiler mechanic, pesticide application, cosmetologist)
If yes, what types of solvents are used? ____
If yes, are their clothes washed at work? ☐ Yes ☐ No
s. Do any of the building occupants regularly use or work at a dry-cleaning service?
☐ No
☐ Unknown
☐ Yes, use dry-cleaning regularly (weekly)
☐ Yes, use dry-cleaning infrequently (monthly or less)
☐ Yes, work at a dry-cleaning service
t. Is there a radon mitigation system for the building/structure? ☐ Yes ☐ No
If yes, date of Installation: ________________________________
u. Is the system active or passive? ☐ Active ☐ Passive

9. WATER AND SEWAGE

Water Supply:
☐ Public Water ☐ Drilled Well ☐ Driven Well ☐ Dug Well ☐ Other: ________________
Sewage Disposal:
☐ Public Sewer ☐ Septic Tank ☐ Leach Field ☐ Dry Well ☐ Other: ________________

10. RELOCATION INFORMATION

a. Provide reasons why relocation is recommended: ______________________________________
____
____

b. Residents choose to:
☐ remain in home ☐ relocate to friends/family ☐ relocate to hotel/motel
c. Responsibility for costs associated with reimbursement explained? ☐ Yes ☐ No
d. Relocation package provided and explained to residents? ☐ Yes ☐ No

11. FLOOR PLANS

Draw a plan view sketch of the basement and first floor of the building. Indicate air sampling locations, possible indoor air pollution sources and PID meter readings. If the building does not have a basement, please note.

Basement:

First Floor:

12. OUTDOOR PLOT

Draw a sketch of the area surrounding the building being sampled. If applicable, provide information on spill locations, potential air contamination sources (industries, gas stations, repair shops, landfills, etc.), outdoor air sampling location(s) and PID meter readings.

Also indicate compass direction, wind direction and speed during sampling, the locations of the well and septic system, if applicable, and a qualifying statement to help locate the site on a topographic map.

13. PRODUCT INVENTORY FORM

List specific products found in the residence that have the potential to affect indoor air quality.

Location	**Product Description**	**Size (units)**	**Condition***	**Chemical Ingredients**	**Photo** ** **Y / N**

* Describe the condition of the product containers as Unopened (UO), Used (U), or Deteriorated (D)

** Photographs of the front and back of product containers can replace the handwritten list of chemical ingredients. However, the photographs must be of good quality and ingredient labels must be legible.