



COMMONWEALTH OF MASSACHUSETTS
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DEPARTMENT OF ENVIRONMENTAL PROTECTION

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April 14, 2008

Dear Licensed Site Professionals and Other Interested Parties:

The MassDEP Bureau of Waste Site Cleanup has recently developed a Standard Operating Procedure entitled "*Standard Operating Procedure for Indoor Air Contamination*" ("SOP," August, 2007). This document was written as guidance to MassDEP BWSC staff conducting investigations and remedial activities at sites with known or potential vapor intrusion issues. The SOP was created to promote a consistent, informed and practical approach for MassDEP staff to follow that achieves the performance standards required by the Massachusetts Contingency Plan ("MCP," 310 CMR 40.0000).

This SOP is being made available to you as a technical reference that may be informative when conducting work at sites where vapor intrusion issues are of concern. Please note that because the SOP was written for MassDEP staff, it contains procedural and administrative information that was developed solely for MassDEP staff use and is not applicable to the private sector. Also note that SOP references to specific equipment for field investigations reflect equipment that MassDEP currently uses. Such references do not represent endorsements of particular vendors.

This SOP is *not* a MassDEP policy, and it is not enforceable by any party. Parties conducting investigations related to vapor intrusion concerns are subject to specific regulatory requirements in 310 CMR 40.0000 that are not described in this document. The reader is referred to the regulatory requirements of the MCP and published guidance available on-line at <http://Mass.Gov/dep>.

The Department intends to develop a comprehensive guidance document for use by the regulated community to address the vapor intrusion pathway in the near future and looks forward to working with all interested stakeholders in that effort.

Sincerely,



Janine Commerford
Assistant Commissioner,
MassDEP Bureau of Waste Site Cleanup

	MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION BUREAU OF WASTE SITE CLEANUP Standard Operating Procedure Indoor Air Contamination SECTION I - OPERATIONAL EXPECTATIONS
SOP BWSC-07-01	
SECTION I	

Approved By	Date	Pages	Contact Person
Janine Commerford	August 2007	4	John Fitzgerald

This SOP addresses situations where releases of oil and/or hazardous materials have or may adversely impact air quality within occupied buildings, generally via a subsurface vapor intrusion pathway. Its purpose is to:

- ☞ emphasize the importance of indoor-air contamination problems;
- ☞ articulate clear operational responsibilities and lines of communications; and
- ☞ provide program staff with technical information and guidelines, procedural recommendations, and practical *Rules of Thumb* to enable them to better understand, recognize, prioritize, and respond to indoor air contamination events.

This SOP is segmented into four Sections:

- ❖ Section I - A "bottom line" articulation of operational expectations on looking for, assessing, remediating, and managing/communicating vapor intrusion situations;
- ❖ Section II - Technical concepts, guidelines, procedures, and recommendations on investigating and addressing vapor intrusion pathways;
- ❖ Section III - Look-up Tables for Indoor Air Contaminants; and
- ❖ Section IV - A "Toolbox" of practical forms, procedures, guidelines, data, and informational resources, including standardized bid specifications for state-funded installations of sub-slab depressurization systems.

All staff are expected to become familiar with the operational expectations of Section I, and cognizant of the availability of the detailed guidelines contained in Sections II through IV, for use as the need arises.

No document can anticipate, explain, and/or address every facet of such a complex subject and phenomenon, and nothing contained herein is meant to obviate or limit the exercise of good professional judgment.

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OPERATIONAL PRIORITIZATION & EXPECTATIONS

Why this is a Priority

Of all media pathways, indoor air exposures are perhaps of greatest concern:

- people spend most of their time *inside of buildings*;
- the lungs are an efficient *mass-transfer* mechanism for introducing air contaminants into the body;
- while it is possible to avoid contaminated soils at a site, and purchase bottled water to avoid exposure to contaminants in an on-site water supply, *it is not possible to avoid breathing the air within an impacted occupied structure.*

Of particular concern are indoor air exposures to sensitive receptors, especially pregnant women and young children, in places where these parties spend long periods of time (e.g., school, daycare facility, home). However, even exposures in commercial and/or industrial buildings should be viewed with interest and diligence, especially where contaminant levels are considered an Imminent Hazard.

Responsibilities and Accountabilities

Systems and procedures must be in place in all regional offices to pro-actively identify indoor air contamination events, communicate these findings up the chain of command, and initiate and track subsequent response actions. Operations staff are responsible for understanding and applying the technical and procedural elements presented in this SOP.

The BWSC Deputy Regional Director has overall responsibility and accountability. While it is recognized that the DRD will likely delegate day-to-day operations in this area to a Section or Branch Chief, it is essential that he/she maintain an awareness and stewardship of cases, via regular reports and inquiries.

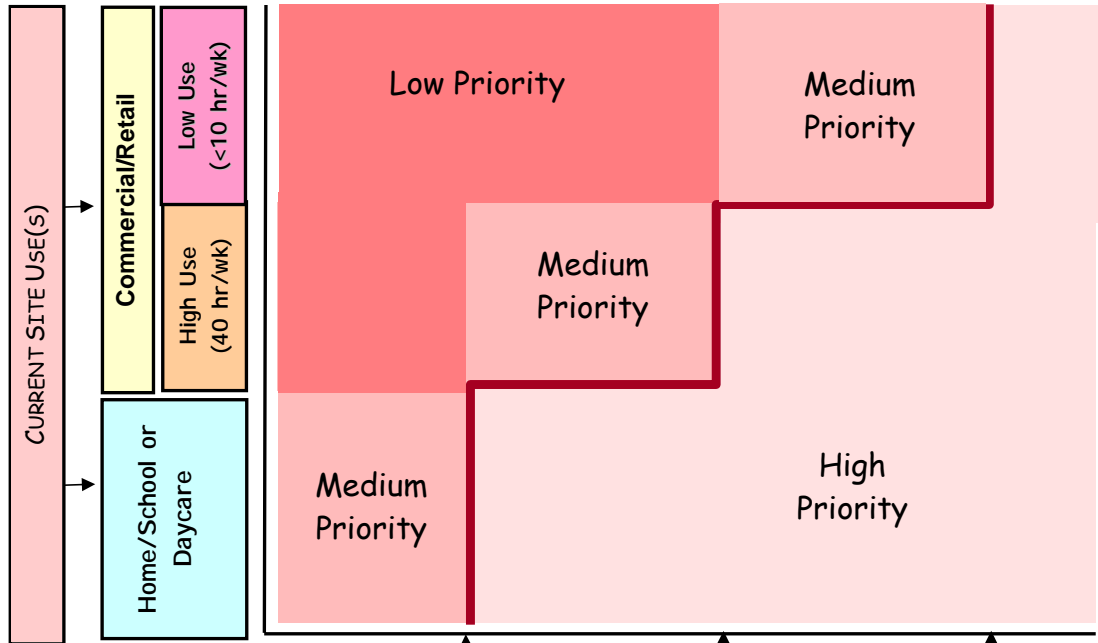
Purpose and Application of this SOP

This SOP is a combination of scientific principles, professional judgments, and BWSC operational and risk-management positions. It attempts to recognize and pragmatically address "real world" issues, limitations, and uncertainties, and is designed to educate and direct staff, to help ensure consistent operations and decisions. Its provisions complement and expand upon broader frameworks articulated in previous policies and SOPs, including BWSC Policy #02-430, *Indoor Air Sampling and Evaluation Guide*, and BWSC SOP #03-01, *Standard Operating Procedures for Conducting Response Actions at Homes, Schools, and Daycare Facilities Using State Bond Funds*. While there will always be site-specific exceptions to the rules, the provisions of this document are expected to be applicable and be applied at most sites. Deviations from this SOP must be approved in writing by the BWSC Director of Response and Remediation.

Vapor-Pathway Prioritization Matrix

SECTION I - OPERATIONAL

The purpose of this matrix is to guide operational efforts to prioritize cases, in recognition of staffing constraints that may exist. Criteria are provided for those contaminants responsible for the majority of vapor intrusions situations. These criteria are based upon years of experience and professional judgments. A lesser prioritization does not infer that vapor intrusion will not occur or will not require attention, but rather that a pathway and/or significant risk are less likely.

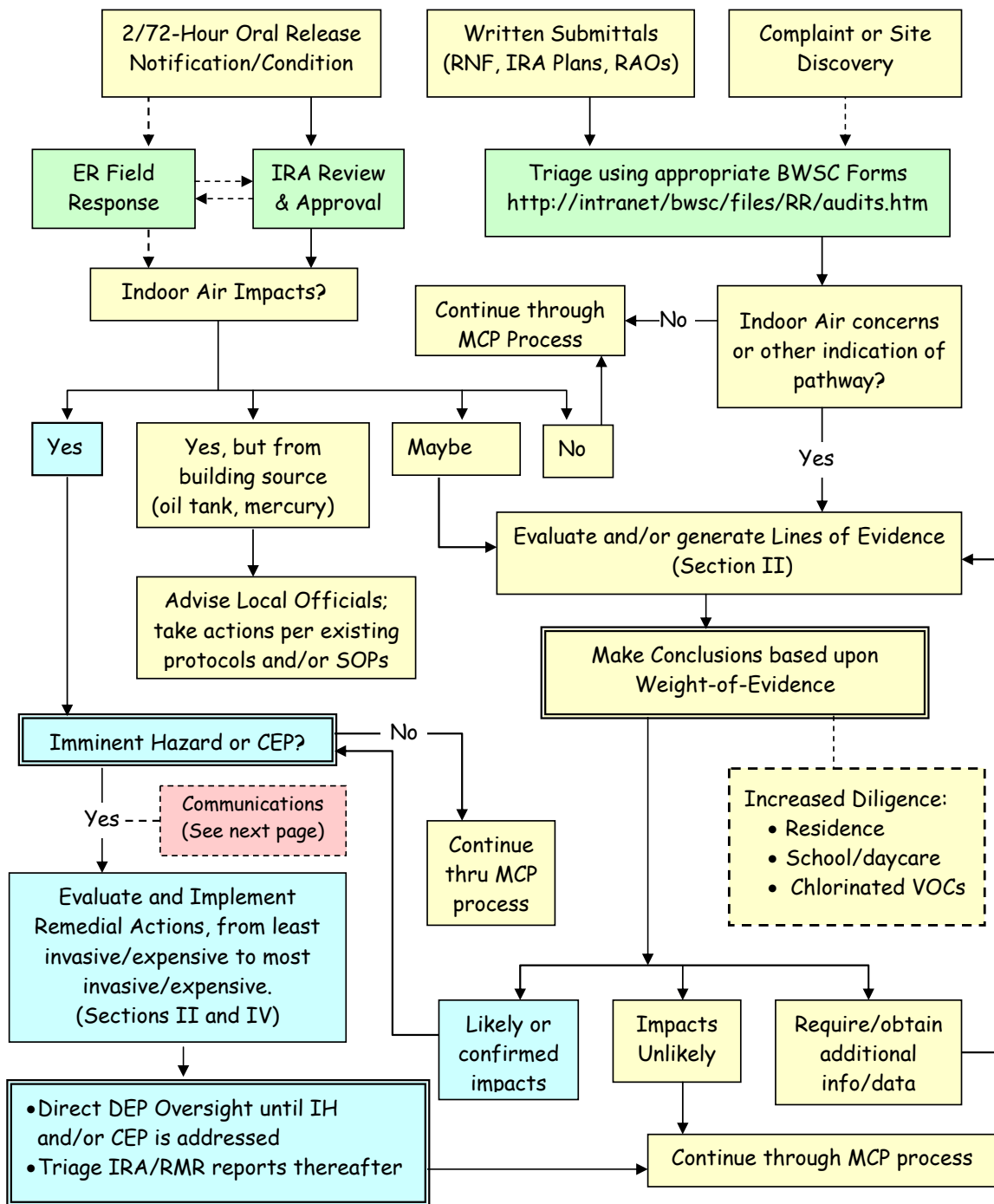


HIGHEST CONCENTRATION/APPARENT THICKNESS AT WATER TABLE INTERFACE IN GW-2 AREA				
PCE µg/L	20 - 49	50 - 199	200 - 900	> 900
TCE µg/L	10 - 29	30 - 119	120 - 500	> 500
VC µg/L	1	2-7	8-30	> 30
Benzene µg/L	500 - 1999	2000 - 4999	5000 - 10,000	> 10,000
NAPL (in)	Gasoline	1/8	½ - 2	> 12
	#2/Diesel	1	2-7	> 36

NOTE Current home/school/daycare considered high priority if located at a site that uses or formerly used chlorinated solvents/dry cleaning fluids, regardless of (known) groundwater condition.

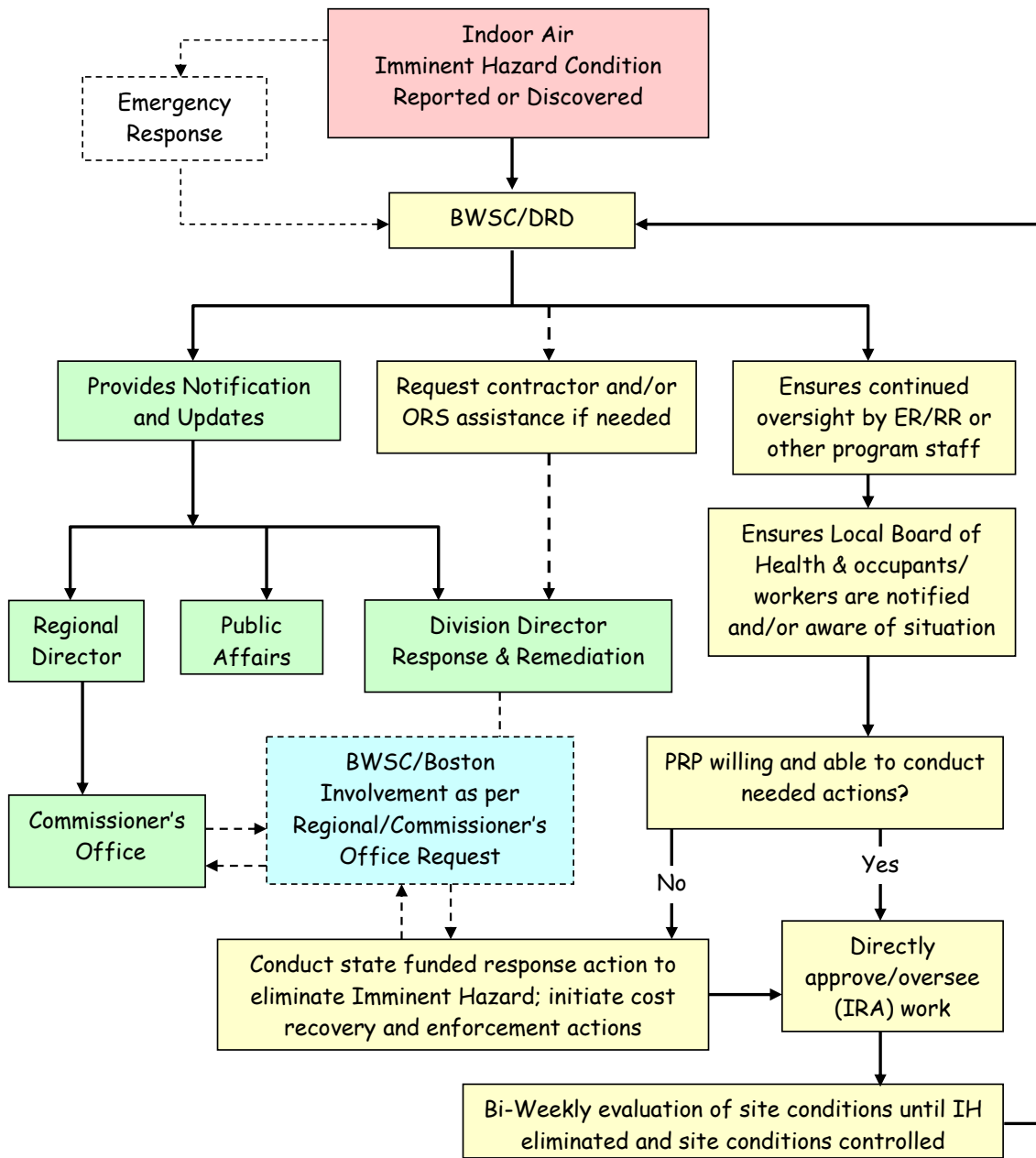
Impacts are often seen in strip malls and other locations where vapor transport is via movement through building conduits or soils, not off-gassing from groundwater.

Overall Approach and Process



Communication and Responsibilities

SECTION I - OPERATIONAL





MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION

BUREAU OF WASTE SITE CLEANUP

Standard Operating Procedure

Indoor Air Contamination

SECTION II - TECHNICAL CONCEPTS AND GUIDELINES

SOP BWSC-07-01

SECTION II

Approved By	Date	Pages	Contact Person
Janine Commerford	August 2007	20	John Fitzgerald

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CONCEPTUAL SITE MODEL

Volatile Organic Compounds (VOCs) in soil and groundwater tend to partition or volatilize into the vapor phase, fill the interstitial (void) spaces of the soil, and subsequently migrate in the vapor phase via diffusive and/or advective forces towards an area of lower concentration or pressure, along the underground pathway(s) of least resistance (See Figure II-1).

In undeveloped areas, migration of vapor-phase contaminants is towards the ground surface and into the ambient air. The presence of a building or other subsurface structure, however, can provide an alternative advective or diffusive "sink". Underpressurization within a building (relative to the ambient atmosphere) can create a significant negative pressure differential between the building/basement air and the surrounding soil, and induce the advective transport of vapor-phase contaminants towards and into the structure.

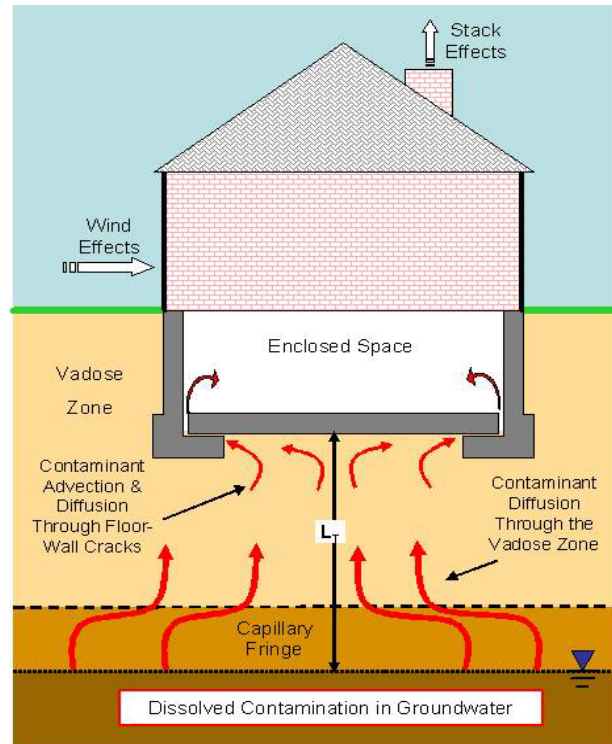


Figure II-1: Vapor Infiltration Pathway

Underpressurization within a building (relative to the ambient atmosphere) can create a significant negative pressure differential between the building/basement air and the surrounding soil, and induce the advective transport of vapor-phase contaminants towards and into the structure.

There are a number of factors that can and do lead to building underpressurization:

- thermal differences between indoor air and the surrounding soils;
- wind and barometric changes;
- stack effects of chimneys and flues;
- the operation of exhaust fans/vents; and
- negative pressures created by the use of combustion air in gas and oil furnaces.

The existence of a frost layer tends to exacerbate vapor-phase intrusion during winter months, by temporarily eliminating the ground surface/ambient-air transport pathway. This is also when combustion furnaces will be in operation, and when household ventilation will be

at a minimum. While buildings with basements are most at risk, vapor phase intrusion may also occur within slab-on-grade structures.

Diffusion - slow migration of contaminants caused by the random kinetic energy of molecules; movement is from areas of higher concentration to areas of lower concentration.

Advection - more rapid migration of contaminants caused by the bulk movement of soil gases; movement is from areas of higher pressure to areas of lower pressure.

Johnson and Ettinger¹ have postulated that diffusion is the predominant vapor-phase transport mechanism from source areas, but that advective transport generally predominates in the areas beneath and adjacent to buildings. It is generally believed that most vapor-phase intrusion occurs via cracks in masonry foundations (as opposed to diffusion through concrete). Of

particular concern are the small perimeter cracks that generally develop in poured concrete foundations at the intersection of the footing/wall/slab. Other problematic entry points include the annular space around incoming utility pipes, as well as shear, settling, or shrinking cracks that can develop over time within the walls or slab. In strip malls and other multi-tenant buildings, vapor transport can also occur between units via HVAC systems or annular spaces, subsurface drains, tunnels, and other void spaces. This is a particular concern with Dry Cleaners.

The mechanisms that create pressure differentials are complex and temporally variable. The magnitude of building underpressurization that can be created by these mechanisms has been reported to be in the range of 1 to 50 Pascals.² This underpressurization leads to a pressure coupling effect on surrounding soils, producing a measurable decrease in soil gas pressures, thus resulting in a pressure gradient and advective flow. This pressure coupling is highly variable and site-specific; although usually most significant within 1 or 2 meters of a building, measurable effects have been reported up to 8 meters from structures.³

Extremely small pressure differences are significant in the evaluation of soil gas intrusion. The typical pressure measurement unit is the Pascal (Pa).

1 Pa= 0.004 inches of water column (w.c.)

1 inch of water column = 0.036 psi

Special gauges are needed to measure such pressure differentials. A Magnehelic gauge is capable of measuring as little as 0.5-1.0 Pa.

While seasonal changes in vadose zone moisture content will influence soil/air permeability in near-surface soils (less than 1 meter below grade), it is generally believed that soil moisture and permeability conditions remain reasonably constant at depth⁴. One significant exception in this regard, however, are soils directly beneath structures, where moisture contents may be lowered due to (a) the lack of rain/snow-melt infiltration, and (b) volatilization of water from soil void spaces via the bulk movement of soil gases into the overlying structure. With less water in void spaces, VOC vapor migration may be enhanced; an important element when evaluating and modeling vapor transport. Note that MassDEP has adopted a generic soil moisture condition of 0.06 (volumetric) in calculating MCP Method 1 GW-2 standards, based

upon this consideration, and soil moisture data from substructure soil samples.

The most pronounced impacts via the soil gas infiltration pathway occur as the result of VOC-saturated soils and/or Non-Aqueous Phase Liquids (NAPL) beneath or immediately adjacent to a structure. The partitioning of dissolved VOCs from groundwater is a less dramatic (though more insidious) pathway of concern. While groundwater plumes can travel thousands of feet and impact distant structures in this manner, it is important to understand that aqueous-phase partitioning is a water-table phenomenon; even a few feet of clean water overlying a dissolved VOC plume can prevent overlying impacts, given the very slow nature of liquid-phase diffusion. This "fresh water lens" situation is not uncommon in large plumes, where infiltrative and hydrodynamic gradients push plumes down with increasing distance from the source (See Figure II-2). Profiling groundwater contaminant concentrations through and beneath the water table interface (e.g., via direct-push microwells) is a useful technique to better characterize concern at these distant buildings.

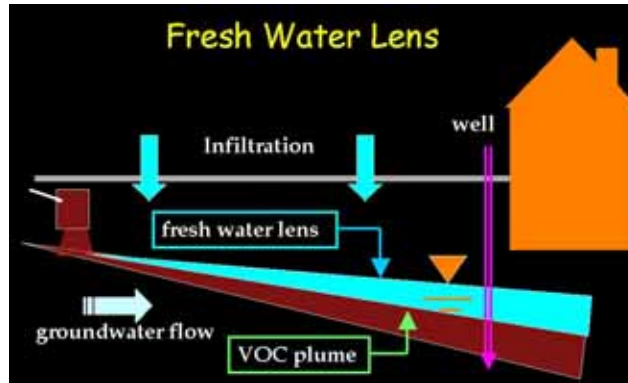


Figure II-2: Fresh Water Lens Phenomenon

Obtaining soil gas data beneath a structure of concern is also desirable, to provide qualitative evidence on a potential pathway, and semi-quantitative information on the potential magnitude of indoor air impacts. Obtaining vapor samples from just beneath a concrete slab is preferred, as vapors tend to accumulate here due to the existence of settlement void spaces. Conversely, obtaining soil gas samples from probes outside the structure may yield data with a negative bias, especially if the ground cover allows infiltration of precipitation, as such infiltration can displace and/or re-solubilize VOC compounds.

Chlorinated VOCs (e.g., PCE, TCE, DCE, VC) tend to be more problematic indoor air contaminants, as compared to non-chlorinated VOCs (e.g., petroleum products). This is because chlorinated VOCs do not biodegrade as readily as many other VOCs. Because of the relatively high biodegradation rate (especially under aerobic conditions), dissolved petroleum VOC groundwater plumes (excluding MtBE) generally do not migrate more than a few hundred feet from the point of release (e.g., UST). Conversely, chlorinated VOCs can travel thousands of feet in the dissolved phase. Whereas petroleum VOCs can rapidly biodegrade within the vadose zone beneath structures, chlorinated VOCs vapors can move with little attenuation. Recent reports have even suggested that the build-up of biogenic

gases (CO₂) from the (relatively rapid) biodegradation of petroleum hydrocarbons can also create a barrier to the movement of hydrocarbon vapors at depth to overlying buildings.⁵

DETERMINING WHETHER A VAPOR INTRUSION PATHWAY IS PRESENT

In some cases, the existence of a vapor intrusion pathway is obvious, due to odors and/or site conditions and events. In other cases, the impact is not apparent, but readily confirmed after the generation of investigational data.

One of the biggest challenges to MassDEP staff, however, can be making a determination as to whether a vapor intrusion pathway is present at a structure when site data is ambiguous. Uncertainties in this regard are generally due to the presence of low concentrations of chemicals within indoor air due to factors unrelated to an environmental release of oil or hazardous materials, including: the use of consumer, commercial and/or industrial products, cigarette smoke, and off-gassing from the building materials themselves.

Knowledge of concentrations of chemicals commonly present within indoor air is not only important in the identification of vapor intrusion pathways, but is also germane in the evaluation of risk posed by chemicals of interest. Most chemicals present within indoor air at typical levels are not present at a level that would be considered a significant risk, based on the calculated Hazard Index or Excess Lifetime Cancer Risk. There are a few common contaminants, however, where levels within the range of typical indoor air concentrations are high enough to meet the definition of an Imminent Hazard (e.g., benzene). Even when chemicals detected within indoor air do not pose an Imminent Hazard or significant risk, knowledge of typical indoor air concentrations is important, with respect to evaluating the possible existence of Critical Exposure Pathways at homes or schools.

LINES OF EVIDENCE

The general steps in conducting a lines of evidence evaluation of vapor intrusion pathways is outlined in Flowchart II-1 (page 17). Steps are not always linear, as concerns over the existence of the pathway can proceed in a forward direction, upon the discovery of a groundwater contaminant plume, or from a backwards direction, based upon odor or air testing data from an occupied building.

In general, investigative steps should be progressively taken until such time as the totality of evidence reasonably supports the existence or absence of the pathway. Possible steps and considerations in this regard are listed and discussed in Table II-1. In most cases, it is not necessary to assemble and weigh all possible lines of evidence to make judgments.

Further elaboration and guidance in this regard are provided below:

Data Generation and Evaluation - The *Level of Effort* needed for a lines of evidence approach is site-specific, commensurate with (a) the sensitivity of the receptors of concern, (b) the nature and toxicity of the contaminants of concern, (c) site complexities and heterogeneities, and (d) data gaps and needs of the Conceptual Site Model. For example, the potential discharge of chlorinated solvent vapors into a large school building with complex sub-surface/sub-slab conditions will warrant a relatively high level of effort and dense data collection network, including multiple rounds of soil gas and indoor air measurements in multiple locations. Once a sufficient amount of data is generated, a decision on the existence of a vapor intrusion pathway is made based upon a *Weight of Evidence* approach.

Typical Indoor Air Concentrations - It is important to understand that published concentrations of chemicals within indoor air are not synonymous with "background", as that term is used in the MCP. Specifically, in the MCP context, a "background" indoor air concentration of a chemical compound is what is actually present in any given structure, absent a vapor intrusion pathway. *Unlike soil and groundwater, however, it is generally not possible to determine (actual) background indoor air concentrations. One cannot test neighboring homes to establish this condition, given variations in building materials, use of consumer products, ventilation rates, etc. For that reason, published data from large-scale studies are often used to identify expected levels of common chemicals within a structure absent a vapor intrusion pathway. Therefore, given that this published data is not equivalent to actual "background", when referencing this data, it is not appropriate to state that a contaminant is present in building air "below background". The more appropriate statement would be that OHM is likely present in building air "within the range of typical indoor air concentration levels."*

MassDEP's Upper Percentile Values of Indoor Air Concentrations -The availability, quality, and relevance of published indoor air concentration data varies, and is subject to methodological biases and uncertainties. In 2007, MassDEP convened a workgroup to look at available indoor air studies. As a result of this effort, the workgroup selected a small group of studies it found to be the most defensible and representative for use in identifying the range of typical indoor air concentrations (see <http://www.mass.gov/dep/cleanup/iawg.htm>). A detailed tabulation of the study databases is provided in Section IV, Toolbox 6.

Having identified appropriate studies to use as sources of typical indoor air data, it is necessary for MassDEP to make more specific programmatic decisions as to how that data should be used in a regulatory process. For example, many studies report

concentrations of indoor air contaminants within stated statistical percentile ranges, such as 50th percentile, 95th percentile, etc. Guidance on the use of these studies, therefore, needs to address which percentile ranges should be applied to MCP decisions.

MassDEP has identified Upper Percentile Values from the range of typical indoor air concentrations as appropriate for use in:

1. Determining the need to obtain additional lines of evidence (e.g., soil gas) necessary to confirm or refute the presence of a vapor intrusion pathway or Critical Exposure Pathway, in cases where only indoor air data exist; and/or
2. As a discrete element in a lines of evidence evaluation, in cases where multiple assessment elements have been generated (e.g., groundwater, soil, soil gas, models, etc.)

These Upper Percentile Values are provided in Table I of Section III for common site contaminants.

At sites where indoor air contaminants are not posing significant risk, for purposes of making determinations on vapor intrusion or the existence of a Critical Exposure Pathway (as opposed to determining a condition of significant risk), the detection of indoor air contaminants at or below Upper Percentile Values should generally terminate the need for further investigation. This assumes that adequate testing has been conducted over a sufficient period of time to obtain representative indoor air concentrations, including expected "worst case" conditions during winter months (see MassDEP Policy *Indoor Air Sampling and Evaluations Guide*, WSC-02-430, at <http://www.mass.gov/dep/ors/files/indair.pdf>)

*While an important evaluation tool and metric, MassDEP's Upper Percentile Values, as well as other published indoor air concentration values, are generic and may **NEVER** be used as the sole basis to justify a condition of No Significant Risk at a specific site per the provisions of 40.0902(3) (i.e., such values should not be used alone to justify that the indoor air concentrations are representative of MCP "background" and therefore, considered No Significant Risk for the purposes of supporting a Response Action Outcome). At sites where indoor air contaminants do pose a significant risk, even where the concentrations of these contaminants fall within the range of typical indoor air concentrations, it is **ALWAYS** necessary to obtain multiple lines of evidence to confirm or refute the presence of a vapor intrusion pathway. Importantly, there are a small number of contaminants (e.g., benzene) that can exceed an MCP risk limit (e.g., Excess Cancer Risk Limit) even at levels typically present within the*

indoor air. These contaminants are identified in bold type in Table I/Section III. For these contaminants, it is ALWAYS necessary to obtain multiple lines of evidence to confirm or refute the presence of a vapor intrusion pathway.

SECTION II - TECHNICAL

Table II-1 - Assembling and Weighing Lines of Evidence on the Existence of a Vapor Intrusion Pathway

Evidence		Steps/Considerations/Discussion	
Indoor Air Data		Compare to MassDEP Upper Percentile Values of Indoor Air Concentrations (see Table III-1). <i>Assuming that an adequate investigation and evaluation was conducted</i> , if all contaminants are below listed values, in the absence of evidence to the contrary (e.g., odors or additional test data), conclude pathway is not present, except for contaminants with Upper Percentile Indoor Air Concentrations in excess of allowable MCP risk limits (bolded in Table III-1). Be sure to obtain/evaluate outdoor air data if exterior sources are suspected (e.g., building near active gasoline dispensing station).	
PID screening		Use PID unit to screen likely entry points of vapors in lowest building level (e.g., basement), including cracks in floor or walls, sumps, annular spaces around utility pipes, and the wall/floor interface.	
Sub-Slab vapors		Install small-diameter vapor probes through building/basement slab. Screen with PID and/or GC and/or GC/MS. Rule of Thumb: assume 10 - 100 fold dilution of chlorinated solvents, and 100 - 1000 fold dilution of petroleum hydrocarbons (BTEX) vapors (i.e., concentrations of chlorinated solvents within air above slab will be 10 to 100 times less than concentrations of those solvents in the sub-slab soil gas). Better results can be obtained using site-specific modeling (e.g., Johnson & Ettinger), in consideration of building-specific factors (e.g., air exchange rate, amount of cracks). Assume a soil moisture concentration no greater than 0.06, absent site-specific data.	
Analytical/Forensics	Chlorinated VOCs	Degradation products of certain chlorinated VOCs can sometimes be used as "indicator compounds" for the vapor intrusion pathway. This is because these compounds are not commonly used in commercial products. Their presence within indoor air would be a strong indication of the existence the pathway, and their ratios in soil gas vs. indoor air could be an indication of the soil gas to indoor air attenuation (dilution) factor. ⁶	
		Degradation compounds	Parent compound
		1,1-dichloroethylene 1,1-dichloroethane Cis-1,2-dichloroethylene	1,1,1-trichloroethane trichloroethylene
	Gasoline	The chromatogram for fresh gasoline (e.g., from containers or equipment stored in a basement) will be predominated by lighter aliphatic compounds and MtBE or ethanol, as opposed to the chromatogram for gasoline vapors infiltrating from the environment, which will be predominated by the soluble components of gasoline with high Henry Law's Constants (BTEX).	
Radon	On occasion, radon can be used as a tracer compound, similar to the chlorinated solvent breakdown products (i.e. to establish/quantitate vapor intrusion pathway). However, literature citations suggest problems in this regard, so care should be exercised.		

SECTION II - TECHNICAL

It is understood that a vapor infiltration pathway may still be present at a site where indoor air concentrations are at or below an Upper Percentile Value . However, similar to the use of soil and groundwater background values in MCP Method 1 standards, MassDEP has made a decision to generally not pursue situations of this nature, as long as there is a condition of No Significant Risk.

Outdoor Air Sampling and Analysis - While in general typical indoor air concentrations of common chemicals exceed typical outdoor (ambient) air levels, there can be localized exceptions. For example, benzene and other hydrocarbons may be elevated in areas proximate to active gasoline dispensing stations. Since outdoor air impacts indoor air quality, it is essential that synoptic indoor/outdoor data be obtained in such cases, and advisable that such data be obtained in all indoor air sampling efforts.

Petroleum Sources within Basements - When undertaking a lines of evidence approach to determine whether petroleum releases to the environment are creating a vapor intrusion pathway at a building, it is necessary to consider what petroleum products are present and/or used within the structure. The three most common materials are fuel oil, gasoline, and consumer products.

Fuel Oil - Homes and buildings frequently contain a freestanding fuel oil tank in the lowest level (e.g., basement). The indoor air in such buildings could contain elevated level of petroleum hydrocarbons from this source, at least in the area or level where the tank is located. Data from a recent study by Haley and Aldrich⁷, however, suggest that typical indoor air concentrations of APH hydrocarbons (i.e., aliphatic and aromatic ranges) *in living areas* are similar in homes with or without oil heat.

Gasoline: Many homes and businesses have gasoline stored within a structure (e.g., in storage containers and/or equipment). When assessing vapor intrusion from a gasoline environmental release, it is necessary to consider contributions from such sources. One way to do this is analytically, by examining the chemistry of the air sample data indicating elevated gasoline-related contaminants (i.e., BTEX, M+BE, aliphatic/aromatic hydrocarbons). This can be done by qualitatively viewing GC/FID or GC/MS total ion chromatograms, and looking for the low-molecular-weight volatile aliphatic compounds (and M+BE) that would be indicative of a fresh gasoline product (i.e., from storage in the structure), as opposed to the more weathered signature of an environmental release, which is likely to be predominated by the higher-molecular-weight compounds, and, in the case of a groundwater migration pathway, those compounds that are most water soluble and volatile (i.e., BTEX). While M+BE has a high vapor pressure, it also is highly soluble

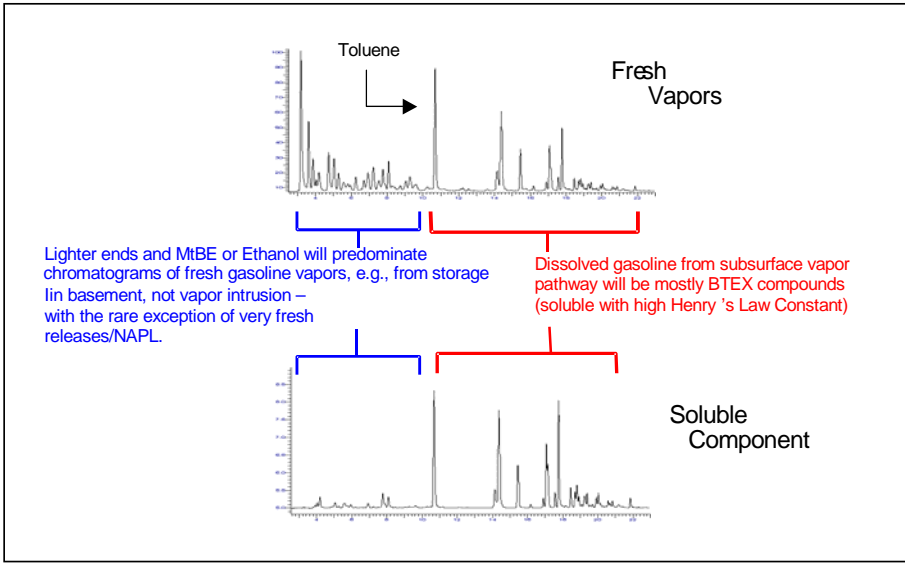


Figure II-3: Chromatographic Signatures of Gasoline Sources

SECTION II - TECHNICAL

a

It has a low Henry's Law Constant. This results in high concentrations of MtBE in vapors from a pure gasoline product, but low concentrations of MtBE from contaminated groundwater. (See Figure II-3)

Hydrocarbon Containing Products - It is important to consider that many common consumer/building products contain the same petroleum constituents that are found in gasoline and fuel oils, including toluene and xylenes. Absent a source of such (individual) products in the environment (e.g., a spill of pure toluene), high concentrations of specific compounds of this nature within indoor air, without the proportional presence of other petroleum constituents, would be indicative of such a background, non-MCP source.

Attached Garages - Recent data⁶ suggests the presence of an attached garage at a home can significantly increase the presence of BTEX compounds within the living space of the structure. If such a possibility were of importance at a site, synoptic sampling of the living space and garage area would be recommended.

SOIL GAS INVESTIGATIONS

Soil gas investigations are often a critical element in generating and weighing lines of evidence in vapor intrusion situations.

Detailed guidance on installing and sampling soil gas probes is provided in Section IV, Toolbox 3. Below is a summary of key considerations and parameters when designing or reviewing a soil gas sampling effort relative to vapor intrusion investigations.

Where to Install Probes

It is important that soil gas sampling probes be installed within the footprint of the building being investigated, generally through a concrete slab on the lowest level of the structure (e.g., basement). Soil gas probes installed outside of the footprint of a structure may produce data with a negative bias, as indicated in Figure II-4.

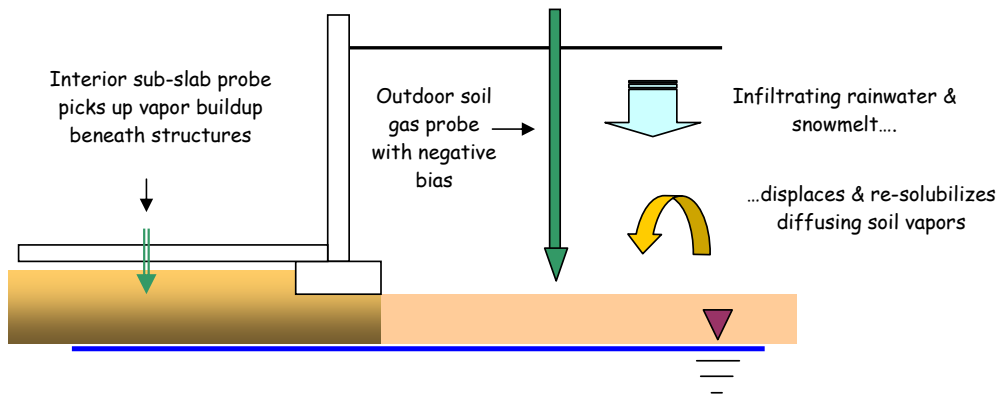


Figure II-4: Negative Bias of outdoor soil gas probes

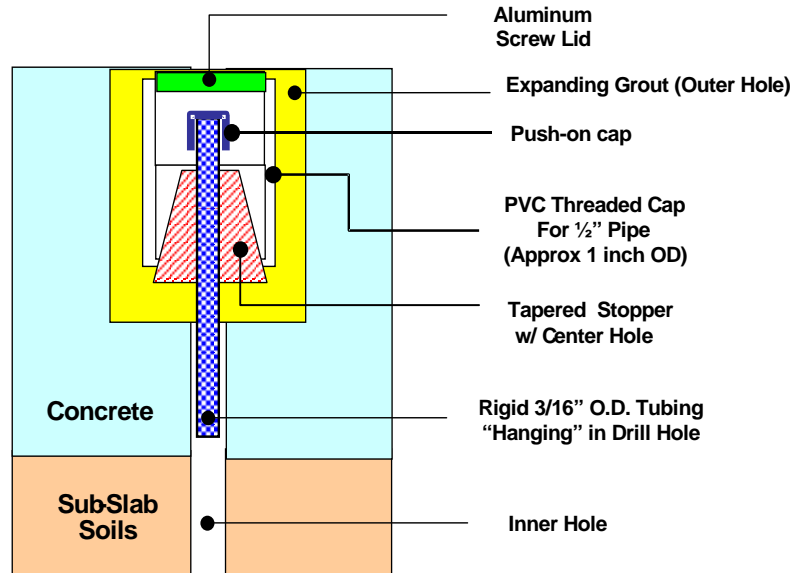
How many Sub-Slab Probes to Install

At least two probes should be installed in a typical single family home; more in larger buildings. These probes should generally be permanent, to allow for multiple sampling rounds, and should be installed in inconspicuous areas such as utility closets or beneath stairs. Studies and agency experience have shown that vapor concentrations beneath slabs can be highly variable (from point to point), and that it is not always the case that the highest levels will be found in the center of the structure⁶.

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Sub Slab Probe Construction

Temporary probes may be acceptable in cases where vapor impacts are unlikely and/or installation is conducted during the early fall, when vapor build up is likely to be at a maximum. Otherwise, permanent installations are preferred (though most consultant/LSPs are often reluctant to commit in this regard). Permanent sub-slab



SECTION II - TECHNICAL

Figure II-5: Example sub-slab soil gas probe construction

probes should be small (less than 1 inch in diameter) installations designed to sample the space immediately beneath the slab. Often, differential settlement beneath floor slabs leads to an interconnected series of void spaces that may have a pronounced affect on soil gas movement and collection, and thus should be included in characterization efforts. As short circuiting during sub-slab probe sampling efforts is a significant concern, these probes must be constructed in a

manner to ensure an airtight connection with the subsurface. One possible design is depicted in Figure II-5.

How to Sample Sub-Slab Probes

Sub-slab probes can be sampled using air pumps, meters (e.g., PID meters), and/or

vacuum canisters, with vapor collection into a Summa canister, Tedlar bags, or some other suitable container (note that BWSC/NERO has demonstrated acceptable accuracy for screening purposes by vapor sampling into a common 40 mL VOA vial).

It is not necessary to obtain "time weighted average" samples of sub slab soil gases. However, care should be exercised to avoid sampling at too high a rate or via too high a vacuum, as this can lead to short-circuiting. The California EPA and US EPA staff have recommended a maximum sampling rate of 0.1 to 0.2 Liters/minute.⁶ Empirical and mathematical evaluations of "purge volume" concerns indicate that pre-evacuation of 5 probe volumes should suffice⁶. For a ½ inch diameter probe cored 4 inches into/through a basement slab, 5 probe volumes would equate to approximately 250 mL (about 1-2 minutes of sampling with a PID meter).

The use of a PID meter for obtaining sub-slab vapor samples is also advantageous in that it can produce continuous, real-time concentration data, to evaluate trends, and/or detect possible short-circuiting situations (See Figure II-6). As a PID is non-destructive, samples can be obtained from the outlet of the meter (e.g., tubing on outlet attached to Tedlar bag).

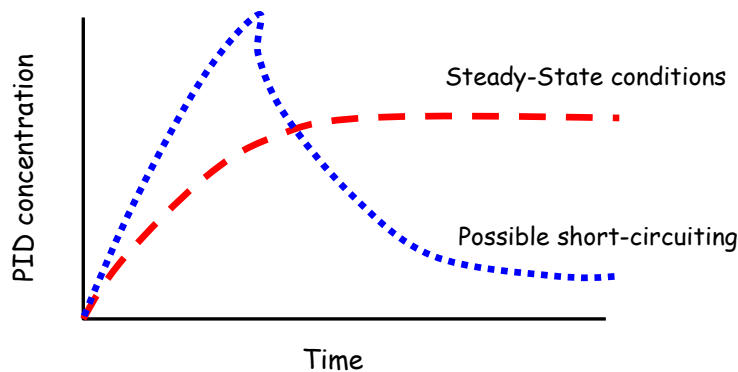


Figure II-6: Real-time monitoring during probe sampling

When to Sample Sub-Slab Probes

Whereas "worst case" indoor-air impacts to a structure are often in the winter months (December to March), maximum sub-slab vapor concentrations may occur during the early fall, just before heating systems are activated. Under this model, vapor levels build up under the slab over the spring and summer months, via diffusion processes. While such a scenario has been observed at certain sites, other site-specific variables (e.g., depth to groundwater) could lead to alternative results. However, at a minimum, it would be advisable to require the testing of (permanent) sub-slab soil probes during the early fall (September - October) and

during the winter months (January - February).

Recommended Analytical Testing of Sub-Slab Probes

In some cases, use of a PID meter may be sufficient to rule out vapor intrusion pathways. This should generally be limited to petroleum contamination only (i.e., not for chlorinated solvents). Tedlar bag (or other container samples) are generally analyzed via a GC procedure (e.g., using an FID, PID, and/or ECD/ELCD detector). Summa canisters are generally analyzed by TO or APH procedures.

AIR TESTING PARAMETERS AND METHODS

A summary of air testing approaches and methodologies is contained in Section IV, Toolbox 2. In the vast majority of cases, VOCs and/or petroleum hydrocarbons are the contaminants of interest in the investigation of a vapor migration pathway.

VOC screening may be done via PID or GC methods. Definitive characterization is accomplished via a GC/MS technique, most often via EPA Method TO-15, which collects whole air samples in specially prepared canisters (e.g., SUMMA®). Collecting whole air samples in this manner is advantageous, to avoid "break through" issues with sorbent tubes, and to allow the lab to draw multiple samples, if needed. In some cases, it may be necessary to use other VOC sampling and analysis methods, including Method TO-1 and TO-2.

The APH Method is a DRAFT procedure developed by MassDEP to characterize the composition and concentrations of complex mixtures of petroleum hydrocarbons (e.g., gasoline, kerosene, jet fuel and fuel oils) in air samples. Data are generated in a format that permits characterization of the exposures and risks from those exposures using MassDEP's VPH framework. Originally issued in 2000, it has yet to be finalized, although a number of laboratories are conducting the procedure. Basically a modification of EPA Method TO-15, the APH Method as written utilizes SUMMA® canisters to collect whole air samples. While conceptually sound, and capable of producing reliable data, there are still concerns over the capabilities of the method; specifically, its ability to reliably detect and quantitate heavier molecular weight hydrocarbons (e.g., naphthalenes). It is possible that the method may either under-report these compounds (because they adhere to the SUMMA® canister and are not introduced into the GC), or over-report these compounds (when carry-over compounds from a previous use of the canister get released to the GC).

When should staff select/require TO-15 as opposed to the APH procedure? Clearly, when dealing with non-petroleum contaminants (e.g., PCE, TCE), use of TO-15 is sufficient. When dealing with petroleum sources, the following guidelines should be applied:

- APH is in general the preferred method. However, this method is still draft, and not utilized by all air testing laboratories. Moreover, in laboratories that do conduct this procedure, it is slightly more costly than Method TO-15 (perhaps 20 - 25% more expensive).
- When suspicions exist of a vapor-infiltration pathway via off-gassing from a migrating dissolved hydrocarbon plume, the use of TO-15 may be acceptable. In these situations, it is the soluble component of the fuels that generally predominate the mixture (e.g., BTEX), and significant concentrations of aliphatic and aromatic hydrocarbon fractions are less likely to be present. However, this assumption must be verified through an evaluation of groundwater chemistry (e.g., does the groundwater at this location have significant concentrations of VPH hydrocarbon fractions) and/or qualitative evaluation of the TO-15 total ion chromatogram (e.g., to demonstrate the lack of numerous non-target peaks suggestive of a more complex mixture).
- When separate-phase fuel is believed to be the source of vapors (e.g., LNAPL), a more complex mixture is likely to be present, and APH (or equivalent techniques) must be used.

When undertaking testing programs using either TO-15 or APH procedures, it is important to use the Conceptual Site Model approach to optimize efforts and minimize expenses:

- ☞ It is usually not necessary to obtain 24-hour time-weighted canister samples; a difficult and expensive proposition. Note that this time interval originated from ambient air testing programs, where concentrations of contaminants varied over a 24-hour period due to industrial emissions and/or atmospheric conditions. That is usually not the case when assessing a subsurface vapor migration pathway, especially in basements, where vapor infiltration is more related to building depressurization phenomena. In cases where "steady state" conditions are likely to exist, with respect to basement ventilation and furnace operations, 4-hour sample collection is usually sufficient.
- ☞ It is often not necessary to obtain samples on each floor of a potentially impacted structure, absent a site-specific reason to do so (e.g., HVAC system with basement air intake and sensitive receptors on upper floors). Generally, a basement and first floor samples should suffice, to obtain lines of evidence for an environmental pathway (i.e., sample chemistry and concentrations in basement vs. first floor sample). In cases where significant concentrations of contaminants are present in lower living units, however, it would be appropriate to test additional overlying floors as necessary to define attenuation, especially if sensitive receptors are present (e.g., bedrooms for children).

MITIGATING RISKS FROM VAPOR INFILTRATION PATHWAY

Degree of Mitigation

Once a pathway of relevance is confirmed, it should be evaluated with respect to risk issues and, in cases of homes and schools, Critical Exposure Pathways:

- in all cases, an Imminent Hazard condition must be promptly addressed and eliminated. Eventually, a condition of No Significant Risk must be achieved; and
- to the extent feasible, Critical Exposure Pathways must be eliminated or mitigated, with feasible defined as benefit vs. cost. Note that feasible in this context is not synonymous with possible, but must consider such issues as effectiveness, costs, fate of contaminant, access, and logistical issues. *If the owner of an owner-occupied home does not want a sub-slab depressurization system installed or operated in his/her home, and if a condition of No Significant Risk exists, that measure would be considered infeasible, with respect to the need to address a Critical Exposure Pathway.*

Approach

In general, after conducting any necessary emergency response activities (e.g., building venting), further mitigative remedial measures should generally proceed in an iterative fashion, starting with the least invasive/least costly, and progressing as needed to more and more invasive and costly measures, until remedial endpoints are achieved (see Flowchart II-3).

ONGOING COMMERCIAL/INDUSTRIAL OPERATIONS

When evaluating human health risks from an environmental release of OHM (e.g., vapor infiltration pathway), the appropriate metrics are the MCP risk management standards (Hazard Index & ECLR), not occupational health standards (e.g., OSHA standards). The only time worker safety standards are appropriate when evaluating environmental exposures is in the protection of site remediation workers (per 40.0018).

While it is not permissible to evaluate environmental exposures using occupational health standards, there are sites where consideration of ongoing commercial/industrial activities is appropriate. The most common situations of this nature involve active dry cleaners and active petroleum dispensing operations, where the environmental chemicals of concern are also being used at the site as part of a permitted commercial or industrial operation, and where the environmental

component of exposure/risk is insignificant, in comparison to the process-related emissions. In such cases, it does not make sense to require a remedial measure (e.g., SSD system) to protect on-site workers to IRA risk-management metrics, if ongoing and allowable occupational exposures to the same chemical are substantially higher.

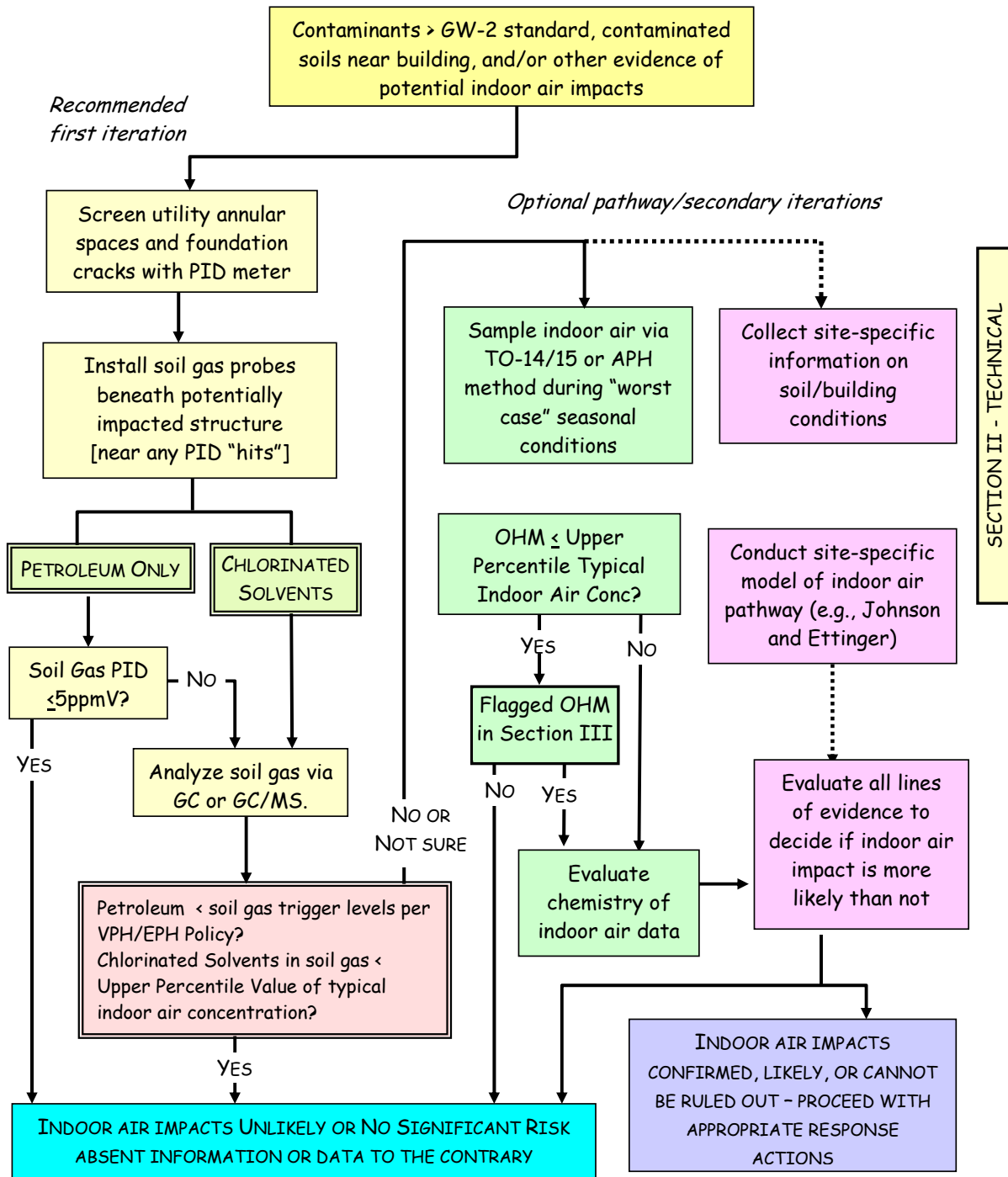
In such cases, the following approach will be applied:

- The vapor intrusion pathway shall NOT be considered in an Imminent Hazard or Substantial Hazard evaluation in areas of an on-going commercial or industrial operation where permitted uses and discharges of the chemical(s) of concern are present within the indoor air, at concentrations at least one order of magnitude higher than the levels that would be present in that space based upon the vapor intrusion pathway alone. This is consistent with the focus of the Imminent and Substantial Hazard evaluations in 40.0953 and 40.0956 on current site uses and current site conditions.
- The vapor intrusion pathway WILL be considered a relevant foreseeable exposure pathway in such ongoing commercial or industrial operations for the purposes of evaluating a site for a condition of No Significant Risk.
- The vapor intrusion pathway WILL be considered a continuing source of inter-media mass transfer of OHM, per 40.1003(5), in all cases where such a pathway is or could result in indoor air concentrations of the chemical(s) of concern that would be deemed a condition of Significant Risk. In such cases, the filing of a Class A or B RAO would not be permissible.

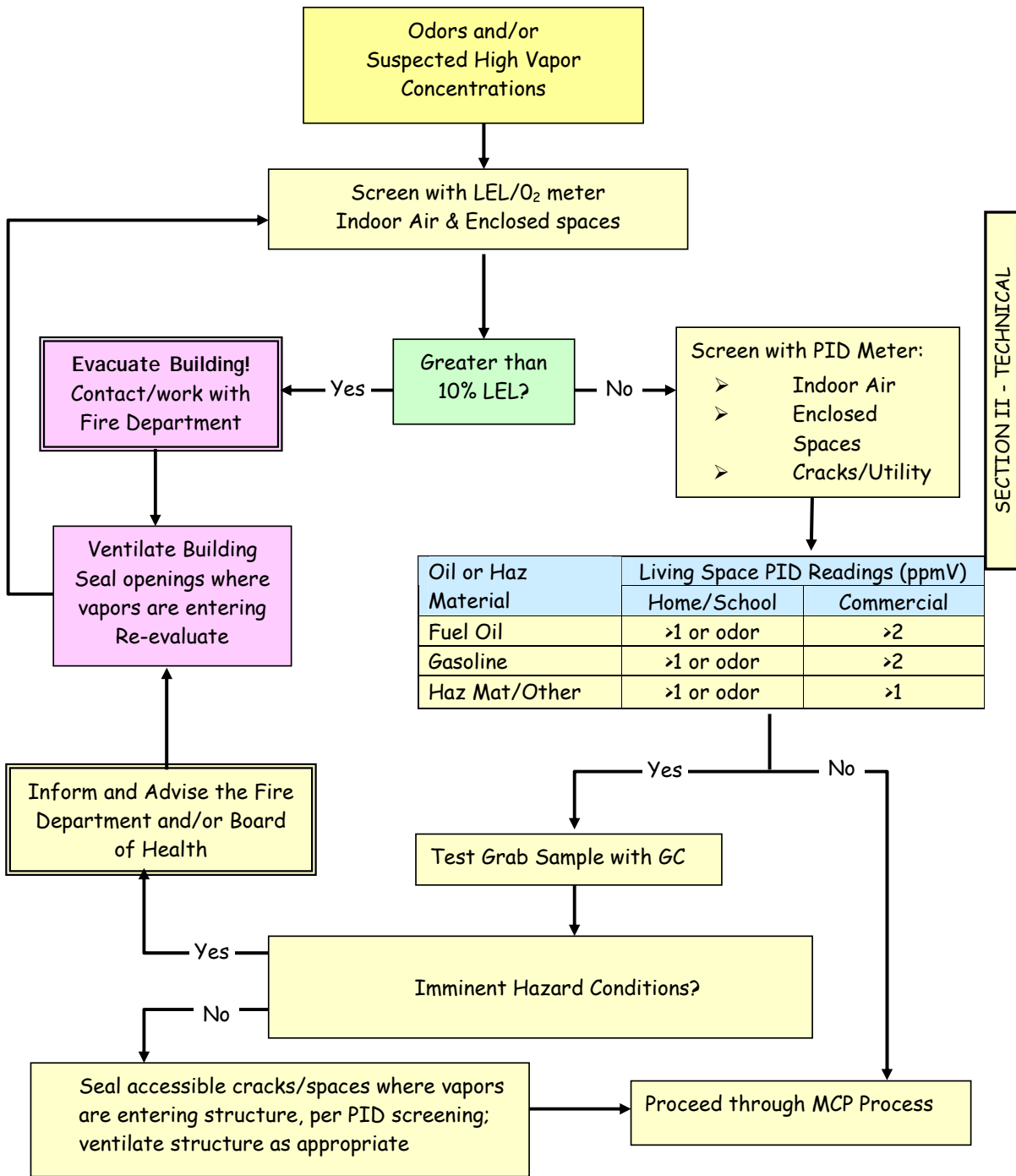
It is important to stress that the above approach applies only to ongoing and active business, commercial, and/or industrial operations that are actively using the chemicals of concern in a licensed and permitted manner. Vapor discharges into neighboring buildings or spaces that are NOT licensed and permitted to operate such processes and do not use such chemicals are appropriate exposures that should be considered in an Imminent Hazard and Substantial Hazard evaluation. (e.g., neighboring/common-wall businesses in a strip mall containing a dry cleaner should be evaluated for Imminent and Substantial Hazards via this pathway).

Moreover, the approach stated above would no longer be applicable at active operations if and when the site use changes (e.g., when an active dry cleaning operation is terminated).

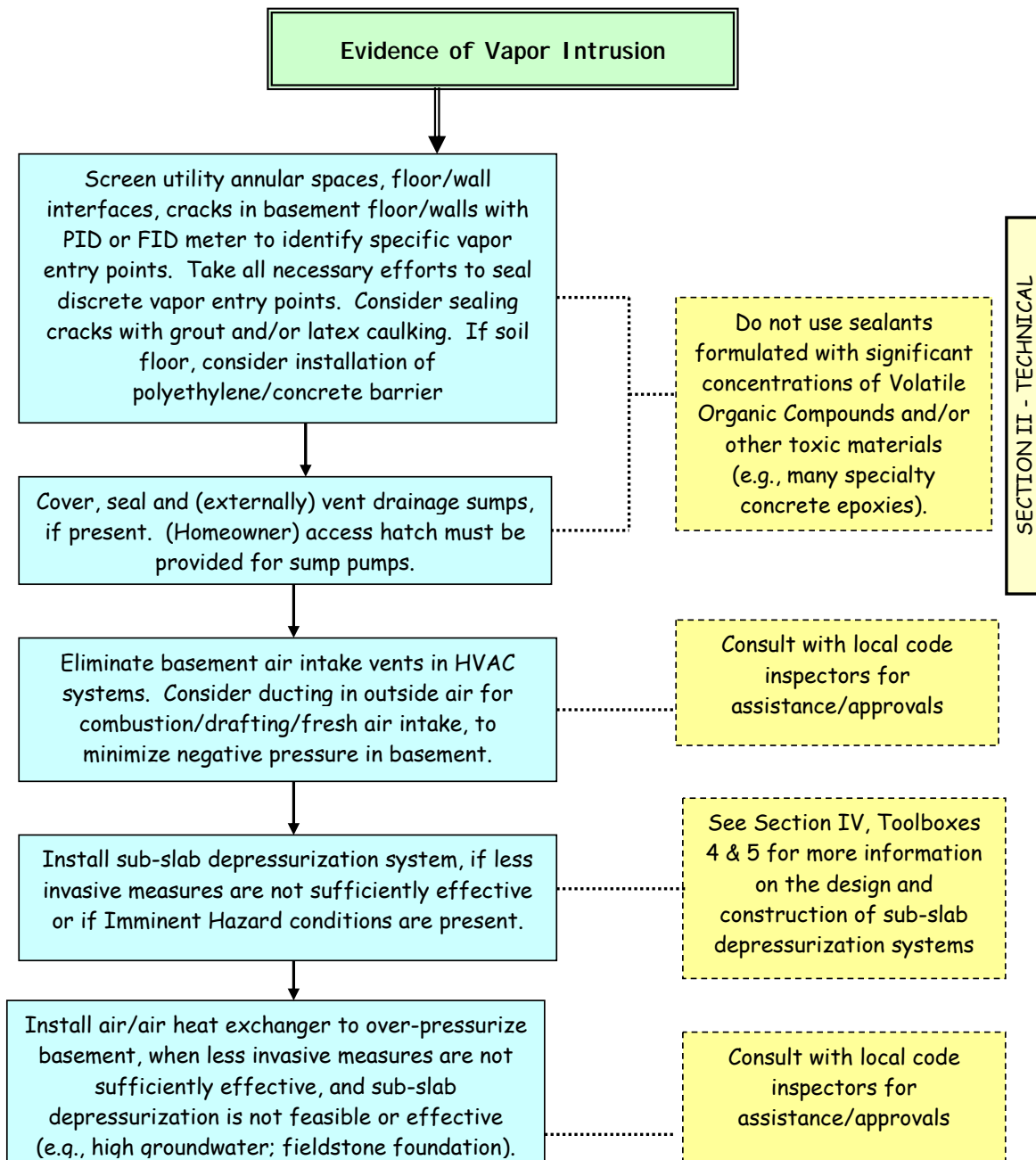
Flowchart II-1: Vapor Pathway Lines of Evidence



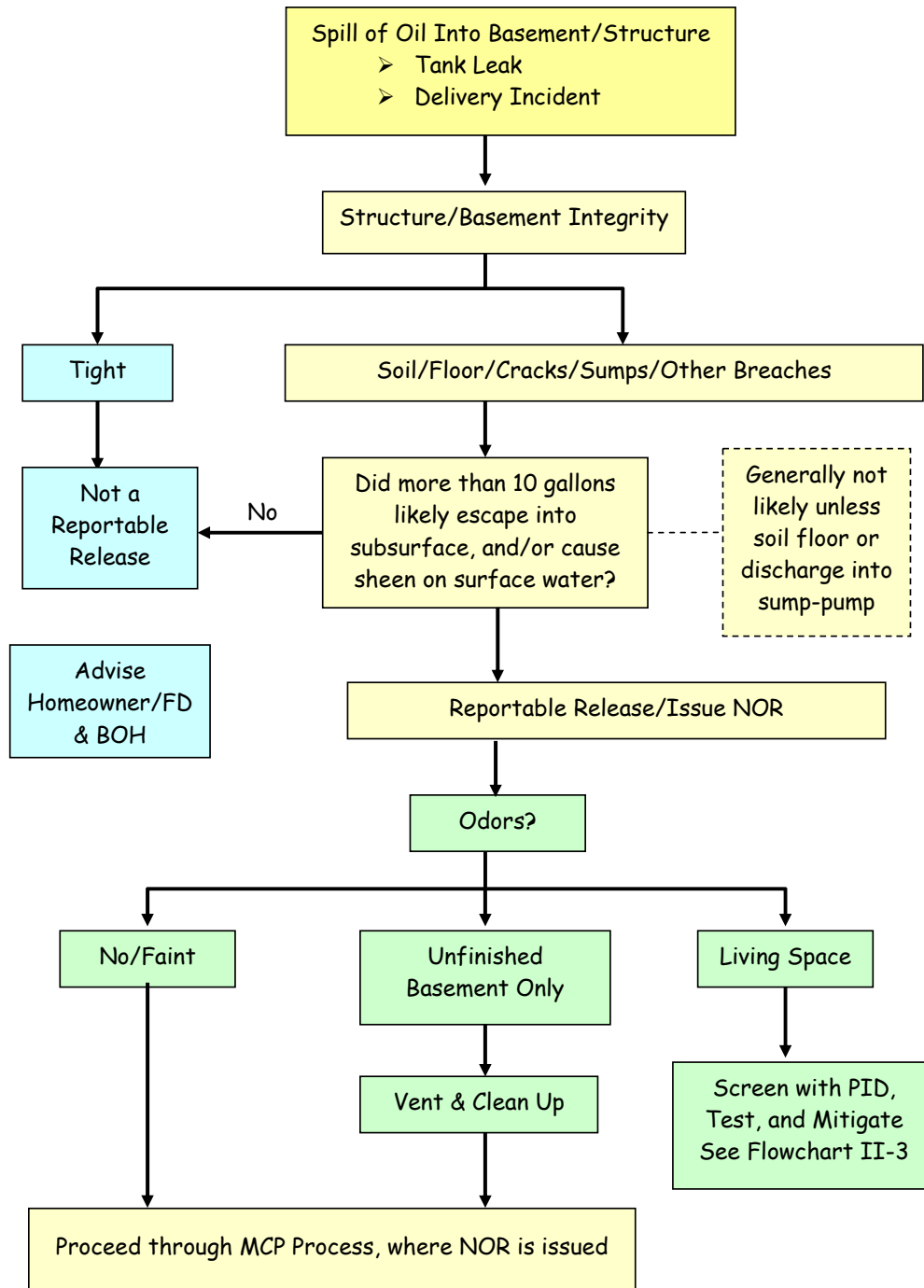
Flowchart II-2: Response Approach to Emergency Conditions



Flowchart II-3: Hierarchy of Vapor Mitigation Efforts
Following Emergency Actions/Venting



Flowchart II-4: Residential Fuel Oil Spills



SECTION II - TECHNICAL

¹ Johnson, Paul C. and Ettinger, R.A., *Heuristic Model for Predicting the Intrusion Rate of Contaminated Vapors Into Buildings*, ES&T, 1991, 25, 1445-1452.

² Nazaroff, W.W. et. Al., *Experiments on Pollutant Transport from Soil into Residential Basements by Pressure-Driven Airflow*, ES&T, 1987, 21, 459-466

³ Bonnefous, Y.C., et. Al., *Field Study and Numerical Simulation of Subslab Ventilation Systems*, ES&T, 1992, 26, 1752-1759.

⁴ Garbesi, K., et al., *Soil Gas Entry Into an Experimental Basement: Model Measurement Comparisons and Seasonal Effects*, ES&T, 1993, 27, 466-473.

⁵ API, *Collecting and Interpreting Soil Gas Samples from the Vadose Zone*, Publication Number 4741, November 2005

⁶ DiGiulio, Dominic C., and Paul, Cynthia J., *Assessment of Vapor Intrusion in Homes Near the Raymark Superfund Site Using Basement and Sub-Slab Air Samples*, EPA/600/R-05/147, March 2006.

⁷⁷ Unpublished Data, Haley and Aldrich, *Residential Indoor Air Quality Data, Massachusetts .Indoor Air Background Study - 2004/2005*.



SOP BWSC-07-01

SECTION III

MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION
 BUREAU OF WASTE SITE CLEANUP
Standard Operating Procedure
Response to Indoor Air Contamination
 SECTION III - INDOOR AIR CONTAMINANT LOOK-UP TABLES

Approved By	Date	Pages	Contact Person
Janine Commerford	August 2007	19	John Fitzgerald

This SOP addresses situations where releases of oil and/or hazardous materials have or may adversely impact air quality within occupied buildings, generally via a subsurface vapor transport pathway. Its purpose is to:

- ☞ emphasize the importance of indoor-air contamination problems;
- ☞ articulate clear operational responsibilities and lines of communications; and
- ☞ provide program staff with technical information and guidelines, procedural recommendations, and practical *Rules of Thumb* to enable them to better understand, recognize, prioritize, and respond to indoor air contamination events.

This SOP is segmented into four Sections:

- ❖ Section I - A "bottom line" articulation of operational expectations on looking for, assessing, remediating, and managing/communicating vapor intrusion situations;
- ❖ Section II - Technical concepts, guidelines, procedures, and recommendations on investigating and addressing vapor intrusion pathways;
- ❖ Section III - Look-up Tables for Indoor Air Contaminants; and
- ❖ Section IV - A "Toolbox" of practical forms, procedures, guidelines, data, and informational resources, including standardized bid specifications for state-funded installations of sub-slab depressurization systems..

All staff are expected to become familiar with the operational expectations of Section I, and cognizant of the availability of the detailed guidelines contained in Sections II through IV, for use as the need arises.

No document can anticipate, explain, and/or address every facet of such a complex subject and phenomenon, and nothing contained herein is meant to obviate or limit the exercise of good professional judgment.

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Table 1	Indoor Air Concentration Look-up Table Residential/School Criteria
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USE MASSDEP "SHORT FORMS" FOR MOST UP-TO-DATE RISK CALCULATIONS AND FOR MULTIPLE CONTAMINANTS

Contaminant	MCP No Significant Risk ¹				MCP Imminent Hazard ²		Upper Percentile Value of typical indoor air conc ³		Convert Factor ⁸ $\frac{\mu\text{g}/\text{m}^3}{\text{ppbV}}$
	HI = 0.2		ELCR = 1×10^{-6}		$\mu\text{g}/\text{m}^3$	ppbv	$\mu\text{g}/\text{m}^3$	ppbv	
	$\mu\text{g}/\text{m}^3$	ppbv	$\mu\text{g}/\text{m}^3$	ppbv					
ACETONE	160	67			8000	3400			2.37
ALDRIN (pesticide)	0.02	0.001	3 EE^{-4}	3 EE^{-5}	0.03	0.002			14.93
BENZENE	6.0	1.8	0.3	0.1	21	6.6			3.19
BIPHENYL, 1,1-	0.4	0.1			20	3.2			6.3
BIS(2-CHLOROETHYL)ETHER			0.007	0.001	0.4	0.1			5.85
BIS(2-CHLOROISOPROPYL)ETHER	28	4.0	0.2	0.03	14	2.0			6.99
BROMODICHLOROMETHANE	14	2.0	0.1	0.02	7.9	1.1			6.71
BROMOFORM	14	1.4	2.1	0.2	130	13			10.35
BROMOMETHANE	1	0.3			50	13			3.89
CARBON TETRACHLORIDE	86	13	0.2	0.03	9.3	1.5			6.3
CHLORDANE (pesticide)	0.1	0.008	0.02	0.001	1.4	0.1			16.77
CHLOROANILINE, p-	2.8	0.5			140	27			5.24
CHLOROBENZENE	4	0.9			200	43			4.62
CHLOROFORM	130	27	0.1	0.02	6.1	1.3			4.87
CHLOROPHENOL, 2-	3.5	0.7			180	34			5.28
DIBROMOCHLOROMETHANE	14	1.7	0.1	0.01	5.8	0.7			8.51
DICHLOROBENZENE, 1,2- (o-DCB)	40	6.6			2000	330			6.01

Contaminant	MCP No Significant Risk ¹				MCP Imminent Hazard ²		Upper Percentile Value of typical indoor air conc ³		Convert Factor ⁸ $\frac{\mu\text{g}/\text{m}^3}{\text{ppbV}}$
	HI = 0.2		ELCR = 1×10^{-6}		$\mu\text{g}/\text{m}^3$	ppbv	$\mu\text{g}/\text{m}^3$	ppbv	
	$\mu\text{g}/\text{m}^3$	ppbv	$\mu\text{g}/\text{m}^3$	ppbv	$\mu\text{g}/\text{m}^3$	ppbv	$\mu\text{g}/\text{m}^3$	ppbv	
DICHLOROBENZENE, 1,3- (m-DCB)	40	6.6			2000	330			6.01
DICHLOROBENZENE, 1,4- (p-DCB)	160	26	0.3	0.1	20	3			6.01
DICHLOROETHANE, 1,1-	100	25			5000	1200			4.05
DICHLOROETHANE, 1,2-	11	2.7	0.1	0.02	5.4	1.3			4.05
DICHLOROETHYLENE, 1,1-	40	10			2000	500			3.97
DICHLOROETHYLENE, CIS-1,2-	7	1.7			350	88			3.97
DICHLOROETHYLENE, T-1,2-	14	3.5			700	180			3.97
DICHLOROMETHANE (MeCl)	600	170	5	1.4	300	86			3.48
DICHLOROPHENOL, 2,4-	2.1	0.3			110	17			6.67
DICHLOROPROPANE, 1,2-	0.8	0.2	0.1	0.03	7.4	1.6			4.62
DICHLOROPROPENE, 1,3-	4	0.9	0.6	0.1	35	7.7			4.54
DIELDRIN (pesticide)	0.04	0.002	5 EE^{-4}	3 EE^{-5}	0.03	0.002			15.58
DIETHYL PHTHALATE	560	61			28000	3000			9.08
DIMETHYL PHTHALATE	7000	880			3.5 EE^{+5}				7.93
DIMETHYLPHENOL, 2,4-	14	2.8			700	140			4.99
DINITROPHENOL, 2,4-	1.4	0.2			70	9.3			7.53
DINITROTOLUENE, 2,4-	1.4	0.2	0.01	0.002	0.7	0.01			7.44

Table 1	Indoor Air Concentration Look-up Table Residential/School Criteria
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USE MASSDEP "SHORT FORMS" FOR MOST UP-TO-DATE RISK CALCULATIONS AND FOR MULTIPLE CONTAMINANTS

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	HI = 0.2		ELCR = 1×10^{-6}						
	$\mu\text{g}/\text{m}^3$	ppbv	$\mu\text{g}/\text{m}^3$	ppbv	$\mu\text{g}/\text{m}^3$	ppbv	$\mu\text{g}/\text{m}^3$	ppbv	
DIOXANE, 1,4-	24	6.7	0.6	0.2	34	9.4			3.6
ETHYLBENZENE	200	46			10000	2300			4.34
ETHYLENE DIBROMIDE	2	0.3	0.01	0.001	0.6	0.08			7.69
HEPTACHLOR (pesticide)	0.2	0.01	0.002	1 E^{-4}	0.1	0.007			15.26
HEPTACHLOR EPOXIDE (pesticide)	0.009	0.001	9 E^{-4}	6 E^{-5}	0.05	0.003			15.91
HEXACHLOROBENZENE	0.6	0.05	0.005	4 E^{-4}	0.3	0.03			11.66
HEXACHLOROBUTADIENE	0.1	0.01	0.1	0.01	6.4	0.6			10.67
HEXACHLOROCYCLOHEXANE, (gamma-HCH) (Lindane, a pesticide)	0.2	0.02	0.006	0.001	0.4	0.03			11.9
HEXACHLOROETHANE	0.6	0.06	0.6	0.1	30	3.1			9.69
MERCURY	0.1	0.007			3	0.4			8.22
METHYL ETHYL KETONE	1000	340			50000	1700			2.94
METHYL ISOBUTYL KETONE	600	150			30000	7300			4.09
METHYL MERCURY	0.004				0.2	0.02			8.22
METHYL TERT BUTYL ETHER	600	170			30000	8300			3.6
METHYLNAPHTHALENE, 2-	10	1.7			500	86			5.81
NAPHTHALENE (mothballs)	0.6	0.1			30	5.7			5.24

Table 1	Indoor Air Concentration Limits Residential/School Criteria	Note: The risk-based concentrations for tetrachloroethylene have been calculated using the Unit Risk Factor published by MassDEP. This value is under review. When the revised URF is final, this table will be revised accordingly. See http://mass.gov/dep/toxics/sourcest.htm#chemical .
USE MASSDEP "SHORT FORMS" FOR MOST UP-TO-DATE RISK CALCULATIONS		

Contaminant	MCP No Significant Risk ¹				MCP Imminent Hazard ²		Upper Percentile Value of typical indoor air conc ³		Convert Factor ⁸ μg/m ³ ppbV
	HI = 0.2		ELCR = 1 x 10 ⁻⁶		μg/m ³	ppbv	μg/m ³	ppbv	
	μg/m ³	ppbv	μg/m ³	ppbv					μg/m ³
PENTACHLOROPHENOL	0.01	0.001	0.07	0.006	0.7	0.06			10.88
PETROLEUM HYDROCARBONS									
Aliphatics									
C5 to C8	40	N/A		N/A	2000	N/A			N/A
C9 to C12	40				2000	N/A			N/A
PETROLEUM HYDROCARBONS									
C9 to C10 Aromatics	10	N/A		N/A	500	N/A			N/A
PHENANTHRENE	10	1.4			500	69			7.28
PHENOL	52	14			2700	700			3.84
PYRENE	10	1.2			500	61			8.26
RDX	2.1	0.2	0.1	0.01	4.5	0.5			9.08
STYRENE	200	47	4.1	1.0	250	59			4.25
TETRACHLOROETHANE, 1,1,1,2-	21	3.1	0.3	0.05	19	2.8			6.87
TETRACHLOROETHANE, 1,1,2,2-	19	2.7	0.04	0.006	2.4	0.4			6.87
TETRACHLOROETHYLENE	920	140	0.04	0.006	2.6	0.4			6.79
TOLUENE	1000	270			50000	13300			3.76
TRICHLOROBENZENE, 1,2,4-	40	5.4			2000	270			7.4

Contaminant	MCP No Significant Risk ¹		MCP Imminent Hazard ²		Upper Percentile Value of typical indoor air conc ³		Convert Factor ⁸		
	HI = 0.2		ELCR = 1 x 10 ⁻⁶				$\frac{\mu\text{g}/\text{m}^3}{\text{ppbV}}$		
	$\mu\text{g}/\text{m}^3$	ppbv	$\mu\text{g}/\text{m}^3$	ppbv	$\mu\text{g}/\text{m}^3$	ppbv	$\mu\text{g}/\text{m}^3$	ppbv	
TRICHLOROETHANE, 1,1,1-	1000	190			52000	9500			5.46
TRICHLOROETHANE, 1,1,2-	15	2.7	0.2	0.03	10	1.8			5.46
TRICHLOROETHYLENE	36	6.7	1.4	0.3	82	15			5.36
TRICHLOROPHENOL, 2,4,5- (pesticide)	70	8.7			3500	430			8.06
TRICHLOROPHENOL 2,4,6- (pesticide)			0.8	0.09	45	5.6			8.06
VINYL CHLORIDE	20	7.8	0.3	0.1	16	6.2			2.58
XYLENES (Mixed Isomers)	20	4.6			1000	230			4.34

Understanding and Correctly Using Table 1: Residential/School Criteria

Note	Explanation
1	The "MCP No Significant Risk" concentration values correspond to a Hazard Index (HI) of 0.2 and, for carcinogens, an Excess Lifetime Cancer Risk (ELCR) level of 1×10^{-6} . These indices are MORE CONSERVATIVE than the "Bottom Line" MCP risk management standards of HI=1 and ELCR= 1×10^{-5} , in order to account of the presence of multiple contaminants. The LOWER of the HI and ELCR values should be applied to determine acceptable indoor air concentration values. If indoor air is predominantly or exclusively contaminated by ONE compound, multiply the [HI = 0.2] value by 5 to derive an acceptable concentration for non-cancer health effects, and the [ELCR = 1×10^{-6}] value by 10 to derive an acceptable concentration for cancer risks.
2	The "MCP Imminent Hazard" concentration values were derived by: <ul style="list-style-type: none"> ☞ Multiplying the [HI = 0.2] value by 50 [to calculate an HI value of 10, which is defined at 40.0955 to be an Imminent Hazard] ☞ Multiplying the [ELCR = 1×10^{-6}] value by 60 [$\times 10$ to go to 1×10^{-5} value then $\times 30$ years/5 years for short-term exposures] The LOWER of the HI and ELCR values were used to determine the Imminent Hazard concentration.
3	Data from selected databases (See http://www.mass.gov/dep/cleanup/iawq.htm). For most contaminants, 90 th percentile concentrations are provided. For those contaminants where the 90 th percentile concentration is in excess of MCP risk management standards, the 75 th percentile value is provided. If the 75 th percentile value is still in excess of MCP risk management standards, a "flag" is notated, and the value is in bold. For flagged/bolded contaminants, it is necessary to obtain multiple lines of evidence to confirm or refute the existence of a vapor intrusion pathway. Note that these values are in most cases DIFFERENT from "background" values used to derived the MCP Method 1 GW-2 standards (through 2006). For contaminants that are not flagged/bolded, for purposes of making determinations on vapor intrusion or the existence of a Critical Exposure Pathway, the detection of indoor air contaminants at or below an Upper Percentile Value of typical indoor air concentrations should generally terminate the need for further investigation. This assumes that adequate testing has been conducted over a sufficient period of time, including expected "worst case" conditions during winter months.
4	These compounds are biological breakdown products of chlorinated solvents, and are reportedly not contained in most commercial products in significant concentrations. Therefore, they are unlikely to be detected within un-impacted buildings. Their presence within indoor air would be evidence of a vapor intrusion pathway.
5	It is important to note the units when evaluating air contaminant data. The two most common units are $\mu\text{g}/\text{m}^3$ and parts-per-billion by volume (ppbv). It is possible to convert between units by using the Ideal Gas Law. The values in this column may be used for this purpose, i.e., [Concentration in $\mu\text{g}/\text{m}^3$] / [Conversion Factor] = [Concentration in ppbv]. Many people mix up units when looking at air standards - ALWAYS double-check to make sure you are clear on this!

Table 2	Indoor Air Concentration Look-up Table Commercial/Industrial Criteria					
	Contaminant	Commercial Office & Retail Imminent Hazard ¹		Occupational Exposure Concentration Limits 8 hours/day (Lower of OSHA PEL or NIOSH REL) ²		Convert Factor ³ $\mu\text{g}/\text{m}^3$ ppbV
		$\mu\text{g}/\text{m}^3$	ppbv	$\mu\text{g}/\text{m}^3$	ppbv	
ACETONE	27,000	11,000	590,000	250,000	2.37	
ALDRIN (pesticide)	0.1	0.01	300	20	14.93	
BENZENE	71	22	320	100	3.19	
BIPHENYL, 1,1-	68	11	1300	200	6.3	
BIS(2-CHLOROETHYL)ETHER	1.4	0.2	29,000	5000	5.85	
BIS(2-CHLOROISOPROPYL)ETHER	48	6.8	NL	NL	6.99	
BROMODICHLOROMETHANE	27	3.7	NL	NL	6.71	
BROMOFORM	440	43	5200	500	10.35	
BROMOMETHANE	170	44	78,000	20,000	3.89	
CARBON TETRACHLORIDE	32	5.1	13,000	2000	6.3	
CHLORDANE (pesticide)	4.8	0.3	500	30	16.77	
CHLOROANILINE, p-	470	91	NL	NL	5.24	
CHLOROBENZENE	680	150	350,000	75,000	4.62	
CHLOROFORM	21	4.4	9700	2000	4.87	
CHLOROPHENOL, 2-	610	120	NL	NL	5.28	
DIBROMOCHLOROMETHANE	20	2.4	NL	NL	8.51	
DICHLOROBENZENE, 1,2- (o-DCB)	6800	1100	300,000	50,000	6.01	

Table 2	Indoor Air Concentration Look-up Table Commercial/Industrial Criteria					
	Contaminant	Commercial Office & Retail Imminent Hazard ¹		Occupational Exposure Concentration Limits 8 hours/day (Lower of OSHA PEL or NIOSH REL) ²		Convert Factor ³ $\frac{\mu\text{g}/\text{m}^3}{\text{ppbV}}$
		$\mu\text{g}/\text{m}^3$	ppbv	$\mu\text{g}/\text{m}^3$	ppbv	
DICHLOROBENZENE, 1,3- (m-DCB)	6800	1100	NA	NA	6.01	
DICHLOROBENZENE, 1,4- (p-DCB)	68	10	450,000	75,000	6.01	
DICHLOROETHANE, 1,1-	17000	4200	410,000	100,000	4.05	
DICHLOROETHANE, 1,2-	18	4.4	4000	1000	4.05	
DICHLOROETHYLENE, 1,1-	6800	1700	NA	NA	3.97	
DICHLOROETHYLENE, CIS-1,2-	1200	300	400,000	100,000	3.97	
DICHLOROETHYLENE, TRANS-1,2-	2400	600	800,000	200,000	3.97	
DICHLOROMETHANE (MeCl)	1000	290	87,000	25,000	3.48	
DICHLOROPHENOL, 2,4-	370	56	NL	NL	6.67	
DICHLOROPROPANE, 1,2-	25	5.4	350,000	75,000	4.62	
DICHLOROPROPENE, 1,3-	120	26	4500	1000	4.54	
DIELDRIN	0.1	0.007	250	16	15.58	
DIETHYL PHTHALATE	95,000	10,000	5000	550	9.08	
DIMETHYL PHTHALATE	1 EE +6		50,000	630	7.93	
DIMETHYLPHENOL, 2,4-	2400	480	NL	NL	4.99	
DINITROPHENOL, 2,4-	240	32	NL	NL	7.53	
DINITROTOLUENE, 2,4-	2.4	0.03	1500	200	7.44	
DIOXANE, 1,4-	120	32	3600	1000	3.6	

Table 2	Indoor Air Concentration Look-up Table Commercial/Industrial Criteria					
	Contaminant	Commercial Office & Retail Imminent Hazard ¹		Occupational Exposure Concentration Limits 8 hours/day (Lower of OSHA PEL or NIOSH REL) ²		Convert Factor ³ $\mu\text{g}/\text{m}^3$ ppbV
		$\mu\text{g}/\text{m}^3$	ppbv	$\mu\text{g}/\text{m}^3$	ppbv	
ETHYLBENZENE	34000	7800	430,000	100,000	4.34	
ETHYLENE DIBROMIDE	2.2	0.3	3800	50	7.69	
HEPTACHLOR (pesticide)	0.4	0.03	460	30	15.26	
HEPTACHLOR EPOXIDE	0.2	0.01	NL	NL	15.91	
HEXACHLOROBENZENE	1.0	0.1	NL	NL	11.66	
HEXACHLOROBUTADIENE	22	2.0	2100	20	10.67	
HEXACHLOROCYCLOHEXANE, GAMMA (gamma-HCH) - Lindane (pesticide)	1.3	0.1	500	42	11.9	
HEXACHLOROETHANE	100	11	9700	1000	9.69	
MERCURY	10	1.2	4900	60	8.22	
METHYL ETHYL KETONE	170000	58,000	590,000	200,000	2.94	
METHYL ISOBUTYL KETONE	100,000	25,000	210,000	50,000	4.09	
METHYL MERCURY	0.7	0.07	8	1	8.22	
METHYL TERT BUTYL ETHER	100,000	28,000	NL	NL	3.6	
METHYLNAPHTHALENE, 2-	1700	290	NL	NL	5.81	
NAPHTHALENE (mothballs)	100	19	520	10	5.24	
PENTACHLOROPHENOL (preservative)	2.4	0.2	540	50	10.88	
PETROLEUM HYDROCARBONS						

Contaminant	Commercial Office & Retail Imminent Hazard ¹		Limits 8 hours/day (Lower of OSHA PEL or NIOSH REL) ²		Convert Factor ³ $\mu\text{g}/\text{m}^3$ ppbV
	$\mu\text{g}/\text{m}^3$	ppbv	$\mu\text{g}/\text{m}^3$	ppbv	
	Aliphatics				
C5 to C8	6800	N/A	NL	NL	N/A
C9 to C12	6800	N/A	NL	NL	N/A
C9-C18	6800	N/A	NL	NL	N/A
Aromatics					
C9 to C10	1700	N/A	NL	NL	N/A
PHENANTHRENE	1700	230	NL	NL	7.28
PHENOL	9000	2300	19,000	5000	3.84
PYRENE	1700	210	NL	NL	8.26
STYRENE	850	200	210,000	50,000	4.25
TETRACHLOROETHANE, 1,1,1,2-	65	9.5	NA	NA	6.87
TETRACHLOROETHANE, 1,1,2,2-	8.2	1.2	6900	1000	6.87
TETRACHLOROETHYLENE	8.7	1.3	680,000	100,000	6.79
TOLUENE	170,000	45,000	380,000	100,000	3.76
TRICHLOROBENZENE, 1,2,4-	6800	920	370,000	5000	7.4
TRICHLOROETHANE, 1,1,1-	180,000	32,000	NA	NA	5.46
TRICHLOROETHANE, 1,1,2-	34	6.1	55,000	10,000	5.46
TRICHLOROETHYLENE	280	52	540,000	100,000	5.36

Note:
 The risk-based concentrations for tetrachloroethylene have been calculated using the Unit Risk Factor published by MassDEP. This value is under review. When the revised URF is final, this table will be revised accordingly.
 See <http://mass.gov/dep/toxics/sourcest.htm#chemical>.

Table 2	Indoor Air Concentration Look-up Table Commercial/Industrial Criteria					
	Contaminant	Commercial Office & Retail Imminent Hazard ¹		Occupational Exposure Concentration Limits 8 hours/day (Lower of OSHA PEL or NIOSH REL) ²		Convert Factor ³ $\frac{\mu\text{g}/\text{m}^3}{\text{ppbV}}$
		$\mu\text{g}/\text{m}^3$	ppbv	$\mu\text{g}/\text{m}^3$	ppbv	
TRICHLOROPHENOL, 2,4,5- (pesticide)	12,000	1500	NL	NL	8.06	
TRICHLOROPHENOL 2,4,6- (pesticide)	150	19	NL	NL	8.06	
VINYL CHLORIDE	54	21	2600	1000	2.58	
XYLENES (Mixed Isomers)	3400	780	430,000	100,000	4.34	

Understanding and Correctly Using Table 2: Commercial/Industrial Criteria

Note	Explanation
1	Commercial Office & Retail "Imminent Hazard" - These concentration values were derived by adjusting the residential/school Imminent Hazard (IH) concentration values (which assume 24/7 exposure) to a 50-hour/week-exposure assumption, i.e., multiplying by a factor of 3.36 (168 total hours in a week /50 hour work week).
2	<p>Occupational Exposure Concentration Limits - These are values that are legally permissible (OSHA Permissible Exposure Limits) and/or generally applied (NIOSH Recommended Exposure Limits) to protect workers from exposures to hazardous chemicals generated as part of a manufacturing or business-related process (NOT from environmental pathways). Most of these limits are substantially higher than what is considered acceptable under the MCP, primarily because occupational standards consider economic issues (unlike the MCP), and because less conservative factors are applied in interpreting toxicological data and setting risk management standards. These values are designed for healthy, adult workers and NOT for sensitive populations, such as children or pregnant women. Moreover, in the case of OSHA PELs, many standards are decades old and out-of-date, and have not been updated because of legal and/or political constraints.</p> <ul style="list-style-type: none"> ☞ When considering what is acceptable for exposures to MCP-regulated releases, <i>occupational standards alone are not sufficient</i>, even for healthy adults. An office or retail worker being exposed to PCE via a vapor intrusion pathway from an MCP-regulated release is subject to both OSHA and MCP risk management standards. In virtually all cases, the MCP acceptable risk standards (Hazard Index and Excess Lifetime Cancer Risk limits) are <u>much</u> more stringent than OSHA standards. ☞ While MCP standards generally dictate what is acceptable, it is important to note and consider the comparable occupational limit(s), to provide perspective in gauging the level of significance and sense of urgency of a situation, and to consider risk communication issues. For example, for MCP regulated releases, more than 8.7 ppbv of Tetrachloroethylene (PCE) in a store in a strip mall next to a dry cleaner could be considered an Imminent Hazard. Conversely, workers within that dry cleaner are legally allowed to be exposed to 100,000 ppbV of PCE from dry cleaning operations. This is a dichotomy that is difficult for the public (and even MassDEP staff) to comprehend, and we need to be sensitive to it.
3	It is important to note the units when evaluating air contaminant data. The two most common units are $\mu\text{g}/\text{m}^3$ and parts-per-billion by volume (ppbv). It is possible to convert between units by using the Ideal Gas Law. The values in this column may be used for this purpose, i.e., $[\text{Concentration in } \mu\text{g}/\text{m}^3] / [\text{Conversion Factor}] = [\text{Concentration in ppbv}]$. Many people mix up units when looking at air standards - ALWAYS check to make sure you are clear on this!
NL = Not Listed in cited source; NA = not available from cited source (even though the chemical may be listed) N/A = Not applicable	

Table 3	Indoor Air Concentration Look-up Table General Properties				NOTE UNITS!			
Contaminant	Vapor Density ¹	Sat Vapor Conc @ 70°F ²	50% Odor Recog Threshold ³	Odor Description	Explosivity Concern ⁴		PID Meter ⁵	
	Air = 1	ppmV	ppmV		Flash Point °F	LEL %	IP	CF @ 10.6 eV
ACETONE	2.0	256,000	6.5	Sweet, mint-like odor	0	2.5	9.69	1.1
ALDRIN	NA	NA	0.002	Mild chemical odor	NA	NA	NA	NL
AMMONIA	0.6	1,000,000	0.72	Pungent, suffocating odor	<0	15	10.18	9.70
BENZENE	2.77	104,000	0.76	Aromatic odor	12	1.2	9.24	0.53
BIPHENYL	5.31	NA	0.005	Pleasant characteristic odor	235	0.6	7.95	NL
BIS(2-CHLOROETHYL)ETHER	4.93	1,085	0.024	Fruity, pungent, chlorinated solvent-like odor	131	2.7	NA	NL
BIS(2-CHLOROISOPROPYL)ETHER	NA	NA	0.16	NA	NA	NA	NA	NL
BROMODICHLOROMETHANE	NA	NA	NA	NA	NA	NA	NA	NL
BROMOFORM	8.7	5,700	0.65	Chloroform-like odor	NA	NA	10.48	2.5
BROMOMETHANE	3.27	1,000,000	10.3	Chloroform-like odor	NA	NA	10.54	1.7
BUTYRALDEHYDE	2.5	123,000	0.009	Sweet rancid odor	20	2.5	NL	NL
CARBON TETRACHLORIDE	5.3	126,000	5	Characteristic ether-like odor	NA	NA	11.47	NL
CHLORDANE	14	NA	0.00025	Pungent chlorine-like odor	NA	NA	NL	NL
CHLORINE DIOXIDE	NA	1,000,000	NA	Unpleasant odor, similar to chlorine and nitric acid	NA	NA	10.31	NL
CHLORINE GAS	2.49	1,000,000	NA	Pungent, irritating odor	NA	NA	11.48	NL
CHLOROANILINE, p-	4.41	NA	NA	NA	235	2.2	NA	NL
CHLOROBENZENE	3.88	12,600	0.11	Almond-like odor	82	1.3	9.07	0.4

Table 3	Indoor Air Concentration Look-up Table				NOTE UNITS!			
	General Properties							
	Contaminant	Vapor Density ¹	Sat Vapor Conc @ 70°F ²	50% Odor Recog Threshold ³	Odor Description	Explosivity Concern ⁴		PID Meter ⁵
Air = 1		ppmV	ppmV	Flash Point °F		LEL %	IP	CF @ 10.6 eV
CHLOROFORM	4.12	218,000	43	Pleasant odor	NA	NA	11.42	NL
CHLOROPHENOL, 2-	NA	2,700	0.0018	Medicinal odor	NA	NA	NA	NL
DIBROMOCHLOROMETHANE	NA	NA	NA	NA	NA	NA	NA	5.3
DICHLOROBENZENE, 1,2- (o-DCB)	5.05	1,370	25	Pleasant aromatic odor	151	2.2	9.06	0.47
DICHLOROBENZENE, 1,3- (m-DCB)	5.08	2,200	NA	NA	146	2.02	NA	NL
DICHLOROBENZENE, 1,4- (p-DCB)	5.08	NA	0.09	Mothball-like odor	150	2.5	8.98	NL
DICHLOROETHANE, 1,1-	3.4	253,000	15	Chloroform-like odor	2	5.4	11.06	NL
DICHLOROETHANE, 1,2-	3.4	87,000	0.3	Pleasant, chloroform-like odor	56	6.2	11.05	NL
DICHLOROETHYLENE, 1,1-	NA	682,000	15.8	Mild, sweet chloroform-like odor	<70	6.5	10.00	0.82
DICHLOROETHYLENE, CIS-1,2-	3.34	227,000	NA	Slightly acrid, chloroform-like odor	36	9.7	9.65	0.80
DICHLOROETHYLENE, TRANS-1,2-	3.34	375,000	8.5	Slightly acrid, chloroform-like odor	43	9.7	9.65	0.45
DICHLOROMETHANE (MeCl)	2.93	493,000	78	Sweet, ether-like odor	NA	NA	NA	NL
DICHLOROPHENOL, 2,4-	5.62	NA	0.1	Medicinal odor	NA	NA	NA	NL
DICHLOROPROPANE, 1,2-	3.9	56,000	0.13	Sweet odor	60	3.4	10.87	NL
DICHLOROPROPENE, 1,3-	3.83	NA	0.5	Irritating sharp, sweet chloroform-like odor	95	5.3	NA	0.96
DIELDRIN	13.2	NA	NA	Mild chemical odor (like insecticide)	NA	NA	NA	NL
DIETHYL PHTHALATE	7.66	NA	NA	Very slight aromatic odor (pesticide)	322 (oc)	0.7	NA	NL

Table 3	Indoor Air Concentration Look-up Table				NOTE UNITS!			
	General Properties							
	Contaminant	Vapor Density ¹	Sat Vapor Conc @ 70°F ²	50% Odor Recog Threshold ³	Odor Description	Explosivity Concern ⁴		PID Meter ⁵
Air = 1		ppmV	ppmV	Flash Point °F		LEL %	IP	CF @ 10.6 eV
DIMETHYL PHTHALATE	6.69	NA	NA	Slight aromatic odor	295	0.9	9.64	NL
DIMETHYLPHENOL, 2,4-	6.35	NA	0.0001	NA	NA	NA	NA	NL
DINITROPHENOL, 2,4-	6.35	NA	NA	NA	NA	NA	NA	NL
DINITROTOLUENE, 2,4-	6.27	NA	NA	Characteristic odor	404	NA	NA	NL
DIOXANE, 1,4-	3.03	41,000	1.8	Mild ether-like odor	55	2	9.13	1.3
ETHANOL	1.59	62,000	53	Weak vinous odor	55	3.3	10.47	10.0
ETHYL ACETATE	3.04	101,000	2.77	Ether-like fruity odor	48	1.4	10.01	4.6
ETHYLBENZENE	3.66	10,100	0.23	Aromatic odor	55	0.8	8.76	0.52
ETHYLENE DIBROMIDE	6.48	14,000	13	Sweet odor	NA	NA	9.45	1.7
ETHYLENE GLYCOL	2.14	NA	NA	Odorless	232	3.2	NA	16
FORMALDEHYDE	1.07	NA	8.14	Pungent suffocating odor	<0	7	10.88	NL
FUEL OIL #2/DIESEL	>1	NA	0.11-0.7 ⁶	Home Heating Fuel	136	0.8	NA	0.66
GASOLINE	3-4	NA	0.025 ⁶	Gasoline	-36	1.4	NA	.85 -1
HEPTACHLOR (pesticide)	NA	NA	0.0001	Camphor-like odor	NA	NA	NA	NL
HEPTACHLOR EPOXIDE (pest)	NA	NA	0.001	NA	NA	NA	NA	NL
HEXACHLOROBENZENE	9.8	NA	NA	NA	NA	NA	NA	NL
HEXACHLOROBUTADIENE	8.99	NA	0.56	Mild, turpentine-like odor	NA	NA	NA	NL
HEXACHLOROCYCLOHEXANE, GAMMA (gamma-HCH) (Lindane)	NA	NA	NA	Musty odor	NA	NA	NA	NL

Table 3	Indoor Air Concentration Look-up Table				NOTE UNITS!			
	General Properties							
	Contaminant	Vapor Density ¹	Sat Vapor Conc @ 70°F ²	50% Odor Recog Threshold ³	Odor Description	Explosivity Concern ⁴		PID Meter ⁵
Air = 1		ppmV	ppmV	Flash Point °F		LEL %	IP	CF @ 10.6 eV
HEXACHLOROETHANE	8.16	NA	NA	Camphor-like odor	NA	NA	11.22	NL
HYDRAZINE	NA	15,000	NA	Ammonia-like odor	99	2.9	8.93	2.6
HYDROCHLORIC ACID	NA	NA	NA	Pungent, irritating odor	NA	NA	12.74	NA
ISOPROPANOL	2.07	47,000	60	rubbing alcohol	53	2	NA	6.0
JET FUEL JET-A/KEROSENE	>1	NA	0.08-1 ⁶	Petroleum-like	100+/-	0.7	NA	0.6
MERCURY	NA	NA	NA	Odorless	NA	NA	NA	NL
METHANOL	1.11	135	76	Sweet pungent odor	52	6	NA	NL
METHYL ETHER	1.617	1,000,000	NA	Faint ethereal odor	NA	NA	NA	3.1
METHYL ETHYL KETONE	6.69	NA	5.4	Characteristic odor	16	1.4	NA	0.9
METHYL ISOBUTYL KETONE	3.45	21,000	1.2	Pleasant odor	73	1.4	NA	0.8
METHYL MERCURY	NA	NA	NA	NA	NA	NA	NA	NL
METHYL METHACRYLATE	3.45	40,000	NA	Acrid fruity odor	50 oc	1.7	9.7	1.5
METHYL TERT BUTYL ETHER	NA	NA	NA	Anesthetic-like odor	-14	1.7	NA	0.91
METHYLNAPHTHALENE, 2-	NA	NA	0.006	NA	208	NA	NA	NL
MINERAL SPIRITS	NA	NA	NA	Kerosene-like odor	100+/-	0.8	NA	0.7
NAPHTHALENE	4.42	NA	0.004	Mothball-like odor	174	0.9	8.12	0.42
PENTACHLOROPHENOL	9.2	NA	NA	Benzene-like odor	NA	NA	NA	NL
PETROLEUM DISTILLATES	NA	NA	NA	Gasoline or kerosene-like odor	<141	1.1	NA	0.71

Table 3	Indoor Air Concentration Look-up Table				NOTE UNITS!			
	General Properties							
	Contaminant	Vapor Density ¹	Sat Vapor Conc @ 70°F ²	50% Odor Recog Threshold ³	Odor Description	Explosivity Concern ⁴		PID Meter ⁵
Air = 1		ppmV	ppmV	Flash Point °F		LEL %	IP	CF @ 10.6 eV
PHENANTHRENE	6.14	NA	0.004	Faint aromatic odor	NA	NA	NA	NL
PHENOL	3.24	NA	0.002	Sweet acrid flower	175	1.8	3.5	1
PHOSPHORIC ACID	NA	NA	NA	Odorless	NA	NA	NA	NL
POTASSIUM HYDROXIDE	NA	NA	NA	Odorless	NA	NA	NA	NL
PROPANE	1.5	1,000,000	NA	ethyl mercaptan odor additive	<0	2.1	11.07	NL
PYRENE	NA	NA	NA	NA	NA	NA	NA	NL
RDX	NA	NA	NA	NA	NA	NA	NA	NL
SODIUM BISULFITE	NA	NA	NA	Slight sulfur dioxide-like odor	NA	NA	NA	NL
SODIUM HYDROXIDE	NA	NA	NA	Odorless	NA	NA	NA	NL
SODIUM HYPOCHLORITE	NA	NA	NA	Bleach-like odor	NA	NA	NA	NL
STODDARD SOLVENT	NA	NA	NA	NA	110	0.8	NA	0.71
STYRENE	1.1	6,000	0.16	Sweet floral odor	88	0.9	8.4	0.4
SULFURIC ACID	3.4	NA	NA	Odorless	NA	NA	NA	NL
TETRACHLOROETHANE, 1,1,1,2-	NA	NA	NA	NA	NA	NA	NA	NL
TETRACHLOROETHANE, 1,1,2,2-	NA	6,000	0.76	Pungent, chloroform-like odor	NA	NA	11.1	NL
TETRACHLOROETHYLENE	5.83	NA	2.3	Mild, chloroform-like odor	NA	NA	9.32	0.57
TETRAHYDRAFURAN	2.5	179,000	NA	Ether-like odor	6	1.8	9.45	1.7
TOLUENE	3.14	31,000	4	Sweet pungent benzene-like odor	40	1.1	8.82	0.5

Table 3	Indoor Air Concentration Look-up Table General Properties				NOTE UNITS!			
	Contaminant	Vapor Density ¹ Air = 1	Sat Vapor Conc @ 70°F ² ppmV	50% Odor Recog Threshold ³ ppmV	Odor Description	Explosivity Concern ⁴ Flash Point °F LEL %		PID Meter ⁵ IP CF @ 10.6 eV
TOLUENE DIISOCYANATE	6	NA	1.4	Sharp pungent odor	260	0.9	NA	NL
TRICHLOROBENZENE, 1,2,4-	3.26	NA	1.5	Aromatic odor	222	2.5	NA	0.5
TRICHLOROETHANE, 1,1,1-	4.6	138,000	6	Chloroform-like odor	>200	7.5	11	NL
TRICHLOROETHANE, 1,1,2-	4.6	25,000	NA	Sweet chloroform-like odor	<74	6	11	NL
TRICHLOROETHYLENE	4.53	81,000	127	Chloroform-like odor	>200	8.0	9.45	0.54
TRICHLOROPHENOL, 2,4,5-	>1	NA	NA	Phenol odor	NA	NA	NA	NL
TRICHLOROPHENOL 2,4,6-	NA	NA	.00002	Strong phenol odor	NA	NA	NA	NL
TURPENTINE	NA	NA	NA	Characteristic odor	95	0.8	NA	0.3
VINYL ACETATE	3	124,000	0.4	Pleasant fruity odor	18	2.6	9.9	1.2
VINYL CHLORIDE	NA	1,000,000	150	Pleasant odor	<0	3.6	9.99	2.0
XYLENES (Mixed Isomers)	3.7	NA	0.005	Aromatic odor	81	0.9	8.56	0.49

Understanding and Correctly Using Table 3: General Properties

Note	Explanation
1	Vapor Density - indicates whether the vapor-phase state of the chemical is lighter (<1) or heavier (>1) than air. Most chemical and petroleum vapors are heavier than air, i.e., a <u>concentrated</u> vapor cloud would tend to "sink". In many cases, however, dilute mixtures are encountered (i.e., diluted in air). In these situations, movement of the contaminant is more a function of air movement than vapor density factors.
2	Saturated Vapor Concentration is the maximum amount of that chemical that could exist in a vapor state at 70°F. In most cases, this level is never approached. However, this value is useful to get a sense for the relative concentrations of a chemical that may exist in the vapor state, for comparison to LEL and health criteria. Note that this concentration is highly sensitive to temperature, with significantly lower saturation levels at lower temperatures, and significantly higher levels at higher temperature. The values provided in this table were obtained via use of the ALHOHA model in CAMEO (NOAA)
3	Odor Recognition Threshold is the minimum concentration of a chemical in air that is discernable as a distinct odor. This sense is highly variable among the general population, so odor data is often cataloged and presented as percentiles; i.e., the 50% Odor Recognition Threshold is the concentration of a chemical that 50% of the population should be able to detect and recognize. Although the use of odor is NOT a recommended means to evaluate chemical vapors (given exposure concerns), this data can be useful in evaluating spill events, with respect to what may have been released and it's minimum "ball park" concentration in air.
4	The Flash Point of a substance is the minimum temperature required to create an explosive vapor. The LEL (Lower Explosive Limit) is the lowest concentration of that vapor needed to explode, typically presented in units of % (i.e., percent of chemical in air, with 1% = 10,000 ppmV). Use both values to judge the threat of explosion (i.e., with a high flash point e.g., 150°F there will not be an explosive threat at ambient temperatures, but may be a threat in a fire situation). Most Flash Point temperatures are by the "close cup" method; some are by "open cup" (o.c.); for some chemicals, it is not clear which value was used. NA means not applicable and/or not available.

Understanding and Correctly Using Table 3: General Properties (continued)

Note	Explanation
5	<p>The presented Calibration Factors (CF) are from RAE Systems publication TN-106 (http://www.raesystems.com/AppTech_Notes/TN). They are valid for PIDs with a lamp energy of 10.6 eV, and are approximate for PIDs with lamp energies of 10 +/- eV. These units can detect chemicals that have Ionization Potentials (IPs; also known as Ionization Energies) of 10 +/- or less electron Volts (eVs).</p> <ul style="list-style-type: none"> ☞ Typically, PID units are calibrated with isobutylene. In these cases, the PID reading in ppmV x the CF = the concentration of that chemical in air. Thus, when evaluating a release of toluene, a PID meter reading of 100 ppmV would indicate the presence of 50 ppmV of Toluene (i.e., 100 ppmV x 0.5 = 50 ppmV) ☞ Note that PIDs are not selective, and will quantify ALL (ionizable) chemicals that may be present in the air. Thus, it is important to have a good sense for what is likely present in the air to interpret PID meter results.
6	<p>The odor recognition thresholds for petroleum fuels are variable, given that these products are complex chemical mixtures with varying formulations and additives (e.g., MtBE or ethanol in gasoline). Little information is available on odor recognition thresholds for this reason. The values cited are from the following sources:</p> <ul style="list-style-type: none"> ☞ Fuel Oil #2/Diesel - Maine DEP (http://www.environmental-center.com/articles/article1320/article1320.pdf) & MSDS from MFS Oil Company (http://www.mfaoil.com/MSDS/No2%20Diesel%20Fuel.pdf#search=%22MFA%20oil%20MSDS%20fuel%20oil%20%232%22) ☞ Gasoline - ATSDR (http://www.atsdr.cdc.gov/MHMI/mmg72.html) ☞ Jet Fuel/Kerosene - ATSDR (http://www.atsdr.cdc.gov/toxprofiles/tp75-c3.pdf)
<p>NL = Not Listed in cited source; NA = not available from cited source (even though the chemical may be listed)</p>	



MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF WASTE SITE CLEANUP

Standard Operating Procedure
Indoor Air Contamination

SOP BWSC-07-01

SECTION IV

SECTION IV - TOOLBOXES

Approved By	Date	Pages	Contact Person
Janine Commerford	August 2007	68	John Fitzgerald

This SOP addresses situations where releases of oil and/or hazardous materials have or may adversely impact air quality within occupied buildings, generally via a subsurface vapor transport pathway. Its purpose is to:

- ☞ emphasize the importance of indoor-air contamination problems;
- ☞ articulate clear operational responsibilities and lines of communications; and
- ☞ provide program staff with technical information and guidelines, procedural recommendations, and practical *Rules of Thumb* to enable them to better understand, recognize, prioritize, and respond to indoor air contamination events.

This SOP is segmented into four Sections:

- ❖ Section I - A "bottom line" articulation of operational expectations on looking for, assessing, remediating, and managing/communicating vapor intrusion situations;
- ❖ Section II - Technical concepts, guidelines, procedures, and recommendations on investigating and addressing vapor intrusion pathways;
- ❖ Section III - Look-up Tables for Indoor Air Contaminants; and
- ❖ Section IV - A "Toolbox" of practical forms, procedures, guidelines, data, and informational resources, including standardized bid specifications for state-funded installations of sub-slab depressurization systems.

All staff are expected to become familiar with the operational expectations of Section I, and cognizant of the availability of the detailed guidelines contained in Sections II through IV, for use as the need arises.

No document can anticipate, explain, and/or address every facet of such a complex subject and phenomenon, and nothing contain herein is meant to obviate or limit the exercise of good professional judgment.

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Toolbox 1

Indoor Air Survey/Sampling Form

APPENDIX 1 - INDOOR AIR SURVEY/SAMPLING FORM

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BWSC

Massachusetts Department of Environmental Protection
Bureau of Waste Site Cleanup
INDOOR AIR EVALUATION/SAMPLING FORM

RTN:

Town:

Staff:

Address:

Name/Identifier:

BUILDING INFORMATION (check all that apply)

Type	<input type="checkbox"/> Residential <input type="checkbox"/> School/Daycare <input type="checkbox"/> Commercial <input type="checkbox"/> Industrial <input type="checkbox"/> Mixed <input type="checkbox"/> Other
Foundation Type	<input type="checkbox"/> Full <input type="checkbox"/> Finished <input type="checkbox"/> Partial Basement/Crawl Space <input type="checkbox"/> Slab-on-Grade
Foundation Material(s):	<input type="checkbox"/> Fieldstone <input type="checkbox"/> Concrete Block <input type="checkbox"/> Poured Concrete <input type="checkbox"/> Other:
Foundation Integrity:	<input type="checkbox"/> No Cracks/Open Joints <input type="checkbox"/> Moderate Cracks/Open Joints <input type="checkbox"/> Many Cracks/Open Joints
Basement/Slab Floor:	<input type="checkbox"/> Concrete/Good Integrity <input type="checkbox"/> Concrete with Cracks <input type="checkbox"/> Earthen Floor <input type="checkbox"/> Carpet/Flooring
Basement Use:	<input type="checkbox"/> Storage/Infrequent Use <input type="checkbox"/> Recreation/Living Space <input type="checkbox"/> Bedrooms <input type="checkbox"/> Other:
Drainage Sump	<input type="checkbox"/> No <input type="checkbox"/> Yes Standing Water in Sump? <input type="checkbox"/> No <input type="checkbox"/> Yes Product in Sump? <input type="checkbox"/> No <input type="checkbox"/> Yes
HVAC	<input type="checkbox"/> Steam/Hot Water <input type="checkbox"/> Ducted HVAC System - HVAC Air Intake in Basement? <input type="checkbox"/> No <input type="checkbox"/> Yes
Odors?	<input type="checkbox"/> No <input type="checkbox"/> Yes:

USE/STORAGE OF OIL OR HAZARDOUS MATERIALS

Oil Tank	<input type="checkbox"/> None Observed <input type="checkbox"/> Basement <input type="checkbox"/> Attached Garage <input type="checkbox"/> Other:
Gasoline Storage	<input type="checkbox"/> None Observed <input type="checkbox"/> Basement <input type="checkbox"/> Attached Garage <input type="checkbox"/> Other:
Other OHMs	<input type="checkbox"/> None Observed <input type="checkbox"/> Paints/Stains <input type="checkbox"/> Cleaning Solvents <input type="checkbox"/> Other:

PID Screening of cracks/annular spaces

PID screening of annular space around utilities pipes through basement wall/floor? Yes No Not Accessible

PID screening of cracks in wall/floor and/or wall/floor interfaces? Yes No Not Accessible No Cracks

PID screening of space above drain sump? Not Applicable Not Accessible Yes No

PID Results (Isobutylene)	Location	PID PPMV	Sketch

Comments

More Comments on Back: No Yes

INDOOR AIR EVALUATION/SAMPLING FORM - ADDITIONAL NOTES

Toolbox 2 – Air Sampling Techniques and Procedures

Table 2-1: Summary of General Air Monitoring Approaches & Techniques

Table 2-1: Summary of General Air Monitoring Approaches & Techniques			
Instrument/Method	Positive Features	Negative Features	
Analytical Screening Methods	Photo-ionization Detectors (PID)	<ul style="list-style-type: none"> ☞ On-site detection and quantification ☞ Indication of Imminent Hazard/Evacuation conditions ☞ Identification of vapor entry points 	<ul style="list-style-type: none"> • Low sensitivity • Low specificity • Interferences (e.g. humidity for PID)
	Flame Ionization Detectors (FID)		
	Portable Gas Chromatograph	<ul style="list-style-type: none"> ☞ On-site detection and quantification ☞ Allows use of simple collection device such as a Tedlar bag, syringe, or even VOA vial 	<ul style="list-style-type: none"> • Concerns over skills of operator and QA/QC • Cannot provide positive identification
Collection Methods	Evacuated canisters (e.g. SUMMA) Typically 1 L or 6 L	<ul style="list-style-type: none"> ☞ Capability of taking multiple aliquots for analysis ☞ Ease of Use 	<ul style="list-style-type: none"> • More expensive than adsorbent tube method • Low recoveries for heavy organics
	Adsorbent media tubes	Less expensive than evacuated canister method	<ul style="list-style-type: none"> • Breakthrough problems • May require special handling to prevent sample deterioration
	Passive badge sampler	<ul style="list-style-type: none"> ☞ Can monitor longer-term period of time ☞ Relatively inexpensive 	<ul style="list-style-type: none"> • High humidity can produce erroneous results • Possible back-diffusion off sampling medium • Possible interferences between compounds

Toolbox 2 – Air Sampling Techniques and Procedures

Table 2-2: EPA & MassDEP Indoor Air Sampling and Analysis Method

Method	Type Compounds	Sampling and Analysis Approach	Detection Limit	Advantages	Disadvantages
TO-1	<p>VOCs (80° to 200°C)</p> <p>[e.g., benzene, toluene, xylenes]</p>	TENAX ADSORPTION AND GC/MS OR GC/FID ANALYSIS	0.01-100 ppbv	<ul style="list-style-type: none"> • Large volume of air can be sampled. • Water vapor is not collected. • Wide variety of compounds collected. • Low detection limits. • Standard procedures available. • Practical for field use. 	<ul style="list-style-type: none"> • Highly volatile compounds and certain polar compounds are not collected. • Rigorous clean-up of adsorbent required. • No possibility of multiple analysis. • Low breakthrough volumes for some compounds. • Desorption of some compounds difficult. • Interference by structural isomers common • Contamination of adsorbent and blanks can be problematic. • Artifact formation possible on sorbent.
	<p>Ambient air is drawn through organic polymer sorbent where certain compounds are trapped. The cartridge is transferred to the laboratory, thermally desorbed and analyzed using GC/MS or GC/FID.</p>				
TO-2	<p>Highly volatile VOCs (-15° to +120°C)</p> <p>[e.g., vinyl chloride, chloroform, chlorobenzene]</p>	CARBON MOLECULAR SIEVE ADSORPTION AND GC/MS OR GC/FID ANALYSIS	0.1-200 ppbv	<ul style="list-style-type: none"> • Trace levels of volatile organic compounds are collected and concentrated on sorbent material. • Efficient collection of polar compounds. • Wide range of application. • Highly volatile compounds are adsorbed. • Easy to use in field. 	<ul style="list-style-type: none"> • Some trace levels of organic species are difficult to recover from the sorbent. • Interference by structural isomers common. • Water is collected and can de-activate adsorption sites. • Thermal desorption of some compounds may be difficult.
	<p>Selected volatile organic compounds are captured on carbon molecular sieve adsorbents. Compounds are thermally desorbed and analyzed by GC/MS or GC/FID techniques.</p>				

Table 2-2: EPA & MassDEP Indoor Air Sampling and Analysis Method

Method	Type Compounds	Sampling and Analysis Approach	Detection Limit	Advantages	Disadvantages
TO-3	VOCs nonpolar (-10° to +200°C) [e.g., vinyl chloride, methylene chloride, acrylonitrile]	CRYOGENIC PRECONCENTRATION AND GC/FID/ECD ANALYSIS	0.1-200 ppbv	<ul style="list-style-type: none"> Collects wide variety of volatile organic compounds. Standard procedures are available. Contaminants common to adsorbent materials are avoided. Consistent recoveries. 	<ul style="list-style-type: none"> Moisture levels in air can cause freezing problems with cryogenic trap. Difficult to use in field. Expensive. Integrated sampling is difficult. Compounds with similar retention times will interfere.
	Vapor phase organics are condensed in a cryogenic trap. Carrier gas transfers the condensed sample to a GC column. Adsorbed compounds are eluted from the GC column and measured by FID or ECD.				
TO-4	Pesticides/PCBs [e.g., PCBs, 4,4-DDE, DDT, DDD]	HIGH VOL FILTER AND PUF ADSORBENT FOLLOWED BY GC/FID/ECD OR GC/MS DETECTION	0.2pg/m ³ -200 ng/m ³	<ul style="list-style-type: none"> Low detection limits. Effective for broad range of pesticides/PCBs PUF reusable. Excellent collection and retention efficiencies for common pesticides and PCBs. 	<ul style="list-style-type: none"> Breakdown of PUF adsorbent may occur with polar extraction solvents. Contamination of glassware may compromise detection limits. Loss of some semi-volatile organics during storage. Extraneous organics may interfere. Difficulties in identifying individual pesticides and PCBs if using ECD.
	Pesticides/PCBs sorbed on filter and Polyurethane Foam (PUF) adsorbent trap. Trap returned to lab, solvent extracted and analyzed by GC/FID/ECD or GC/MS.				

Table 2-2: EPA & MassDEP Indoor Air Sampling and Analysis Method

Method	Type Compounds	Sampling and Analysis Approach	Detection Limit	Advantages	Disadvantages
TO-11A	Formaldehyde & other aldehydes/ ketones [e.g., acetaldehyde, acrolein]	DNPH-CARTRIDGE AND HPLC/UV DETENTION	0.5-100 ppbv	<ul style="list-style-type: none"> • Proven technology. • Sampling system is portable and light weight. 	<ul style="list-style-type: none"> • Interference from isometric aldehydes, ketones and other compounds with the same HPLC retention time as formaldehyde. • Carbonyls on the DNPH cartridge may degrade if an ozone denuder is not employed. • Interference from Liquid water captured on the DNPH cartridge during sampling. • O₃ and UV light deteriorates trapped carbonyls on cartridge.
	An ambient air sample is drawn through a commercially-coated DNPH cartridge at a rate of 500-1200mL/minute. The cartridges are returned to the laboratory in screw-cap glass vials. The cartridges are then removed from the vials, eluted, and analyzed by isocratic reverse phase HPLC w/ UV detect at 350 nm.				
TO-13A	PAHs [e.g., benzo(a)pyrene, naphthalene, fluorene]	PUF OR XAD-2 ADSORBENT CARTRIDGE AND GC/MS ANALYSIS	0.5-500 ng/m ³	<ul style="list-style-type: none"> • Allows for sample dilution if concentration is too high during analysis. • Repeated analysis is possible. • High-volume sampling 	<ul style="list-style-type: none"> • Method has interferences due to contamination of solvents, reagents, glassware, and sampling hardware. • Coeluting contaminants may cause interference with target analytes. • Heat, ozone, NO₂ and ultraviolet light may

Table 2-2: EPA & MassDEP Indoor Air Sampling and Analysis Method

Method	Type Compounds	Sampling and Analysis Approach	Detection Limit	Advantages	Disadvantages
		Ambient air is drawn through a glass fiber filter and a polyurethane foam (PUF) or XAD-2 adsorbent cartridge by means of a high volume sampler. The filter and PUF cartridge are extracted using 10% diethyl ether. The extract is concentrated using Kuderna-Danish technique, diluted and cleaned up using column chromatography. The cleaned extract is then analyzed by gas chromatography mass spectrometry (GC/MS).		<p>provides for lower detection limits.</p> <ul style="list-style-type: none"> • Filter and PUF are low cost. 	cause sample degradation.
TO-14A	<p>VOCs (non-polar)</p> <p>[e.g., toluene, benzene, chlorobenzene]</p>	<p>SPECIALLY-PREPARED CANISTER AND GC/FID/ECD OR GC/MS ANALYSIS</p> <p>Whole air samples are collected in an evacuated stainless steel canister. VOCs are concentrated in the laboratory with cryogen trap. VOCs are revolatilized, separated on a GC column, and passed to one or more detectors for identification and quantitation.</p>	0.2-25 ppbv	<ul style="list-style-type: none"> • Best method for broad speciation of unknown trace volatile organics. • Simple sampling approach. • Good QA/QC database. • Proven field and analytical technology. 	<ul style="list-style-type: none"> • Limited to non-polar compounds due to use of permeation type dryer. • Sample components may be adsorbed or decompose through interaction with container walls. • Water condensation at high humidity may be a problem at high concentrations (ppm). • Complex equipment preparation required. • Expensive analytical equipment.
TO-15	<p>VOCs (polar/non-polar)</p> <p>[e.g., methanol, benzene, xylene, nitrobenzene]</p>	<p>SPECIALLY-PREPARED CANISTER AND GC/MS ANALYSIS</p>	0.2-25 ppbv	<ul style="list-style-type: none"> • Incorporates a multisorbent /dry purge technique or equivalent for water management thereby addressing a more extensive set of compounds. 	<ul style="list-style-type: none"> • Expensive analytical equipment. • Operator skill level very important.

Table 2-2: EPA & MassDEP Indoor Air Sampling and Analysis Method

Method	Type Compounds	Sampling and Analysis Approach	Detection Limit	Advantages	Disadvantages
		Whole air samples are collected in a specially-prepared canister. VOCs are concentrated on a solid sorbent trap or other arrangement, refocused on a second trap, separated on a GC column, and passed to an MS detector for identification and quantification		<ul style="list-style-type: none"> Establishes method performance criteria for acceptance of data. Provides enhanced provisions for quality control. Unique water management approach allows analysis for polar VOCs. 	
TO-17	<p>VOCs (polar/non-polar)</p> <p>[e.g., alcohols, ketones, benzene, toluene, o-xylene, chlorobenzene]</p>	MULTI-BED ADSORBENT TUBE FOLLOWED BY GC/MS	0.2-25 ppbv	<ul style="list-style-type: none"> Large selection of sorbents to match with target analyte list. Better water management using hydrophobic sorbents than Compendium Method TO-14A. Proven technology. 	<ul style="list-style-type: none"> Rigorous clean-up of sorbent required. No possibility of multiple analysis. Must purchase thermal desorption unit for analysis. Desorption of some VOCs is difficult. Contamination of adsorbent can be a problem.
		Ambient air is drawn through a multi-bed sorbent tube where VOCs are trapped. The cartridge is returned to the laboratory, thermally desorbed and analyzed by GC/MS or other methods.			
APH	<p>C5-C12 +/- Hydrocarbons</p> <p>[gasoline; fuel oil plus Target VOCs]</p>	SPECIALLY-PREPARED CANISTER AND GC/MS DETECTION AND QUANTITATION OF HYDROCARBON RANGES	<p>25-100 µg/m3</p> <p>Ranges</p> <p>2-20</p>	<ul style="list-style-type: none"> Detects and Quantitates ranges of hydrocarbons Allows for risk-based evaluation of hydrocarbon contamination 	<ul style="list-style-type: none"> Draft Procedure (MassDEP) Poor recoveries likely for naphthalenes and heavier hydrocarbons

Table 2-2: EPA & MassDEP Indoor Air Sampling and Analysis Method

Method	Type Compounds	Sampling and Analysis Approach	Detection Limit	Advantages	Disadvantages
		Whole air samples are collected in an evacuated stainless steel canister. VOCs are concentrated in the laboratory with cryogen trap. VOCs are revolatilized, separated on a GC column, and passed to MS detector. Hydrocarbon Ranges and Target Analytes are detected and quantitated.	µg/m ³ Targets		

Toolbox 3

Installation and Sampling of Soil Gas Probes

1.00 Introduction

Regional offices have been provided with soil gas sampling equipment manufactured by Kerfoot Technologies Inc. (formerly KV Associates) of Mashpee, MA, including a Bosch® electric vibratory hammer drill. Some regional offices also have a gas chromatograph.

The purpose of this SOP is to articulate step-by-step instructions on how to obtain representative soil gas samples by use of this equipment.

NOTE: ALWAYS CONTACT DIGSAFE WHEN REQUIRED AND WHEN APPROPRIATE!

2.00 Temporary Soil Vapor Point Installation and Sampling

BWSC uses a product distributed by KV Associates called the Macho System® (See Figure 2-1). Upon completion of a sampling event, the Macho System® components are retrieved out of the ground, to be re-used at another location. This system is used by BWSC for both outdoor and indoor soil vapor-sampling applications

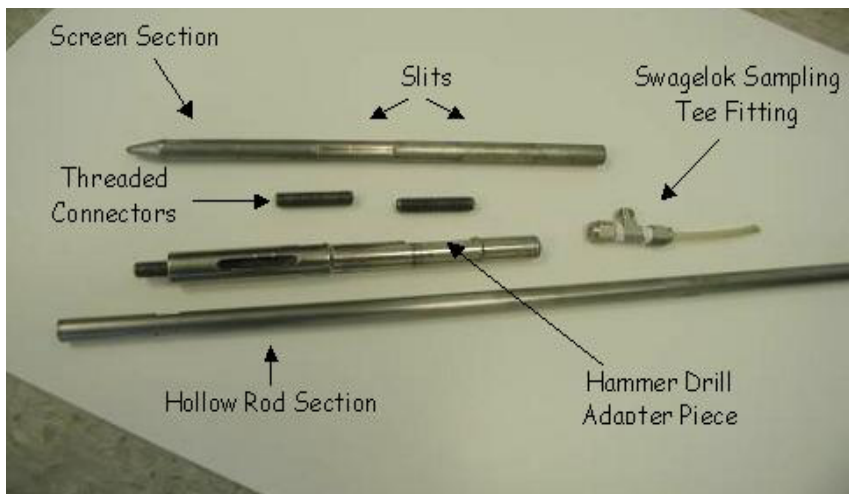


Figure 2-1 - Kerfoot Technologies Inc. "Macho System"

Toolbox 3 - Soil Gas Sampling Probes

2.10 Materials and Equipment

The system consists of the following components:

- a 9.0 inch long by $\frac{5}{8}$ inch outside diameter (O.D.) screen section containing 2 rows of four, #10 slot slits;
- Four - 2.5 foot long by $\frac{5}{8}$ inch O.D. hollow driving rod sections;
- Six - $1\frac{3}{4}$ inch long by $\frac{5}{16}$ inch O.D. hollow threaded studs;
- a hammer drill adapter piece, and;
- for indoor applications, a 1 inch diameter masonry drill bit used to drill out a pilot hole through the concrete foundation slab.

The screen section, hollow rod sections, and hammer drill adapter piece are composed of hardened steel that is plated with nickel.

2.20 Basic Operation

Assembling the Vapor Point: The screen section is connected to a hollow rod section using a threaded stud and the sections are then rotated along the stud until hand tight. Next, the hammer drill adapter piece is connected to the other end of the hollow rod using a threaded stud and hand tightened in a similar manner. The vapor point is now ready for installation.

Advancing Vapor Points: At the time of point advancement, the steel ground-rod drive tool connected to the Bosch drill is slid over the hammer drill adapter piece. The hammer drill adapter will bear the pounding exerted from the hammer drill and protect the threaded end of the hollow rod section from excessive wear. Once the screen section and hollow rod section has been fully advanced (approximately 3 feet below grade), the hammer drill adapter piece is rotated off of the hollow rod section and replaced with another hollow rod section. The vapor point is then driven another 2.5 feet in the same manner as previously described. Once the desired sampling depth has been reached, the hammer drill adapter piece is removed from the hollow rod section and replaced with a Swagelok® stainless steel $\frac{1}{8}$ inch male Tee fitting which will be needed during the vapor sampling task.

Modifying the Sampling Tee: If vapor samples are to be analyzed by an on-site gas chromatograph, modification of the Sampling Tee apparatus is recommended.

To modify the Swagelok® Tee fitting, the three nuts and ferrule assemblies are initially removed (see Figure 2-2). The stem portion of the Tee fitting will later be threaded into the hollow rod section of the soil vapor sample point.

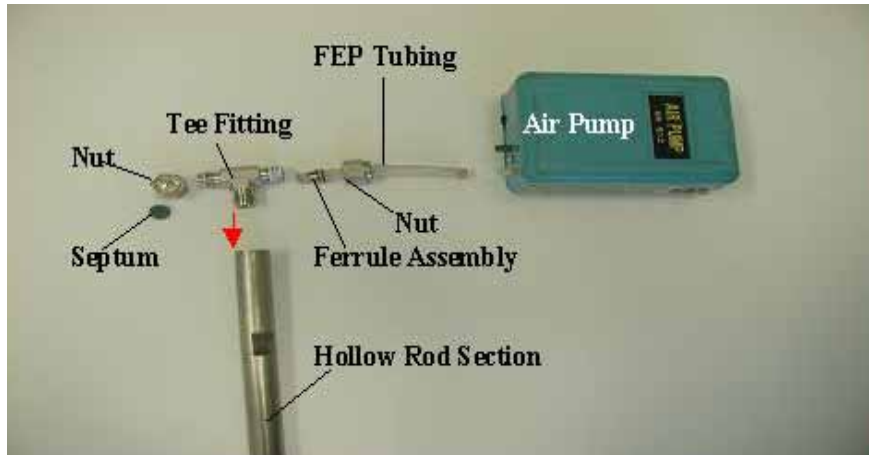


Figure 2-2 - Modified Swagelok® Tee Fitting Assembly

Remove the ferrule assembly from one of the two remaining Tee fitting nuts and insert a 9.5 millimeter disk-type gas chromatograph (GC) injection port septum inside the nut in place of the ferrule assembly. The nut/septum assembly is used as a sampling port when loading a gas-tight syringe. A $\frac{1}{4}$ inch fluorinated type polymer tubing (FEP, PTFE, or facsimile) is inserted into the remaining nut, and the ferrule assembly is slid along the tubing until it seats properly on the inside base of the nut. The other end of the tubing will later be connected to the positive draw port of an air pump or the end of a PID sampling wand. Teflon tape is wound on the Tee fitting threads before the two nuts are screwed back on to the Tee fitting.

2.30 Soil Vapor Collection Procedure

Procedure Overview: The intake end of an air pump or the end of a PID sampling wand is connected to the sampling Tee via FEP or similar type tubing. Soil vapors enter through the probe's screen section and are then

carried through the length of the probe and out the sampling Tee for collection and/or real-time sampling via the PID.

It is not necessary to obtain "time weighted average" samples of sub slab soil gases. However, care should be exercised to avoid sampling at too high a rate or via too high a vacuum, as this can lead to short-circuiting. The California EPA and US EPA staff have recommended a maximum sampling rate of 0.1 to 0.2 Liters/minute.¹ Empirical and mathematical evaluations of "purge volume" concerns indicate that pre-evacuation of 5 probe volumes should suffice¹. For a $\frac{1}{2}$ inch diameter probe cored 4 inches into/through a basement slab, 5 probe volumes would equate to approximately 250 mL (about 1-2 minutes of sampling with a PID meter).

The use of a PID meter for obtaining sub-slab vapor samples is also advantageous in that it can produce continuous, real-time concentration data, to evaluate trends, and/or detect possible short-circuiting situations (See Figure 2-3). As a PID is non-destructive, samples can be obtained from the outlet of the meter (e.g., tubing on outlet attached to Tedlar bag).

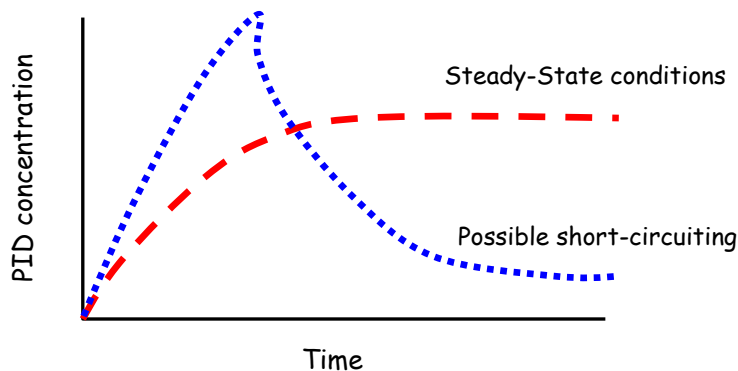


Figure 2-3: Short Circuiting during Vapor Probe Sampling

The potential for short-circuiting is a major problem that can occur at anytime during a soil vapor-sampling event. Short-circuiting is caused by an improper seal somewhere in the vapor sampling system, allowing for the introduction of unwanted ambient air into the system that will ultimately affect the soil vapor sample quality. During a sampling event, short-circuiting may be identified on the PID by noting a sudden, sharp loss of concentration after a higher and/or a steady-state concentration has been achieved; or by noticing no detection of VOCs on the PID in a known area of VOC releases. Make sure that all fittings and sample tubing is tight, and

that the vapor probe is sealed (See Section 4.10 "Short-Circuiting of the Soil Vapor Sampling Point" for more information).

The ideal time to collect a soil vapor sample for GC screening would be at the point a steady-state VOC concentration has been achieved on the PID. For purposes of this document, a steady-state concentration refers to a soil vapor-sampling event being monitored by a PID in which VOC concentrations stabilize over a set time. In general, approximately 2 minutes at a steady VOC PID reading is desirable prior to collecting a sample.

Collecting a VOC Sample For GC Screening:

Soil vapor samples can be collected for GC screening using Tedlar Bags or 40 mL VOA vials. Experience has shown that collection in a 40 mL VOA vial is sufficient for screening purposes, at a cost significantly less than the use of Tedlar Bags (typically, data from 40 mL vials compare to within +/- 30% of data from Summa® Canisters). One point of caution, however, is the possible presence of (non-VOC) contaminants within the vials that may produce false-positive peaks on a chromatogram. While these vials are certified "clean" for aqueous sampling purposes, off-gassing of compounds associated with the plasticizers used in the screw cap can produce discernable peaks on PID and/or ELCD chromatograms. The degree of this problem varies from manufacturer to manufacturer. For this reason, it is important to analyze container "blanks" in each batch of samples.

To collect a sample into a 40 mL vial, a 3/16 inch O.D. FEP tubing originating from the air pump exhaust port or PID exhaust port is inserted into an inverted 40 mL vial and the soil vapor is allowed to flush the vial for approximately one minute (See Figure 2-4). [NOTE: 5/16 inch O.D. FEP tubing may be needed to fit over the PID's exhaust port fitting. The 3/16-inch O.D. FEP tubing will fit snugly inside of the 5/16 inch O.D. tubing].

While pumping, the FEP tubing is then slowly backed out of the VOC vial and the vial is immediately capped. The VOC sample is stored at ambient temperature in the dark until the time of GC analysis. The sample must be analyzed within a 24 hour holding time. If a field GC is present at the time of sample collection, a vapor sample may also be withdrawn using a gas tight syringe by inserting the syringe needle into the septum portion of the sampling Tee or a filled VOC vial.

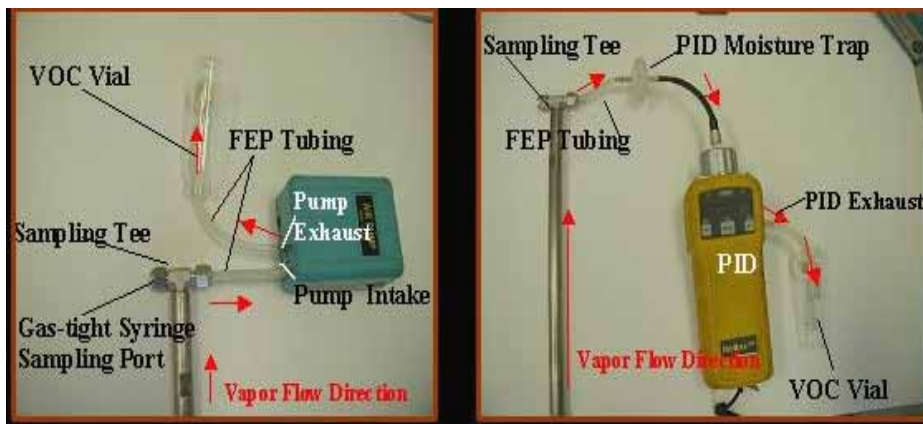


Figure 2-4 - Filling a 40 mL VOA vial for GC screening of air/soil gas sample

Temporary Soil Vapor Point Removal

Upon completion of sample collection, the soil vapor point is manually removed from the ground using a modified 2 ½ ton rated truck jack and adjustable wrench. There are two sets of flat grooves machined near the ends of the screen and hollow rod sections that will accommodate a ½ inch wrench and/or adjustable wrench. The operator will hold the wrench connected to the probe with one hand and pump the jack lever with the other. The probe is slowly backed out of the ground when the jack plate makes upward contact with the wrench as it is advanced up the jack. The operator should observe the probe as it is backed out of the hole to make sure that it is not bending. If the rods appear to be bending, the jack's wooden base plate should be oriented in a different direction or angle to compensate for the direction of the bend. Once the point has been recovered, it is broken down and visually examined for clogged slits at the screen section, etc.

2.40 Cleaning The Temporary Soil Vapor Equipment

Maintenance of the soil vapor point's screen section, solid rod sections, threaded stud connectors, and sampling Tee is an essential step in acquiring representative soil vapor information. With the equipment broken down as illustrated in Figure 2-1, the components should first be visually inspected for dirt or other debris that may hinder the performance of the soil vapor point when being sampled. Slits in the screen section are cleaned by inserting a 0.010 inch or smaller feeler gage, and moving the gage in an "up and down" motion over the entire length of each slit. The sections and connectors should also be cleaned using an Alconox™ or suitable soap

Toolbox 3 - Soil Gas Sampling Probes

wash followed by a clean water rinse. A pipe cleaner can also be used for cleaning out dirt or debris from the inside of the various sections. If contaminated water is encountered during a temporary soil vapor sampling, the equipment must be broken down and the components decontaminated with Alconox soap and water rinsed prior to re-use. If the sampling equipment comes into contact with soil and/or groundwater that are overtly contaminated with petroleum or hazardous material, the equipment Alconox wash and water rinse should be followed by a methanol rinse. Spent methanol should be collected in a suitable container (driller's jar) and labeled accordingly for eventual disposal as generated waste.

3.00 Permanent Soil Vapor Point Installation and Sampling

When installing permanent soil vapor points BWSC may use one of two options depending upon whether the sample being taken is outside of a building, or from beneath the foundation slab of a residence or other building. Once the permanent probe has been installed, vapor samples are monitored for real-time VOCs and/or collected for VOC screening via GC using techniques previously described in Section 2.00 of this document. Materials for both options are available from Kerfoot Technologies, Inc.

Outside of A Building

Using the Bosch hammer drill as a driving tool, a pilot hole is created in the ground by first advancing and then carefully removing the temporary soil vapor probe equipment, and/or by using the 1 1/8 inch diameter by 17 inch long drill bit to drill out the pilot hole. A permanent soil vapor point is then carefully lowered and set in the pilot hole. The permanent soil vapor point consists of a 4 1/4 inch long aluminum shield point with one set of 6 slits located on the shaft of the point, connected by a length of 3/16 inch rigid, high-density polyethylene sample tubing (See Figure 2-5).

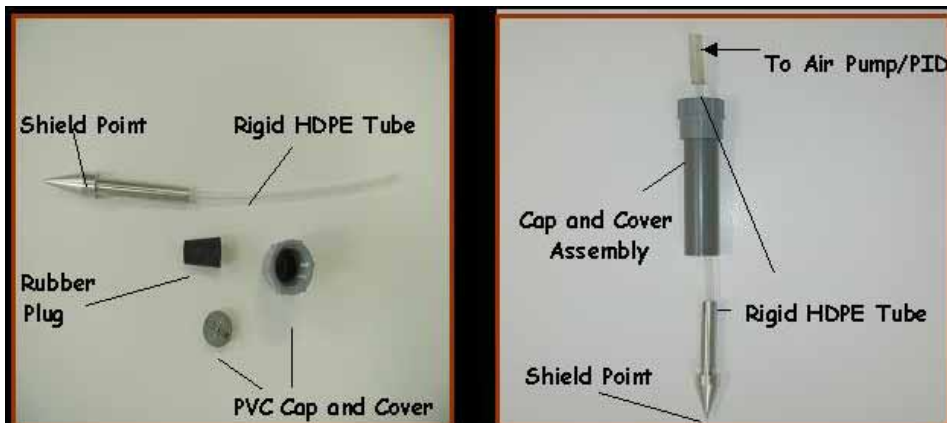


Figure 2-5: Permanent Soil Gas Vapor Probe Outside a Building

Toolbox 3 - Soil Gas Sampling Probes

Within a Building

Using the electric hammer drill and masonry drill bit an approximate $1\frac{1}{8}$ inch pilot hole is drilled through the foundation floor. Most concrete foundation floors are 1 to 8 inches thick. The majority of foundation floors will also have a network of interconnecting void spaces directly under the slab before encountering the subsurface strata. Soil vapor samples are pulled from the void directly under the foundation floor. [NOTE: Before setting the cap in the drilled hole, trim the PVC guard pipe to the desired length with either a hack saw or pipe cutter.]

The top of a $1\frac{1}{8}$ inch PVC cap with rubber stopper is positioned in the drilled hole flush with the top of the foundation floor (See Figure 2-6). Rocktite® or a similar fast drying expansion cement product is then carefully inserted and spread around the outside of the sampling cap using a putty knife and allowed to set until dry (approximately 15 to 20 minutes) before sampling the vapor point. Once the cap has set, a length of 3/16 inch O.D. rigid tube is inserted through the cap's stopper until it is positioned in the void area under the foundation floor. FEP tubing is attached to the end of the rigid tubing and pumped to steady-state if using a PID, or for approximately 1-2 minutes if using the air pump option. A vapor sample is collected as previously described in Section 2.30 "Soil Vapor Collection Procedure" of this document.

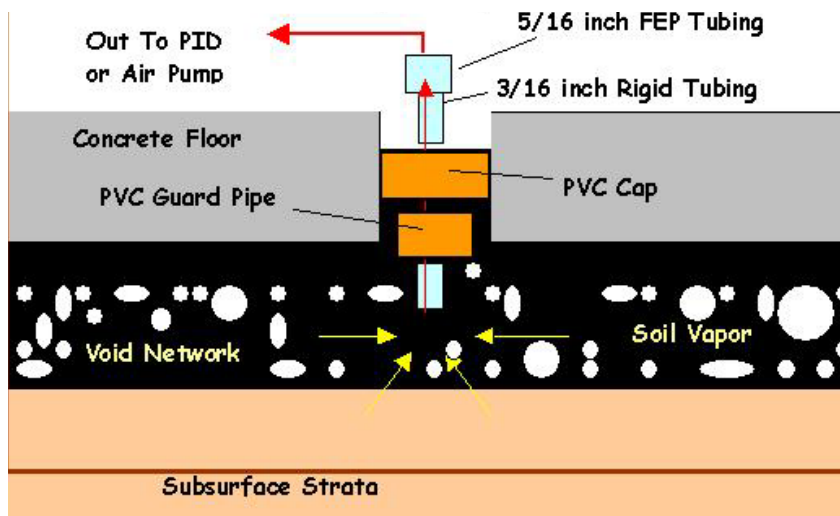


Figure 2- 6 - Example of a permanent soil vapor point under a foundation floor.

Toolbox 3 - Soil Gas Sampling Probes

4.00 Troubleshooting

4.10 Short-Circuiting of the Soil Vapor Sampling Point

The condition commonly referred to as "short-circuiting" can occur at anytime over the duration of soil vapor withdrawal and/or sample collection. In this situation, as the sampling point is undergoing soil vapor withdrawal, ambient air is inadvertently introduced into the vapor stream, adversely affecting the actual VOC levels in the soil vapor. In the case of permanent points, short-circuiting can be caused by the improper sealing of the annular space located between the vapor point cap and concrete floor or ground. In the case of temporary points, short-circuiting may result from the improper sealing around the hollow rod sections and the floor or ground. Short-circuiting may also be caused by something as simple as a leak somewhere along the vapor sample tubing or Swagelok fitting(s) on the sample Tee.

The existence of short-circuiting is effectively monitored by using the following techniques:

1. PID Meter - Under acceptable conditions, if detectable levels of VOCs are present in the vapor stream (approximately 1.0 ppmv and greater), a steady state concentration value will eventually be reached on the PID, perhaps after 2 minutes of steady pumping, and remain at this concentration for the duration of the sampling event. However, after reaching a steady state, if a sudden, sharp loss of PID response is observed, a short-circuit condition may be the likely cause.
2. Flow Meter - Soil vapor flow can be effectively monitored during a pumping event by inserting one flow meter between the soil probe and the pump inlet/PID wand, and another flow meter at the discharge port of the pump/PID. If a short circuit occurs at the soil vapor point, a change of flow should be noted on both flow meters. If a short circuit occurs at the pump, a change of flow will be noted at the flow meter hooked into the pump discharge port. Using flow meters to monitor a soil vapor-pumping event is also beneficial in gaining knowledge on the soil formation's capacity to allow for vapor recharge.
3. Tracers - Opening a bottle of isobutylene calibration gas just above the soil gas probe connection can indicate if ambient air (i.e., containing isobutylene) is infiltrating into the soil gas/soil gas sample. Use of a "magic marker" may also be appropriate, at the conclusion of a sampling event, to confirm the integrity of the sample (use during or before sample collection may produce false positive data).

REFERENCES

¹ DiGiulio, Dominic C., and Paul, Cynthia J., *Assessment of Vapor Intrusion in Homes Near the Raymark Superfund Site Using Basement and Sub-Slab Air Samples*, EPA/600/R-05/147, March 2006.

Toolbox 3 - Soil Gas Sampling Probes

Toolbox 4

Guidance on the Design, Installation, Operation, and Monitoring of Sub Slab Depressurization Systems

1.0 INTRODUCTION

A sub-slab depressurization (SSD) system is a proven technique to eliminate or mitigate vapor intrusion into impacted structures (See Figure 4-1). Based upon traditional radon-mitigation technology, this approach creates a negative pressure field beneath a structure of concern, inducing the flow of VOC vapors to one or more collection points, with subsequent discharge up a stack into the ambient air. In essence, the system "short circuits" the subsurface VOC vapor migration pathway, eliminating or reducing exposures to building occupants.

A system of this nature can typically be installed at a small building (e.g., single family home) for about \$3000 to \$6000, depending upon site conditions. Importantly, this is a somewhat invasive, energy & maintenance intensive remedial measure, and therefore an option of secondary resort. Moreover, there are certain site and building conditions (e.g., high groundwater table) that may preclude or limit its application. Therefore, before pursuing this option, it is essential that conclusive evidence exist documenting the presence of a subsurface VOC source and/or migration pathway, and that less invasive steps be initially considered and/or implemented. Where appropriate, this effort should include investigations to identify possible source/source areas, and source control or mitigation measures.



Figure 4-1: SSD System

2.0 PURPOSE/OBJECTIVE OF SSD SYSTEM

The purpose of an SSD system is to create a negative pressure field directly under a building and on the outside of the foundation (in relation to building ambient pressure). This negative pressure field becomes a sink for any gases present in the vicinity of the structure. VOCs caught in the advective sweep of this negative pressure field are collected and piped to an ambient air discharge point.

While SSD systems are considered a remedial activity and measure under the MCP, they are typically not a component of a site-wide (soil and groundwater) remediation approach. Rather, their design objective is to prevent soil gases from infiltrating a building. Ideally, the extent of depressurization and soil gas removal should be kept to a minimum, to minimize energy, handling, and/or off-gas treatment costs. This is why these systems are most appropriately termed "depressurization" systems, rather than "ventilation" systems.

Even though site remediation is not a design objective, it is in fact an ancillary effect and benefit. Specifically, by venting soil gases contaminated by VOCs, an SSD system facilitates the mass removal of contaminants from subsurface media. Moreover, every cubic foot of vented soil gas has to be replaced by a cubic foot of air, resulting in an influx of oxygen into contaminated areas, which may facilitate the aerobic biodegradation of contaminants.

The significance of this remediation bonus is site dependent, a function of contaminant type, location, mass, and SSD flow rate. While perhaps most beneficial at residential sites contaminated by a leaking fuel oil tank (limited extent of contamination; directly below slab; aerobically degradable contaminants), in most cases SSD systems will not have an appreciable impact on site contaminant levels.

3.0 DESCRIPTION OF THE SSD SYSTEM

A sub-slab depressurization system basically consists of a fan or blower that draws air from the soil beneath a building and discharges it to the atmosphere through a series of collection and discharge pipes. One or more holes are cut through the building slab so that the extraction pipe(s) can be placed in contact with sub grade materials, in order for soil gas to be drawn in from just beneath the slab. In some cases the system may require horizontal extraction point(s) through a foundation wall, although in most cases the pressure field from an extraction point in the slab will extend upward adjacent to the foundation walls.

SSD systems are generally categorized as *Low Pressure/High Flow* or *High Pressure/Low Flow*. Site conditions dictate which approach and system is most appropriate.

Some buildings have pervious fill/soil materials beneath the slab. Soil gas/air movement through such materials is rapid, and only a slight vacuum will create high flowrates. In such cases, the SSD system should utilize a low pressure/high flow fan. Other building slabs are underlain by less pervious materials, and common fan units will not be able to draw the appropriate level of vacuum. In these cases, a high pressure/low flow blower unit is required, capable of creating high vacuum levels.

Low Pressure/High Flow systems generally use 3-4 inch diameter piping; High Pressure/Low Flow systems may use smaller diameter piping. This piping is generally run from the extraction point(s) through an exterior wall to the outside of the building. The piping is

connected to a fan/blower, which is mounted either on the outside of the building or in the attic. Placement of the fan/blower in this manner ensures that a pressurized discharge pipe is not present within occupied spaces (in case of leakage). Exhaust piping is run so that the discharge is above the roofline.

4.0 DESIGN AND INSTALLATION OF SSD SYSTEMS

All SSD systems should be designed in conformance with standard engineering principles and practices. As the work will likely be conducted in close proximity to building inhabitants, safety concerns are a priority. Attempts should be made to minimize noise, dust, and other inconveniences to occupants. Attempts should also be made to minimize alterations in the appearance of the building, by keeping system components as inconspicuously located as practicable.

The installation of an SSD system should be conducted under the direct supervision of a competent professional with specific experience in building vapor mitigation, site remediation, and/or environmental engineering practices. There are many firms that specialize in installing SSD systems for residential radon mitigation, as the same processes described above apply to the intrusion of radon into buildings.

The following sections describe the most important aspects of SSD system design and installation.

4.1 Inspection of Building Foundation

An inspection of the building foundation should be conducted, with particular attention paid to identifying all potential entry routes for VOC contaminated soil gases, such as cracks in concrete walls or slabs, gaps in fieldstone walls, construction joints between walls and slabs, annular space around utility pipes, open sumps, etc. These potential entry points should be surveyed with a portable PID or FID meter; it is often possible to find discrete "hits" (>1 ppmV) at particular points where vapor intrusion is occurring.

All possible entry routes should be sealed off, if possible, to prevent the entrance of soil gas, and enhance the sub-slab negative pressure field when the SSD system is in operation. Sealing/caulking materials should not contain significant amounts of VOC's. Buildings with no slabs should have an impermeable barrier installed before considering SSD.

A particularly problematic feature of commercial and school buildings is the presence of floor drains in lavatories and other areas. Often, the water seal within the plumbing trap of these drains is ineffective, as the water either leaks out or evaporates. This provides a vehicle for soil gases and/or sewer gases to discharge into these areas (especially true in lavatories with fans or vents which create a negative pressure within these rooms). In such cases, efforts

should be made to periodically add water to these traps, or to install a *Dranjer* type seal. (see <http://www.dranjer.ca/>)

4.2 Sub-Slab Materials

Knowledge/information on the fill/soil conditions beneath the slab is desirable. Small diameter test holes can be drilled through the slab at various representative locations to collect sub-slab material for visual inspection. Test holes should be installed above the groundwater table and should not be deeper than one foot. A general evaluation of the material's permeability should be made.

Test holes and visual inspection of sub-slab materials are not essential, however, as system design is based primarily on the results of pressure testing.

4.3 Depth to Groundwater

The depth to groundwater should be ascertained. In general, the groundwater table should be at least 6 inches below the building slab for an SSD system to be effective. Seasonal changes in groundwater elevation should be considered when evaluating the feasibility of SSD systems.

4.4 Diagnostic Tests

The airflow characteristics and capacity of the material(s) beneath the slab should be quantitatively determined by diagnostic testing. This is the most important step in the SSD design process, and should always be performed prior to the design and installation of an SSD system.

Diagnostic testing is conducted by drilling small diameter holes through a building slab, applying a vacuum to one hole, and measuring pressure drops at surrounding test holes. The procedure is analogous to conducting a pump test to gauge aquifer properties and zone of influence. Most reputable and experienced SSD installation contractors have developed empirical (and proprietary) means to conduct and evaluate diagnostic tests. It is not necessary that complete details of this test be provided to MassDEP, as long as overall task and project performance standards are met (i.e., that upon installation and operation of the final system, a negative pressure field is documented beneath all impacted areas).

Within this context, several comments and recommendations are offered:

- ☞ The objective of diagnostic testing is to investigate and evaluate the development of a negative pressure field, via the induced movement of soil gases beneath the slab. This information is in turn used to determine whether a Low Pressure/High Flow or

High Pressure/Low Flow system is necessary, and to determine the number and location of needed system extraction points.

- ☞ Two means are used to monitor and document the development of a negative pressure field: pressure testing and smoke testing. Pressure testing provides a direct and quantitative means to measure a negative pressure field. However, in cases where very pervious fills/subsoils are present, large volumes of air can be moved with relatively little pressure drop, undetectable by even the most sensitive gauge. In these cases, the creation of a negative pressure field can be verified by smoke tests, which demonstrate the (downward) advection of smoke (air) into the ground (i.e., through the slab).
- ☞ Generally, the diagnostic extraction hole should be at least 3/4 inches in diameter; the test holes 3/8 to 5/8 inches in diameter.¹ Test holes should be placed at representative locations, such that the size of the effective pressure field under the slab may be evaluated. Typically, a shop-vac unit is used to pump soil gas from the extraction hole; the pressure drop and flow rate at this extraction point should be monitored and recorded. Pressure drops at the test holes should be measured quantitatively with a pressure gauge (e.g., a magnehelic gauge). A pressure drop of less than 1 Pa (0.004" of water) is generally not considered significant.
- ☞ Extraction and observation holes should be placed in the most unobtrusive locations possible; utility rooms and closets in a finished basement are good choices. Care must be taken to avoid damaging sub-slab utilities or conduits; the oil feed line to a furnace is of particular concern. The discharge from the extraction hole should be vented to the outside air. Following the test, the diagnostic extraction and test holes should be sealed with a portland cement grout, although at least 1 or 2 holes should remain unsealed until after installation of the final SSD system, in order to provide points to demonstrate establishment of a negative pressure field.
- ☞ For larger structures, such as commercial and school buildings, more extensive and involved sub-slab diagnostics are needed. Features such as utility tunnel floors and walls, crawl spaces, internal continuous footings, and/or frost walls should be considered in the diagnostic evaluations, as they can impede airflow.
- ☞ Atmospheric pressure may be of importance at sites where diagnostic testing indicates marginal negative pressure readings. In such cases, barometric pressure data should be obtained and reviewed for the day of testing, and the previous several days. A trend of rising barometric pressure tends to promote advection of air into the ground, which may be falsely interpreted as a negative pressure field created during diagnostic tests. Where concern exists in this regard, the testing should be repeated during a time of falling barometric pressures.

4.5 Location and Construction of Extraction Points

Final system extraction points should be properly located, based upon pressure/smoke test results, to ensure a sub-slab negative pressure field under the entire building. For most private residences, especially one to four family houses, only one or two extraction holes should be needed, unless anomalous conditions (e.g. highly impermeable sub-slab material) exist. High Pressure/Low Flow blowers should be used at sites with impervious subsoils, to minimize the number of extraction points necessary.

Extraction points are constructed by drilling or cutting holes through the building slab, making sure that any vapor barriers are breached and the sub-slab materials are encountered. Wherever practicable, extraction points and piping should be placed in the most unobtrusive locations, particularly in residential dwellings with finished basements.

A 10 to 20 inch diameter pit should be excavated at the extraction point(s), to a depth of about 10 inches. This void can be left open (if structurally acceptable) or backfilled with crushed stone (1/2 to 1 inch diameter, washed). The extraction hole is then patched around the piping using mortar or non-shrink grout, to insure a good seal. There are two important advantages gained by such a pit:

- Bonnefous et. al.² have reported that a pit of this nature can dramatically improve and extend the pressure field beneath a slab; and
- water vapor condensation within the piping system (a particular concern during winter at sites with external discharge piping runs) can be readily infiltrated back into the subsoil, minimizing effects on soil gas extraction.

As a final note, care should be taken to ensure that extraction points/pits intercept the thin void zone that typically exists directly beneath poured slabs. Specifically, differential settlement over time typically creates a series of interconnected void spaces beneath concrete slabs. While the extent and significance of these voids in transmitting soil gases is site-dependent, it makes sense to use every advantage possible.

4.6 Fan and Piping Design

The type of sub-slab material and pressure field characteristics, as determined by diagnostic tests, should determine the type of fan or blower to be used for the SSD system.

Generally, one of two types of units will be specified:

- **Low Pressure/High Flow** - The most common application, used at sites with relatively permeable subsoils, where only low vacuum is needed to produce a negative pressure field beneath impacted areas. (See Figure 4-2) Generally, an in-line centrifugal fan unit is used. These units are simple, quiet, inexpensive (\$100 - \$200), and consume only about 100w of power (the same amount as a 100w light bulb). Typically, these units are capable of inducing 0 - 4 inches of water vacuum, while moving 50 to 300 cubic feet per minute (cfm) of air.³

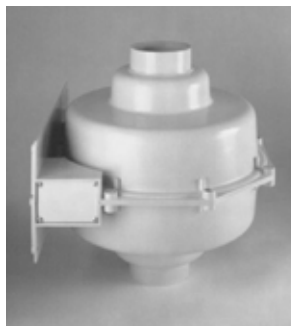


Figure 4-2: SSDS Fan

- **High Pressure/Low Flow** - Required at sites with impervious subsoils (fine sands/silts/tills). Generally, a regenerative blower unit is required to produce the needed level of vacuum - typically 5 to 30 inches of water. At this vacuum level, only 5 to 30 cfm of air is moved. Regenerative blowers are relatively expensive (\$300 - \$500), and require around 300w of power to run. Regenerative blowers can produce a high-pitch whine, which may not be suitable for residential applications without appropriate soundproofing.³

Fans and blowers are designed and specified on the basis of flow vs. pressure. In any given unit, flow is proportional to pressure (or vacuum). The greater the flowrate, the less pressure (or vacuum) that can be maintained. Manufacturers provide information of this nature in tabular and graphical form. A fan or blower selected for a site must have performance characteristics suited (or optimally suited) for the application in question.

Four-inch diameter schedule 40 PVC piping is generally used for Low Pressure/High Flow systems; smaller diameter (1.5-2 inch diameter) schedule 40 PVC for High Pressure/Low Flow system. Aluminum downspout conduit can be used in lieu of PVC, in cases where building owners wish to make the piping as discreet as possible. However, the aluminum conduit is more susceptible to condensation freezing in winter. All piping should be installed with a positive pitch back to the extraction point, to ensure that any condensation is directed back to the extraction sump, or some other moisture collection/discharge point.



Figure 4-3: Outside Fan and Piping

Generally, the fan/blower and discharge piping (all piping after the fan) should be kept outside the building (See Figure 4-3). The discharge piping contains VOCs under positive pressure

during system operation, and in the event of a failure could leak contaminated soil gases into the building, if kept inside. For SSD systems with a fan/blower outside the building, condensate control devices may be necessary in the cold months and the fan must be weatherproofed. If the fan/blower is inside the building, it must be as near as possible to the outside to minimize the amount of discharge piping inside the building. Fans installed in the attic must either be able to sustain the heat in the summer or provisions for fan cooling must be made (See Figure 4-4).



Figure 4-4: Fan in Attic

Units installed in residential buildings must be designed, installed, and operated in a manner that minimizes noise and vibration. This is a particular concern for regenerative blowers and/or units installed in an attic. Special insulation and/or mounting hardware may be necessary in such applications. Attic units should be located as far from sleeping areas as possible.

4.7 System Gauges and Alarms

At a minimum, an in-line pressure gauge or manometer must be installed on every unit. The gauge or manometer must have a clearly marked line or lines showing minimum acceptable vacuum levels (See Figure 4-5).

4.8 Backdrafting

Consideration should be given to the possible occurrence of a flue-gas backdrafting situation in a building equipped with an SSD system. Specifically, oil/gas furnaces and wood stoves/fireplaces vent combustion gases to the ambient air, typically by directing the gases up a chimney.

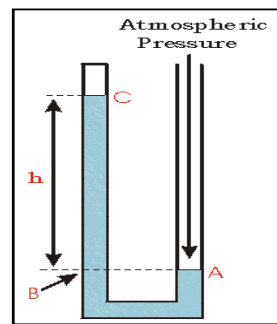


Figure 4-5: Manometer

While newer high-efficiency furnaces use a fan to create a positive discharge to the ambient air, older furnaces rely upon the development of a natural draft, in which the flue gases rise up the chimney due to thermal density differences. Backdrafting can theoretically occur if negative pressures within a building are stronger than the density differential which drives the combustion gases up the chimney. In such cases, potentially deadly combustion gases (e.g., carbon monoxide) could be discharged into the building.

In some extreme cases, the operation of an SSD system could increase the depressurization level of a basement to a point where backdrafting could occur. This is most likely to happen

in an energy efficient (air-tight) home, particularly where significant SSD short-circuiting is occurring (via cracks in slab or leak in extraction piping).

The USEPA has recommended the following procedures to investigate and evaluate the possibility of backdrafting⁴:

- (1) Close all windows and doors, both internal and external.
- (2) Open all HVAC supply and return air duct vents/registers.
- (3) Close fireplace and wood stove dampers.
- (4) Turn on all exhaust and air distribution fans and combustion appliances EXCEPT the appliance being tested for backdrafting.
- (5) Wait 5 minutes.
- (6) Test to determine the indoor/outdoor pressure differential in the room where the appliance being tested is located. If the pressure differential is a negative 5 Pascals or more, assume that a potential for backdrafting exists.
- (7) To begin a test for actual spillage of flue gases, turn on the appliance being tested. (If the appliance is a forced air furnace, ensure that the blower starts to run before proceeding.)
- (8) Wait 5 minutes.
- (9) Using either a smoke tube or a carbon dioxide gas analyzer, check for flue gas spillage near the vent hood.
- (10) Repeat steps (4) through (9) for each natural draft appliance being tested for backdrafting. Extreme or unusual weather conditions need to be considered in evaluating data.

If a backdrafting potential is identified, the SSD system should not be installed or operated until a qualified HVAC contractor corrects drafting problems. In addition to improvements in appliances and flues, make-up air can be ducted from the outside to provide for combustion and drafting. Generally, 6-inch diameter ductwork should be adequate for single-family residential homes.

As an added level of comfort, confirm that one or more carbon monoxide detectors are located in the home (as required by law for all dwellings).

Where appropriate, in addition to a manometer or gauge, a visible and/or audible alarm should be considered, indicating loss of system vacuum or power. In all cases, clear instructions, with the name and phone number of a person to be contacted in such event, should be visible at the extraction points.

4.9 Other Considerations

- The presence of a sump in a basement can provide a significant short-circuiting vehicle to the establishment of a subslab negative pressure field. In such cases, an air tight cover should be installed over the sump; if a sump pump is present, the cover should be equipped with appropriate fittings or grommets to ensure an air tight seal around piping and wiring, and the cover itself should be fitted with a gasket to ensure an air-tight seal to the slab while facilitating easy access to the pump. Note that it is also possible to use the sump as a soil gas extraction point (where appropriate); a number of manufacturers make equipment for just such applications.
- At buildings where establishment of a negative pressure field is difficult, steps can be taken to improve the effectiveness of the SSD system by reducing the degree of underpressurization occurring within the basement. These include:
 - ❖ Ducting make-up air from outside the building for combustion and drafting; and/or
 - ❖ Overpressurizing the basement by using fans to direct air from the rest of the building into the basement, or an air/air heat exchanger to direct outside air into the basement.
- Issues regarding piping routes, fan location, vibration and noise concerns, etc., should be discussed with the building owners and occupants. The local municipal Building Department should also be contacted to determine if any permits are required.
- Electrical work for the fan installation will generally require the utilization of a licensed electrician. At locations where extremely high concentrations of combustible VOCs are expected, explosion-proofed equipment must be used.
- Start-up of the system should not occur until several hours after the extraction hole has been grouted, to allow the grout to cure. Otherwise, the fan/blower could draw moisture from the wet grout and cause the patch to shrink and crack.

5.0 PERFORMANCE STANDARDS

The contractor designing and installing the SSD system should be required to guarantee and demonstrate that the system will effectively prevent the intrusion of VOCs into the building. The specific requirements for demonstrating that performance standards have been met can be set on a case-by-case basis. There are two levels of performance standards for SSD systems: confirmation of pressure field and achievement of indoor air quality goals.

5.1 Confirmation of Pressure Field

The primary performance standard which should be used to confirm effective SSD system operation is the demonstration of a negative pressure field that extends under the entire slab. Pressure and/or smoke testing at representative/worst-case test holes after system startup should provide sufficient information to demonstrate the presence of a negative pressure field. After the pressure field is confirmed following system start-up, monitoring of the in-line manometer or other pressure gauge should be an adequate indicator of satisfactory system operation.

5.2 Indoor Air Quality Monitoring

The creation of an effective sub-slab negative pressure field should result in the reduction of VOC concentrations in the indoor air within the building. After SSD system startup, indoor air quality sampling data should be collected to confirm that concentrations of VOCs in indoor air are reduced (e.g. to levels at or below typical indoor air concentrations). Generally, this confirmatory monitoring should be done 2 to 4 weeks after system startup.

Subsequent to this initial evaluation, consideration should be given to conducting one additional indoor air sampling effort during the "worst case" months of January or February (unless, of course, the initial evaluation is conducted during these months). This is especially true if non-winter SSD negative pressure conditions were marginal.

If indoor air quality data continues to indicate elevated concentrations of VOCs, further evaluation would be necessary to determine if (1) the SSD system is functioning properly, but levels of contaminants in the building exceed typical indoor air concentrations, or (2) the SSD system requires modification or expansion. To make such a determination, a Lines of Evidence approach should be applied, looking at all available information and data (e.g., soil gas data; contaminant concentration trends in basement and first floor; chemical forensics, etc.) Short-circuiting problems are of particular concern, where cracks, holes, sumps, or annular spaces in the building foundation/slab disrupt a negative pressure field.

Once an adequate demonstration of SSD system effectiveness has been made, as long as an adequate negative pressure is maintained at the extraction point(s), indoor air quality should be acceptable. For single-family residential structures, it is generally not necessary to institute a regular or long term indoor air-monitoring program, although periodic checks (every 1-3 years) are advisable. More frequent and/or systematic monitoring programs are advisable for larger and more complex buildings, such as schools.

6.0 REPORT SUBMITTALS

A report documenting system installation and initial startup should be submitted as part of an IRA or RAM process. This report should provide details on diagnostic testing, system components, negative pressure observations, etc., as well as an as-built plan or sketch.

Upon the achievement of steady-state operations, SSD systems are subject to the Remedial Monitoring Report submittal requirements of 40.0027. Once any Imminent Hazard and/or CEP conditions are abated (via a demonstration by pressure field and/or indoor air monitoring data), report submittals can occur on a 6-month schedule, synoptic with IRA or RAM status reports. Generally, semi-annual monitoring reports can consist solely of the documentation of continued operation of the extraction fan within specified negative pressure ranges, and/or occasional verification of sub-slab negative pressure readings from the permanent probe installations. In sensitive settings (e.g., homes or schools), indoor air test data should be obtained every 1-3 years, or more frequently, if conditions change (e.g., negative pressure readings).

7.0 OFF-GAS CONTROLS

In accordance with DEP Policy #WSC-94-150, off-gas control systems are not required for SSD systems, provided that the system will emit less than 100 pounds/year of VOCs and will not cause air pollution/odor problems in the surrounding area

8.0 REFERENCES

¹ DiGiulio, Dominic C., and Paul, Cynthia J., *Assessment of Vapor Intrusion in Homes Near the Raymark Superfund Site Using Basement and Sub-Slab Air Samples*, EPA/600/R-05/147, March 2006.

² Bonnefous, Y.C., et. Al., *Field Study and Numerical Simulation of Subslab Ventilation Systems*, ES&T, 1992, 26, 1752-1759.

³ Crawshaw, D.A., and Crawshaw, G.K., "Migration of Elevated VOC Concentrations in Buildings Arising From Contaminated Groundwater", Proceedings of HMC, Hazardous Materials Research Institute, September, 1990.

⁴ USEPA, "Radon Mitigation Standards", EPA 402-R-93-078, October 1993 (Rev April 1994).

Toolbox 5

MassDEP Design & Installation Specifications For State-Funded Response Actions Sub-Slab Depressurization Systems

1.0 Background and Purpose

This document articulates general design, installation, and operational specifications for sub-slab depressurization (SSD) systems. The specifications contained herein shall be used by response contractors retained by MassDEP to mitigate vapor intrusion pathways to impacted structures. At some sites, it may be necessary to deviate from one or more provisions of this document. In such cases, all recommended alterations must be specifically approved in writing by MassDEP.

2.0 Points of Contact

A MassDEP Project Manager will be designated for each SSD system installation. The Project Manager shall be the sole point of contact with MassDEP. The contractor shall provide a primary and alternative point of contact.

3.0 General System Layout

One or more extraction points are cored through a basement/building slab and connected via PVC piping to an in-line suction fan(s) located outside of the occupied area. The exhaust from the fan is discharged to the atmosphere via a PVC riser pipe attached to an exterior wall. An extraction pipe manometer and at least two sub-slab monitoring probes are permanently installed in each system to allow evaluation of system operations.

4.0 General Performance Standard

- 4.1. The SSD system shall be designed and installed in a manner that will achieve and maintain a negative pressure field under and immediately proximate to the impacted structure. Except as approved by the MassDEP Project Manager, an adequate negative pressure field is defined as at least 0.004 inches W.C. (1 Pascal).
- 4.2. All materials and techniques shall comply with or exceed industry standards and/or normal practices, conform to applicable provisions of this document, and be installed in a professional and competent manner, minimizing inconvenience to

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building occupants. All reasonable steps shall be taken to minimize disturbance of floor coverings, plaster/sheetrock walls and ceilings, exterior walls and sidings, and other building components and accessories.

- 4.3. All work must be conducted in compliance with all applicable mechanical, electrical, building, plumbing, energy and fire prevention codes.

5.0 Sequence of Activities

The contractor shall conduct the following activities in the following order:

- 5.1. Obtain from the MassDEP Project Manager Site Access Agreement forms from the owners of the buildings where the SSD Systems will be installed, and note any special provisions specified on that agreement (e.g., location of fan and/or riser pipes);
- 5.2. Conduct an inspection of each building of interest;
- 5.3. Seal cracks, joints, and other gaps that may compromise SSD system operations;
- 5.4. Perform a diagnostic evaluation of each building to establish design parameters;
- 5.5. Design and install system;
- 5.6. Conduct initial startup and demonstrate compliance with design, installation, and performance standards;
- 5.7. Adjust/fine-tune operations and/or correct any deficiencies; and
- 5.8. Provide final report to MassDEP Project Manager

6.0 Building Survey/Inspection

6.1 Design elements

The contractor shall view the building(s) of concern to identify logistical constraints and/or structural features that could affect system operations and effectiveness, including:

- earthen floors;
- high groundwater table (i.e., within 6 inches of bottom of slab)
- the presence of drainage sumps;
- the presence of floor drains;
- cracks in slabs, walls, and/or at the slab/wall interface;
- annular spaces around utility pipes; and

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- piping/system obstructions.

The contractor shall promptly notify MassDEP of any conditions that may compromise or preclude the effective operation of an SSD system.

6.2. Pre-Construction Documentation

If requested by the MassDEP Project Manager, the contractor shall document pre construction site conditions via digital photos and/or videotaping.

7.0 Sealing of Cracks and Sumps

7.1. Small Cracks and Joints

Accessible cracks and joints up to 1/8th inch (0.125") in width and depth shall be sealed with an elastomeric sealant (e.g., caulking) in accordance with the manufacturer's instructions. These sealants must be specifically designed to seal concrete, have low odor, low VOC content (i.e., less than 100 grams VOCs per Liter), and must not contain ingredients known to cause cancer, birth defects, or other reproductive harm, per the state of California "Proposition 65" (this information/statement should be provided in the product's MSDS). Surfaces to be sealed must be clean, dry, and free of soil, decomposed concrete, dust, grease and debris.

7.2. Large Cracks and Joints

Accessible cracks and joints larger than 1/8th inch (0.125") shall be either (i) sealed in accordance with the provisions of Section 7.1, utilizing a foam backer rod or other comparable filler material as per the manufacturer's instruction; and/or (ii) filled with non-shrinking cementitious material.

7.3. Sumps

7.3.1. The contractor shall ensure that sumps do not drain or pump to a sanitary sewerage system. Exceptions or uncertainties in this regard shall be reported to the MassDEP Project Manager.

7.3.2. Drainage sumps shall be covered by a lid constructed of durable plastic or other rigid material that produces an airtight seal. If a sump pump is present, the lid must be easily removable by the owner/occupant of the building. Electrical wiring and water ejection piping penetrating the lid shall be made airtight by the use of grommets and/or sealants.

7.3.3. If necessary to prevent short-circuiting of the SSD system, a check

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valve or water trap shall be installed on the sump drain/ejection piping.

7.4. Floor Drains

Floor drains that are not in use shall be sealed with concrete or grout, but only if permission is obtained from the building owner. Floor drains that need to be maintained shall be inspected and evaluated with respect to the potential to short-circuit the SSD system. Floor drains that do not have an acceptable water trap shall be so modified or retrofitted with a *Dranjer* or equivalent insert.

8.0 Earthen Floors

8.1. Small areas of earthen floors (less than 50 ft²) shall be sealed by the contractor by placement of a 3-inch layer of concrete.

8.2. Larger areas of earthen floor (50 ft² or more) shall be sealed by the contractor by the placement of an impermeable membrane, consisting of a 6-mil (or 3-mil cross-laminated) polyethylene sheeting, overlapped (at least 12 inches) and sealed at the seams and around penetrations. Other more effective and/or cost-effective sealing techniques may be proposed by the contractor, subject to approval by the MassDEP Project Manager.

9.0 Diagnostic Evaluation

The airflow characteristics and capacity of the material(s) beneath the building slab shall be quantitatively determined by diagnostic testing.

9.1. Identify the location of any sub-slab utility piping or conduits, oil feed lines, or other sub-slab installations. Ensure that all subsequent holes and excavation activities do not puncture or disturb any such installations.

9.2. Drill a 1-inch to 4-inch diameter hole in the building/basement slab, at the proposed location of the SSD system extraction point (Extraction Hole). Unless precluded by structural, utility, or design constraints, this hole should be near an exterior wall (but away from any footings), in the side of the building that the owner has selected as the most desirable location for the SSD riser pipe.

9.3. Advance the Extraction Hole at least 12 inches below grade. Observe and record soil characteristics, and whether groundwater was encountered.

9.4. Drill at least two additional small-diameter holes through the building/basement slab (Monitoring Holes); one or more about half-way between the Extraction Hole and the far end of the area to be served by that extraction point, and one or more near the far end of area to be served by that extraction point. To the

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extent possible, these holes shall be located within inconspicuous areas (e.g., utility rooms, closets, beneath stairs).

9.4.1. Use a rotary hammer drill to core a hole between 5/16 and 1 inch in diameter. Penetrate the slab and core a hole 3-6 inches into the sub-slab materials.

9.4.2. Insert a smaller-diameter tube into the cored hole, taking care that it does not extend to the bottom of the hole. Place putty, modeling clay, beeswax, or some other material in the annular space in a manner that will create an effective seal.

9.5. Use a Magnehelic® or similar-type gauge to measure and record the baseline pressure differential between the void space beneath the slab and the air space above the slab. The gauge should be capable of detecting and quantifying a pressure differential of 0.002 inches of water column (w.c.).

9.6. Apply a vacuum at the Extraction Hole, using a blower/apparatus that can achieve at least 50-inches water column (w.c.) of negative pressure.

9.7. Record the pressure differential in the Monitoring Holes after the application of the vacuum at the Extraction Hole. If a vacuum of less than 0.004 inches of w.c. is observed at a Monitoring Hole (compared to baseline conditions), use smoke to determine if a positive downward flow of air is observable at the Monitoring Hole. Record all data and observations.

9.8. Inform the MassDEP Project Manager if a vacuum of at least 0.004 inches w.c. and/or positive downward flow of air is not observed in each Monitoring Hole, and before proceeding with the design and installation of the SSD system.

10.0 System Design and Installation

10.1. Overall

10.1.1. A generalized depiction of a typical system is provided in Attachment 1.

10.1.2. Generally, smaller buildings (e.g., single-family homes) should require only one extraction point and a single fan. A decision to install more than one extraction point or fan in such cases must be pre-approved by the MassDEP Project Manager.

10.1.3. Generally, larger buildings/building areas (greater than 1400 square feet) should be serviced by multiple extraction points and fans. A decision to the contrary must be pre-approved by the MassDEP Project

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Manager.

10.2. Permits and Approvals

The contractor is responsible for obtaining all needed permits and approvals, with the exception of MassDEP permits and approvals, which will be obtained by the MassDEP Project Manager.

10.3. Suction Fan

10.3.1. On the basis of data and observations obtained during the diagnostic evaluation, select a fan unit.

- Generally, a low-pressure/high flow fan unit should be selected for sites where sub-slab materials or conditions appear to be permeable and transmissive, and/or where negative pressure responses in monitoring holes were rapid and robust.
- Generally, a high-pressure/low flow fan unit should be selected for sites where sub-slab materials or conditions appear to be less permeable or less transmissive, and/or where negative pressure responses in monitoring holes was delayed or highly attenuated.

10.3.2. The specific fan unit selected shall optimally balance the following design objectives:

10.3.2.1. producing sufficient vacuum to ensure a negative pressure field (at least 0.004 inches W.C.) under areas of interest;

10.3.2.2. using the lowest amount of electrical power (watts) to achieve the necessary negative pressure field; and

10.3.2.3. minimizing the amount of operational noise and vibration.

10.3.3. The suction fan unit shall:

10.3.3.1. be UL listed and rated for continuous, all-weather operations, with thermal overload with automatic reset features in the event of a power failure;

10.3.3.2. be contained in a durable, weatherproof, UV resistant housing, installed with removable couplings or flexible connections, mounted and secured in a manner that minimizes the transfer of vibrations to the structure;

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10.3.3.3. be hard-wired into the building power supply, incorporating or including an on/off switch accessible to the building owner/occupants;

10.3.3.4. have a minimum 2-year manufacturer's warranty on parts and labor.

10.3.4. The suction fan unit shall generally be installed outside of the building, between 3 and 5 feet above ground level. Alternative locations may be approved by the MassDEP Project Manager based upon building conditions, vandalism concerns, and/or owner preference.

10.4. Extraction Point(s)

10.4.1. The Extraction Point shall be cored into the slab as near as possible to the exterior wall where the exhaust riser will be located. Logistical or pressure-field constraints that preclude the achievement of this goal must be discussed with the MassDEP Project Manager.

10.4.2. The Extraction Point core shall be 4 inches in diameter, and extend a minimum of 12 inches below the bottom of the slab. Sub-slab materials shall be removed to create a suction pit void space approximately 12 inches in diameter. Where necessary or appropriate, the suction pit shall be backfilled with washed $\frac{1}{2}$ to 1-inch size gravel. The contractor shall inform the MassDEP Project Manager if a larger and/or modified suction pit is necessary to ensure adequate pressure field extension.

10.4.3. A 3-inch diameter PVC pipe shall be inserted into the top of the suction pit, supported in a manner that will permanently prevent downward movement. The annular space between the 3-inch PVC pipe and the concrete slab shall be sealed with a non-shrinking cementitious grout, taking care to maintain the integrity of the suction pit.

10.5. Piping

10.5.1. Piping shall conform to local and applicable building and plumbing codes.

10.5.2. Unless precluded by applicable codes, all system piping shall consist of 3-inch diameter, schedule 40 PVC, with treaded or solvent-welded connections consistent with manufacturer specifications.

10.5.3. Piping shall not block access to building areas requiring maintenance or inspection, and, unless approved by the MassDEP Project Manager, shall not be run across or in front of windows.

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- 10.5.4. All horizontal-piping runs shall be installed at a minimum slope of 1/8 inch per foot in order to drain all condensate back to the Extraction Point(s).
- 10.5.5. All piping within the building space shall be under suction. All pressurized piping runs must be made exterior to the building.
- 10.5.6. The fan discharge pipe shall be routed up an exterior wall, to a point 2 feet above the roofline, and have an attached 180° elbow to prevent inflow of atmospheric precipitation. The termination point must be at least 10 feet above grade, and at least 10 feet from any window, door, operable roof window, air intake, or adjacent building.
- 10.5.7. Horizontal and vertical piping shall be supported at a frequency and in a manner required by applicable building or plumbing codes. Routing of piping shall be done in a manner that does not compromise the structural integrity of the building. Penetrations of joists or beams shall be done only in strict compliance with applicable building codes. All penetrations between discrete building spaces and exterior walls shall be sealed by application of an expanding foam product within the penetration annular space.

10.6. Sampling Ports

- 10.6.1. At least two sampling ports shall be installed in system piping to allow for pressure and vapor-quality testing:
 - 10.6.1.1. One port shall be installed within the building on piping under negative pressure; and
 - 10.6.1.2. One port shall be installed outside the building on piping under positive pressure, just downstream of the fan.
- 10.6.2. Sampling ports shall be brass or nylon threaded 3/16th inch O.D. hose barbs installed into the 3-inch diameter PVC piping via drilling and tapping, using sealants if necessary to produce an airtight and long-lasting connection. The hose barb must be equipped with a cap and/or stopcock to prevent leakage in or out of the PVC piping.

10.7. Electrical

- 10.7.1. All wiring shall be conducted by a Licensed Massachusetts Electrician, in accordance with all applicable provisions of the National Electric Code and any additional local requirements.

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10.7.2. All suction fans shall be hard wired into an appropriate house circuit. An on/off switch shall be provided within the building near the extraction pipe riser and system manometer.

10.7.3. Wiring may not be located in or chased through system piping or heating or cooling ductwork.

10.8. Monitors and Alarms

10.8.1. All systems shall include the installation of a manometer or pressure gauge near the Extraction Point in a location and manner that can be easily monitored by building occupants. The range of such devices shall be consistent with negative pressure levels at that specific location.

10.8.2. When directed by MassDEP, the contractor shall also install an audible and/or visual system off alarm, to be activated in the event a depressurization fan ceases to operate. Audible alarms shall be at least 60 dB in volume.

10.9. Permanent Sub-Slab Monitoring Probes

10.9.1. At least two permanent sub-slab monitoring probes shall be installed to permit long-term monitoring of pressure fields and soil vapor constituents. At least one probe must be in the far end of the pressure field. Generally, permanent probes shall be installed in the same holes used to construct temporary monitoring points during the diagnostic phase.

10.9.2. Drill a 1.5-inch diameter (+/-) outer hole on top of the smaller-diameter hole (used to measure pressure differentials during the diagnostic tests), to a depth of 2 inches, as depicted in Figure 5-1.

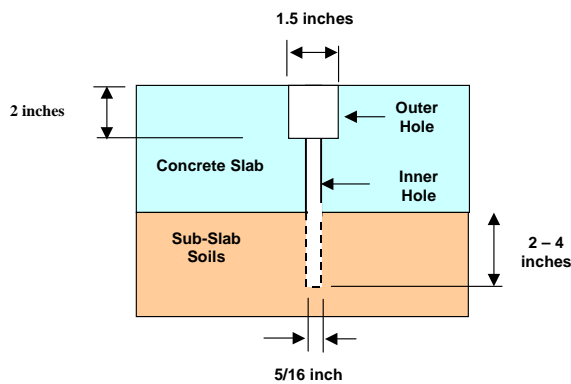


Figure 5- 1 - Drilling Details

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10.9.2.1. Firmly insert a tapered, center-hole Fluroelastomer stopper (Plasticoid Company or equivalent) into the base (smooth end) of a threaded $\frac{1}{2}$ inch PVC pipe cap (actual I.D. approx $\frac{7}{8}$ " , O.D. approx 1"). The stopper must be tightly inserted to create an airtight connection, but must not penetrate more than $\frac{3}{4}$ inch into the 1.5-inch

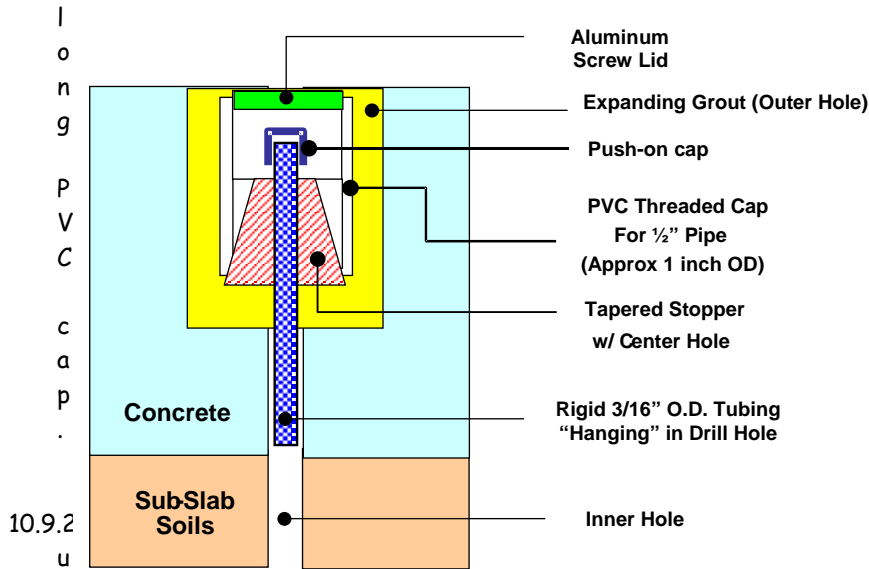


Figure 5-2 - Sub-Slab Monitoring Probe Details

length of $\frac{3}{16}$ th inch (O.D.) rigid tube so that it is 1 inch shorter than the thickness of the concrete slab. Insert this tube through the center hole of the tapered stopper, from the bottom, until $\frac{3}{8}$ th inch of the tube extends through the top (smaller end) of the stopper.

10.9.2.3. Invert the cap/stopper/tube assembly, and place the rigid tube into the Inner Hole, resting the union/stopper on the bottom of the Outer Hole. Ensure that rigid tube is suspended in the Inner Hole, just above the slab/soil interface, as depicted in Figure 5-2.

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10.9.2.4. Insert Rocktite® or a similar fast drying expansion cement product into the Outer Hole area around and beneath the cap/stopper/tube assembly, adjusting the unit such that the top of the cap is flush with the concrete slab. Use a putty knife to ensure proper application and coverage.

10.9.2.5. Finish the installation by applying a push-on cap to the rigid tubing, ensuring an airtight connection, and by installing an aluminum (electrical-conduit-type) screw lid (recessed into the threaded cap).

11.0 System Start-Up and Optimization

- 11.1. The contractor shall activate the system, providing the MassDEP Project Manager with at least 24 hours prior notice.
- 11.2. Immediately following activation, the contractor shall inspect all system components, and conduct any needed adjustments or fine-tuning.
- 11.3. The contractor shall verify proper function of the suction fan and system manometer, gauges, and/or alarms, and verify the achievement of the appropriate vacuum at the Extraction Point, as indicated by the system manometer or gauge.
- 11.4. The contractor shall use a Magnahelic Gauge to measure pressure differential at each of the permanent sub-slab monitoring points. An adequate negative pressure field must be verified by the measurement of at least 0.004 inches W.C. of negative pressure (1 Pascal) within all monitoring points. At probes where the negative pressure reading is less than 0.004 inches W.C., a smoke test shall be performed to document the unambiguous downward flow of building air into the sub-slab.

12.0 Backdrafting Evaluation

- 12.1. The contractor shall conduct a back-drafting evaluation once the system has achieved steady-state operation, to ensure the proper venting of flue-gases from all combustion appliances located directly above the basement or building slab (e.g., oil or gas furnace, water heater, fireplace; wood or coal stove, etc). This evaluation shall be conducted in accordance with procedures specified in the US EPA Radon Mitigation Standard, as reproduced below:

12.1.1. Close all windows and doors, both external and internal.

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- 12.1.2. Open all HVAC supply and return air duct vents/registers.
 - 12.1.3. Close fireplace and wood stove dampers.
 - 12.1.4. Turn on all exhaust and air distribution fans and combustion appliances EXCEPT the appliance being tested for backdrafting.
 - 12.1.5. Wait 5 minutes.
 - 12.1.6. Test to determine the indoor-outdoor pressure differential in the room where the appliance being tested is located. If the pressure differential is a negative 5 Pascals or more, assume that a potential for backdrafting exists.
 - 12.1.7. To begin a test for actual spillage of flue gases, turn on the appliance being tested. (If the appliance is a forced air furnace, ensure that the blower starts to run before proceeding.)
 - 12.1.8. Wait 5 minutes.
 - 12.1.9. Using either a smoke tube or a carbon dioxide gas analyzer, check for flue gas spillage near the vent hood.
 - 12.1.10. Repeat steps (4) through (9) for each natural draft combustion appliance being tested for backdrafting. Seasonal and extreme weather conditions should be considered when evaluating pressure differentials and the potential for backdrafting.
- 12.2. If spillage is confirmed from any natural draft combustion appliance, the contractor shall immediately shut down the SSD system, and notify the MassDEP Project Manager. The SSD system shall not be operated until back-drafting problems are corrected.

13.0 Signage and Labels

- 13.1. The contractor shall affix labels to clearly mark the Extraction Point riser pipe, manometer, fan on/off switch, and other system components as appropriate.
- 13.2. The contractor shall affix markings and a label clearly indicating the acceptable operating range of the system manometer or gauge. This range shall consider normal fluctuations based upon system age and meteorological conditions, but shall have as the lower limit the minimum amount of vacuum required to maintain a negative pressure field beneath the structure, and as an upper limit a reading that is likely to indicate significant system or site modification (e.g., high

Toolbox 5 - Bid Specifications for SSDS

groundwater table).

- 13.3. The contractor shall prominently display a one-page system Information Sheet in the area immediately surrounding the Extraction Point manometer/gauge and fan on/off switch. This Information Sheet must be made weatherproof and tear-resistant by means of lamination, and be modeled after the templates provided in Attachments 2 and 3.

14.0 Site Restoration

The contractor shall clean all work areas of materials and debris associated with the SSD project. It shall not be the contractor's responsibility to repair or restore flooring materials, wallboard, or other building components or materials that were disturbed or removed as reasonably necessary to install the SSD system.

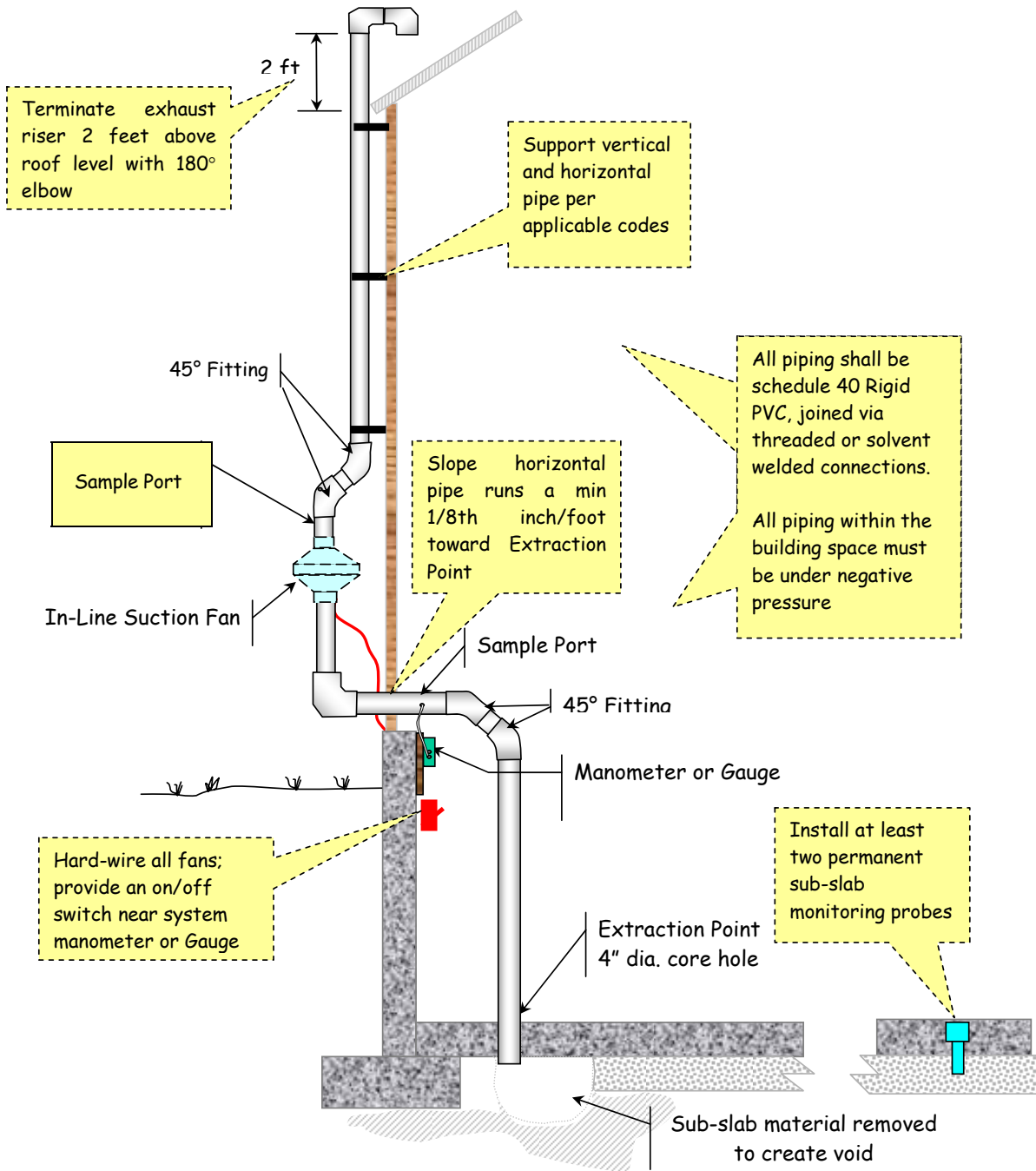
15.0 Required Reports and Documentation

- 15.1. Within 30 days of the system installation and start-up, the contractor shall submit an SSD Completion Report to the MassDEP Project Manager, as provided in Attachment 4.
- 15.2. The contractor shall append to the Completion Report any other materials they deem necessary or appropriate for the installation(s) in question, and/or such additional materials as specified by the MassDEP Project Manager.

Toolbox 5 - Bid Specifications for SSDS

Attachment 1

Typical Sub-slab Depressurization System



Attachment 2

Required Information Sheet

SSD Systems with Manometers

Toolbox 5 - Bid Specifications for SSDS

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Sub-slab Depressurization System

[Address]

What is this?

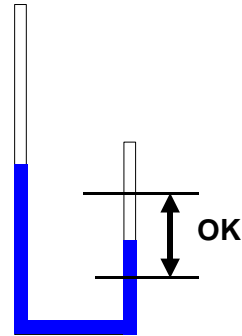
This sheet contains important information about a Sub-Slab Depressurization System that has been installed in this building by the Massachusetts Department of Environmental Protection.

What is a Sub-Slab Depressurization System?

A sub-slab depressurization system is one or more pipes installed through the floor of a building and connected to a fan. The fan creates a vacuum in the pipe, in order to remove potentially harmful vapors that would otherwise enter the building. These vapors are created by polluted soil and/or groundwater under or near this building. The fan and associated piping discharge these vapors to the outdoor air. Although the fan has an on/off switch, it should only be shut off for maintenance or emergencies.

What do I have to do?

Occasionally check to make sure the fan and system are working properly. You can do this by checking the manometer that has been installed on or near a 3-inch diameter plastic (PVC) pipe rising out of the building floor. This manometer is a "U" shaped tube containing a colored fluid that measures the amount of vacuum (negative pressure) being produced by the fan. Markings on the manometer indicate where the colored liquid should be. During a power failure, the fan will shut down, and the manometer will be out of range. However, this should be corrected when power is restored.



What if something goes wrong?

If the manometer is not within the specified range:

- ☞ Check to see that the fan switch (near the manometer) is in the "on" position
- ☞ Check the electrical panel for a tripped circuit breaker or blown fuse
- ☞ Inspect the tubes that connect the manometer to the port on the 3-inch diameter PVC pipe. Ensure that they are securely fastened.
- ☞ Inspect the fan unit, located on an outside wall. Check to ensure that it is operating by listening for a soft hum or by placing a hand on the fan body.

Who should I contact if there is a problem or if I have any questions?

During business hours, call MassDEP at xxx-xxx-xxxx, and ask for the Bureau of Waste Site Cleanup. Explain that you are calling about a sub-slab depressurization system installed in the building by MassDEP.

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Attachment 3

Required Information Sheet

SSD Systems with Gauges

Toolbox 5 - Bid Specifications for SSDS

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IMPORTANT INFORMATION - DO NOT DEFACE OR REMOVE



Sub-slab Depressurization System

[Address]

What is this?

This sheet contains important information about a Sub-Slab Depressurization System that has been installed in this building by the Massachusetts Department of Environmental Protection.

What is a Sub-slab Depressurization System?

A sub-slab depressurization system is one or more pipes installed through the floor of a building and connected to a fan. The fan creates a vacuum in the pipe, in order to remove potentially harmful vapors that would otherwise enter the building. These vapors are created by polluted soil and/or groundwater under or near this building. The fan and associate piping discharge these vapors to the outdoor air. Although the fan has an on/off switch, it should only be shut off for maintenance or emergencies.

What do I have to do?

Occasionally check to make sure the fan and system are working properly. You can do this by checking the gauge that has been installed on or near a 3-inch diameter plastic (PVC) pipe rising out of the building floor. This gauge measures the amount of vacuum (negative pressure) being produced by the fan. Markings on the gauge indicate where the arrow should be. During a power failure, the fan will shut down, and the gauge will be out of range. However, this should be corrected when power is restored.



What if something goes wrong?

If the gauge is not within the specified range:

- ☞ Check to see that the fan switch (near the gauge) is in the "on" position
- ☞ Check the electrical panel for a tripped circuit breaker or blown fuse
- ☞ Inspect the tubes that connect the gauge to the port on the 3-inch diameter PVC pipe. Ensure that they are securely fastened.
- ☞ Inspect the fan unit, located on an outside wall. Check to ensure that it is operating by listening for a soft hum or by placing a hand on the fan body.

Who should I contact if there is a problem or if I have any questions?

During business hours, call MassDEP at xxx-xxx-xxxx, and ask for the Bureau of Waste Site Cleanup. Explain that you are calling about a sub-slab depressurization system installed in the building by MassDEP.

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Attachment 4

Required Completion Report Form

Toolbox 5 - Bid Specifications for SSDS

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**SUB-SLAB DEPRESSURIZATION
SYSTEM
COMPLETION REPORT**

Town:

Address:

Personnel	Contractor Name & Address:				
	Contact:		Phone No.:		
	MassDEP Project Manager Name:				
Dates	Date Project Started:	Date Project Completed:	Date of Completion Report:		
	Use of Building: <input type="checkbox"/> residential <input type="checkbox"/> school <input type="checkbox"/> daycare <input type="checkbox"/> other:				
	Foundation: <input type="checkbox"/> poured concrete <input type="checkbox"/> concrete block <input type="checkbox"/> fieldstone <input type="checkbox"/> other:				
Building Details	Basement Type: <input type="checkbox"/> full basement <input type="checkbox"/> crawlspace <input type="checkbox"/> slab-on-grade <input type="checkbox"/> other:				
	Basement/Lowest Level: <input type="checkbox"/> concrete slab <input type="checkbox"/> earthen floor/crawlspace <input type="checkbox"/> other				
	Concrete Slab/Floor Cracks: <input type="checkbox"/> no cracks <input type="checkbox"/> minimal <input type="checkbox"/> moderate <input type="checkbox"/> substantial				
	Basement Drainage: <input type="checkbox"/> no sump/drain <input type="checkbox"/> sump with drain <input type="checkbox"/> sump with pump <input type="checkbox"/> other				
	<input type="checkbox"/> None <input type="checkbox"/> small cracks <input type="checkbox"/> large cracks <input type="checkbox"/> small area <input type="checkbox"/> large area <input type="checkbox"/> sump <input type="checkbox"/> floor drains				
	Materials: <input type="checkbox"/> elastomeric sealant <input type="checkbox"/> polyethylene sheeting <input type="checkbox"/> grout <input type="checkbox"/> concrete <input type="checkbox"/> other Brand name of sealant(s):				
Diagnostics	Negative Pressure (inches w.c.)		Sub-Slab materials:		
	Probe ID #	Probe ID #	Estimated Depth of groundwater below slab/floor: <input type="checkbox"/> > 6 inches <input type="checkbox"/> > 12 inches <input type="checkbox"/> other/known:		
System	Number Extraction Points:		# Permanent sub-slab probes: <input type="checkbox"/> 2 <input type="checkbox"/> other:		
	Number of Fans:		Feet of PVC pipe used:		
	Monitoring: <input type="checkbox"/> manometer <input type="checkbox"/> gauge <input type="checkbox"/> alarm Range (inches w.c.):				
	Fan Make & Model:				
Startup	Date:		Negative Pressure (inches of W.C.)		
	<input type="checkbox"/> no problems noted <input type="checkbox"/> problems encountered & fixed		Manometer/gauge	Probe #	Probe #
	Backdraft Evaluation	Appliances evaluated: <input type="checkbox"/> furnace <input type="checkbox"/> water heater <input type="checkbox"/> other:			
		Result: <input type="checkbox"/> OK; less than 5 Pascal depressurization <input type="checkbox"/> other:			
Acceptable Range Notated on System Manometer/Gauge:					



**SUB-SLAB DEPRESSURIZATION
SYSTEM
COMPLETION REPORT**

Town:






Address:

Sketch of Building/System Installed

Include the following Detail:

- ☞ Footprint of basement/building area of interest
- ☞ Important site/building features, sumps, drains
- ☞ Location of Extraction Point
- ☞ Location of Pilot Extraction Hole(s) (if different)
- ☞ Location and ID of Permanent Sub-slab Probes
- ☞ Location and ID of Temp Probes (if different)
- ☞ Measurements (ties) to Permanent Sub-slab Probes +/- 0.5 ft
- ☞ Location of outside riser pipe, fan, and fan shut off
- ☞ Horizontal PVC pipe run
- ☞ North Arrow

Use the following Symbols:

-  Extraction Point
-  Permanent sub-slab probe
-  Temporary sub-slab probe
-  Suction Fan
-  Extraction Hole (pilot test)



SUB-SLAB DEPRESSURIZATION
SYSTEM
COMPLETION REPORT

TOWN: _____

ADDRESS: _____

Contractor Check List and Certification

Check each box to certify compliance with MassDEP requirements; explain all exceptions:

- Local permits and approvals obtained as required
- Earthen floors, cracks, sumps and/or floor drains sealed as necessary and appropriate
- Extraction Hole void-space at least 12 inches deep and wide
- Selected suction fan optimal for building and sub-slab characteristics
- Suction fan hard-wired into building circuit with a shut-off switch near Extraction Point
- Suction fan operating properly with minimum noise and vibration
- All system piping 3-inch diameter schedule 40 PVC
- All system piping within building living spaces under negative pressure
- All horizontal piping runs sloped a minimum of 1/8 inch per foot toward Extraction Point
- Exhaust riser pipe terminated 2 feet above roof line and equipped with elbow
- Sampling ports with airtight caps/valves installed before and after suction fan
- Manometer or gauge installed near Extraction Point
- Acceptable operating range clearly displayed on system manometer or system gauge
- At least two permanent sub-slab monitoring probes installed
- Negative pressure confirmed in at least two permanent sub-slab monitoring probes
- Back-drafting evaluation completed and any concerns communicated to MassDEP
- System Information Sheet posted near Extraction Point

To the best of my knowledge and belief, the above is true, accurate and complete

Printed Name: _____ Title: _____

Signature: _____ Date: _____

- Check here if additional explanations or materials are attached or provided on page 4



SUB-SLAB DEPRESSURIZATION
SYSTEM
COMPLETION REPORT

TOWN:

ADDRESS:

Notes and Explanations

Provide any necessary information, detail, explanations, or notes:

Nothing to report

Additional materials are appended to this report

Description:

Attachment 5

Standard Access Agreement

Toolbox 5 - Bid Specifications for SSDS

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Standard Access Agreement to Install Sub-Slab Depressurization System

WHAT IS THE PURPOSE OF THIS FORM?

The Massachusetts Department of Environmental Protection (MassDEP) would like to install a sub-slab depressurization (SSD) system on your property. The purpose of this form is to:

- describe why and how we would install the system;
- explain what your obligations would be if we did install the system;
- obtain your permission to install the system; and/or
- explain what will happen if you decide not to allow us to install the system.

We want to make sure that you understand these issues before you agree to provide access to your property.

WHY DO I NEED A SUB-SLAB DEPRESSURIZATION (SSD) SYSTEM?

An SSD system is used to intercept harmful vapors and gases from beneath buildings. At many homes in New England, SSD systems are installed to intercept radon - a naturally occurring radioactive gas. At this property, MassDEP wishes to install this system to collect chemical vapors that are being generated by polluted soil and/or groundwater located under or near the building.

WHY DOESN'T THE PERSON RESPONSIBLE FOR THIS PROBLEM TAKE CARE OF IT?

MassDEP will work to see that this happens. However, it is sometimes necessary for the agency to take immediate actions when responsible parties cannot be identified, or cannot or will not proceed.

WHAT ARE THE STEPS THAT WILL BE TAKEN TO INSTALL THIS SYSTEM?

Initially, an inspection will be conducted of the building and lowest floor level (e.g., the basement or ground floor). Steps will then be taken to seal cracks or voids in the floor. An airtight cover will be installed over open sumps, but in a manner that will allow you access to sump pumps.

A series of small holes will then be drilled into the floor and a vacuum/blower will be used to determine how well gases move beneath the building, and determine the number and size of needed fans and extraction pipes.

The final system will then be installed, and some of the small holes that were drilled through the floor will be converted into permanent monitoring probes. These probes will be only about 1 inch in diameter, and will be set flush with the floor/slab level. We will



Standard Access Agreement to Install Sub-Slab Depressurization System

make every attempt to locate these holes/probes in inconspicuous areas, like closets or utility rooms.

WHAT WILL THE FINAL SYSTEM LOOK LIKE?

Inside the building, a 4-inch diameter hole will be cored through the lowest floor level (usually a concrete slab in a basement). A 3-inch diameter PVC pipe will be inserted into this hole, and run vertically up the nearest interior wall or post until it reaches ground level, at which point it will run horizontally to and through an exterior wall. (At some sites, more than one pipe must be inserted through the floor). On the exterior wall, the pipe will be connected to a small suction fan, which will be connected to your electrical system. The discharge from the fan will be piped vertically up the exterior wall in a 3-inch diameter PVC pipe to a point 2 feet above the roofline. You can obtain more information, and view diagrams, plans, and pictures of common systems at <http://www.mass.gov/dep/cleanup/homeownr.htm>

WHO WILL INSTALL THE SYSTEM? WILL IT BE DISRUPTIVE?

The system will be installed by a licensed and insured contractor retained by MassDEP, following specifications developed by the agency. The entire installation should be completed in a few days. While reasonable efforts will be made to minimize disruption and accommodate your concerns, it will be your responsibility to repair or replace any floor tiles, wallboard, or other building components altered or disturbed by the project.

WILL I HAVE TO PAY FOR THE INSTALLATION OF THIS SYSTEM?

No. MassDEP will pay for all costs associated with the installation and startup of the system.

HOW WILL THIS SYSTEM OPERATE?

The suction fan will continuously operate, and create a vacuum that will draw-in chemical vapors from beneath the building. These vapors will then be discharged harmlessly into the outdoor air above the roof level. The suction fan is designed for this purpose and for outdoor use, and should last for years. Although the fan creates a slight hum, it is generally not discernable unless you are close by.

WHAT WOULD HAPPEN IF THE SSD SYSTEM IS NOT INSTALLED?

Chemical vapors can enter the building and present a health risk to occupants. Depending upon how high these risks may be, and who may be exposed (e.g., children), if MassDEP is not given permission to install the system, the agency may order the building owner to



Standard Access Agreement to Install Sub-Slab Depressurization System

install a similar system at their expense, and/or request that the local Health Department determine if the building is fit for human occupancy.

WHAT WOULD BE MY OBLIGATIONS IF I GIVE PERMISSION TO INSTALL THE SYSTEM?

1. You will be required to pay for the electricity required to operate the fan. Although the exact size of the fan can only be determined after conducting tests at the site, the average size fan uses approximately 100 watts of power. This is equivalent to continuously running a 100-watt light bulb; at \$0.10 per Kilowatt-hour, this would translate to approximately \$7.30 per month.
2. You will be expected to exercise reasonable efforts to protect the system from damage.
3. You may be periodically asked to provide access to the system so that agency staff or contractors may inspect it (generally not more than once/year).

CAN THIS SYSTEM EVER BE REMOVED?

Yes. This system is a temporary measure to protect your health until such time as the cause of the problem - the polluted soil and groundwater - is cleaned up. Depending upon the site, however, it may be necessary to run this system for a number of years.



Permission to Install Sub-Slab Depressurization System

I, the undersigned, am the owner of the building located at the following address:

Number

Street

Town

I have read the attached Standard Access Agreement, and hereby give permission to MassDEP to install a Sub-Slab Depressurization System at this location, subject to the conditions noted below. I understand that MassDEP will install this system at no expense to myself, and that agency employees and contractors will make reasonable efforts to minimize adverse impacts to my property.

Printed Name: _____

Signature: _____

Date: _____ Telephone: _____

EXHAUST/RISER PIPE

Viewing the front of the building, install the riser pipe on the exterior wall:

- at back of building on left side of building on right side of building
 doesn't matter to be discussed when planning system other:

OTHER CONDITIONS/REQUESTS/COMMENTS:

More on back side of this form

OTHER CONDITIONS/REQUESTS/COMMENTS (continued):

The MassDEP Project Manager for this Site is:

Telephone Number:

Email:

Please return this form to the above person at: MassDEP, [address]

Toolbox 6

Typical Indoor Air Concentrations

See <http://www.mass.gov/dep/cleanup/iawg.htm> for more/updated information

Table 6-1: Summary of published data (courtesy of NYDOH)

http://www.nyhealth.gov/nysdoh/gas/svi_guidance/svi_appendc.htm

Table 6-1: ALL DATA IN UNITS OF $\mu\text{g}/\text{m}^3$								
Compound	NYSDOH Study ²		EPA BASE Data ³		NYSDOH Database ⁴		EPA Database ⁵	
	Homes in NYS 1997 - 2003		Offices 1994 - 1998		Homes in NYS 1989 - 1996		Homes & Offices 1970 - 1988	
	Indoor	Outdoor	Indoor	Outdoor	Indoor	Outdoor	Indoor	Outdoor
1,1,1-trichloroethane	<0.25 - 1.4	<0.25 - 0.38	2.6 - 11	<0.6 - 1.7	<5.0 - 6.7	<2.0 - 2.8	3.0 - 30	0.7 - 3.3
1,1,2,2-tetrachloroethane	<0.25	<0.25	NA	NA	<1.5	<1.5	ND	ND - 0.06
1,1,2-trichloroethane	<0.25	<0.25	<1.3	<12	<1.0	<1.0	NA	ND - 0.14
1,1,-dichloroethane	<0.25	<0.25	<0.5	<0.4	<1.0	<1.0	NA	ND - 0.2
1,1-dichloroethene	<0.25	<0.25	<1.1	<1.0	<1.0	<1.0	ND	ND
1,2-dibromoethane	<0.25	<0.25	<1.3	<1.2	<1.5	<1.5	ND	ND
1,2-dichloroethane	<0.25	<0.25	<0.6	<0.6	<1.0	<1.0	ND	ND - 0.22
1,2-dichlorobenzene	<0.25	<0.25	<0.9	<1.0	<2.0	<2.0	ND	ND - 0.23
1,2-dichloropropane	<0.25	<0.25	<1.4	<1.4	<1.0	<1.0	NA	0.1 - 0.3
1,3-dichlorobenzene	<0.25	<0.25	<0.8	<0.8	<2.0	<2.0	0.32 - 5.6	ND - 1.2
1,2,4-trimethylbenzene	0.78 - 4.4	<0.25 - 1.0	1.7 - 5.1	<1.6 - 3.1	<4.4 - 7.0	<1.0	0.6 - 4.0	2.8 - 7.4

Table 6-1: ALL DATA IN UNITS OF $\mu\text{g}/\text{m}^3$								
	NYSDOH Study ²		EPA BASE Data ³		NYSDOH Database ⁴		EPA Database ⁵	
1,3,5-trimethylbenzene	<0.25 - 1.7	<0.25 - 0.44	<1.5	<1.4	<5.0	<1.0	ND - 5.4	0.2 - 2.5
acetone	10 - 46	3.9 - 23	32 - 60	15 - 32	NA	NA	11 - 27	ND - 6.7
benzene	1.2 - 5.7	<0.25 - 2.6	2.1 - 5.1	1.2 - 3.7	<3.2 - 5	<1.6 - 4.7	3.3 - 21	2.0 - 11
bromo-dichloromethane	NA	NA	NA	NA	<10	<5.0	NA	NA
bromoform	NA	NA	NA	NA	<5.0	<1.0	ND	ND
carbon tetrachloride	<0.25 - 0.68	<0.25 - 0.68	<0.9	<1.0	<3.1	<3.1	ND - 0.8	0.4 - 0.8
chlorobenzene	<0.25	<0.25	<0.7	<0.8	<2.0	<2.0	NA	ND - 1.4
chloroform	<0.25 - 0.54	<0.25	<0.5	<0.4	<1.0 - 4.3	<2.4	ND - 3.4	0.1 - 0.9
cis-1,2-dichloroethene	<0.25	<0.25	<1.0	<1.0	<1.0	<1.0	NA	ND - 0.45
dibromo-chloromethane	NA	NA	NA	NA	<5.0	<5.0	NA	NA
ethylbenzene	0.43 - 2.8	<0.25 - 0.61	<1.6 - 3.4	<1.4 - 1.6	<3.4 - 4.8	<4.3	2.0 - 9.6	1.0 - 5.4
n-hexane	0.63 - 6.5	<0.25 - 1.1	1.6 - 6.4	<1.2 - 2.7	<1.0 - 3.6	<1.5	NA	2.9 - 10
methyl bromide (bromomethane)	<0.25	<0.25	<0.9	<1.0	<1.0	<1.0	NA	0.2 - 12
methyl chloride (chloromethane)	<0.25 - 2.0	<0.25 - 2.0	2.1 - 3.1	2.0 - 3.0	<1.0	<1.0 - 1.4	NA	1.3 - 1.5
methylene chloride	0.38 - 6.3	<0.25 - 0.87	<1.7 - 5.0	<1.8 - 3.0	<3.0 - 5.6	<3.4	NA	1.1 - 6.3
m,p-xylene	0.52 - 4.7	<0.25 - 0.69	4.1 - 12	<3.6 - 7.3	<4.4 - 9.5	<4.3	4.3 - 18	2.0 - 11
methyl-tert-butyl-ether (MTBE)	<0.25 - 6.7	<0.25 - 1.0	<1.7 - 12	<1.8	NA	NA	NA	NA
naphthalene	NA	NA	<2.5	<2.4	<10	<3.5	NA	0.2 - 5.7
o-xylene	0.39 - 3.1	<0.25 - 0.74	<2.4 - 4.4	<1.4 - 2.6	<3.8 - 5.0	<4.3	2.0 - 9.3	1.0 - 6.5

Table 6-1: ALL DATA IN UNITS OF $\mu\text{g}/\text{m}^3$								
	NYSDOH Study ²		EPA BASE Data ³		NYSDOH Database ⁴		EPA Database ⁵	
styrene	<0.25 - 0.68	<0.25	<1.8	<1.6	<1.0	<1.0	ND - 2.8	ND - 1.4
tetrachloroethene	<0.25 - 1.2	<0.25 - 0.34	<1.9 - 5.9	<1.4 - 3.0	<3.7	<3.7	1.7 - 11	0.82 - 5.9
toluene	4.2 - 25	0.68 - 3.3	10.7 - 26	5.9 - 16	6.5 - 25	1.0 - 6.1	NA	0.6 - 20
trichloroethene	<0.25	<0.25	<1.2 - 1.2	<1.5	<2.7	<1.7	ND - 4.5	0.05 - 2.5
vinyl chloride	<0.25	<0.25	<0.9	<1.0	<1.0	<1.0	NA	ND - 0.78
<p>¹The ranges provided in the table represent the 25th percentile to 75th percentile, (middle half), of the results from the EPA and NYSDOH databases and are labeled as background. A single value is the minimum reporting limit for that compound, and indicates that more than 75% of the data are below the detection limit. These databases are comprised of air testing results from studies where there were no known sources of chemicals or chemical spills.</p> <p>²Summary of Indoor and Outdoor Levels of Volatile Organic Compounds From Fuel Oil Heated Homes in NYS, 1997 to 2003. Unpublished. New York State Department of Health, Bureau of Toxic Substance Assessment. See Table 6-2.</p> <p>³Building Assessment and Survey Evaluation (BASE '94-'98). Unpublished. Indoor Environments Division, United States Environmental Protection Agency, Washington, DC.</p> <p>⁴Background Indoor/Outdoor Air Levels of Volatile Organic Compounds in Homes Sampled by the New York State Department of Health, 1989-1996. 1997. New York State Department of Health, Bureau of Toxic Substance Assessment.</p> <p>⁵National Ambient Volatile Organic Compounds (VOCs) Data Base Update. 1988. Nero and Associates, Portland, OR, for the United States Environmental Protection Agency, Research Triangle Park, NC. EPA PB88-195631.</p> <p>< Means "less than". The number following a "less than sign" (<) is the lowest level the laboratory test can reliably measure (reporting limit). If there is a "<" before any number, then the chemical was NOT detected in your sample.</p>								
NA - Not Available			ND - Not Detected. Chemical was not detected, and detection limits were not provided					

Table 6-2
Detailed Data from NYSDOH Study
Indoor and Outdoor Levels of Volatile Organic Compounds from Fuel Oil Heated Homes
1997-2003

http://www.nyhealth.gov/nysdoh/indoor/fuel_oil.htm

Revised November 2005

Table 6-2: Detailed Data 1997-2003 NYSDOH Study – All data $\mu\text{g}/\text{m}^3$															
Chemical	Indoor							Outdoor							
	N	ND(%)	25 th Pctl	50 th Pctl	75 th Pctl	90 th Pctl	Upper F	N	ND(%)	25 th Pctl	50 th Pctl	75 th Pctl	90 th Pctl	Upper F	
1,1,1-TRICHLOROETHANE	400	41.5%	<0.25	0.33	1.1	3.1	2.5	200	62.5%	<0.25	<0.25	0.33	0.60	0.64	
1,1,2,2-TETRACHLOROETHANE	400	96.5%	<0.25	<0.25	<0.25	<0.25	0.38	200	99.5%	<0.25	<0.25	<0.25	<0.25	0.36	
1,1,2-TRICHLOROETHANE	400	96.0%	<0.25	<0.25	<0.25	<0.25	0.38	200	99.5%	<0.25	<0.25	<0.25	<0.25	0.34	
1,1,2-TRICHLOROTRIFLUOROETHANE	400	44.5%	<0.25	0.54	1.1	1.8	2.5	200	48.5%	<0.25	0.46	1.1	1.9	2.5	
1,1-DICHLOROETHANE	400	99.0%	<0.25	<0.25	<0.25	<0.25	0.38	200	100.0%	<0.25	<0.25	<0.25	<0.25	0.36	
1,1-DICHLOROETHENE	400	93.3%	<0.25	<0.25	<0.25	<0.25	0.40	200	99.5%	<0.25	<0.25	<0.25	<0.25	0.40	
1,2,3-TRIMETHYLBENZENE	400	41.0%	<0.25	0.39	1.1	2.7	2.5	200	82.5%	<0.25	<0.25	<0.25	0.39	0.46	
1,2,4-TRICHLOROBENZENE	400	79.8%	<0.25	<0.25	<0.25	3.4	0.47	200	84.0%	<0.25	<0.25	<0.25	2.3	0.44	
1,2,4-TRIMETHYLBENZENE	400	12.3%	0.69	1.9	4.3	9.5	9.8	200	54.5%	<0.25	<0.25	0.81	1.8	1.9	
1,2-DIBROMOETHANE	400	99.3%	<0.25	<0.25	<0.25	<0.25	0.38	200	99.5%	<0.25	<0.25	<0.25	<0.25	0.37	
1,2-DICHLOROBENZENE	400	78.8%	<0.25	<0.25	<0.25	0.72	0.48	200	83.0%	<0.25	<0.25	<0.25	0.60	0.42	
1,2-DICHLOROETHANE	400	98.5%	<0.25	<0.25	<0.25	<0.25	0.37	200	99.5%	<0.25	<0.25	<0.25	<0.25	0.42	
1,2-DICHLOROPROPANE	400	97.8%	<0.25	<0.25	<0.25	<0.25	0.39	200	97.0%	<0.25	<0.25	<0.25	<0.25	0.40	
1,2-DICHLOROTETRAFLUOROETHANE	400	87.3%	<0.25	<0.25	<0.25	0.52	0.42	200	84.5%	<0.25	<0.25	<0.25	0.56	0.48	

Table 6-2: Detailed Data 1997-3003 NYSDOH Study – All data $\mu\text{g}/\text{m}^3$

Chemical	Indoor							Outdoor						
	N	ND(%)	25 th Pctl	50 th Pctl	75 th Pctl	90 th Pctl	Upper F	N	ND(%)	25 th Pctl	50 th Pctl	75 th Pctl	90 th Pctl	Upper F
1,3,5-TRIMETHYLBENZENE	400	25.0%	0.27	0.64	1.7	3.6	3.9	200	71.5%	<0.25	<0.25	0.34	0.69	0.71
1,3-DICHLOROBENZENE	400	79.0%	<0.25	<0.25	<0.25	0.60	0.46	200	85.0%	<0.25	<0.25	<0.25	0.48	0.42
1,4-DICHLOROBENZENE	400	66.5%	<0.25	<0.25	0.54	1.3	1.2	200	82.0%	<0.25	<0.25	<0.25	0.54	0.46
2,3-DIMETHYLPENTANE	400	32.3%	<0.25	0.65	2.2	7.5	5.2	200	73.5%	<0.25	<0.25	0.31	0.96	0.66
2,4-DIMETHYLPENTANE	400	35.8%	<0.25	0.57	2.0	7.7	4.7	200	69.5%	<0.25	<0.25	0.37	0.84	0.78
ACETONE	227	5.3%	10	21	52	110	115	114	6.1%	3.4	6.4	14	44	30
ALPHA-PINENE	400	19.8%	0.33	1.5	4.4	14	10	200	61.0%	<0.25	<0.25	0.53	2.0	1.2
BENZENE	400	7.0%	1.1	2.1	5.9	15	13	200	9.0%	0.57	1.3	2.3	4.3	4.8
BROMOMETHANE	400	77.0%	<0.25	<0.25	<0.25	0.60	0.48	200	81.0%	<0.25	<0.25	<0.25	0.47	0.45
CARBON TETRACHLORIDE	400	50.3%	<0.25	<0.25	0.59	0.81	1.3	200	54.0%	<0.25	<0.25	0.6	0.81	1.2
CHLOROBENZENE	400	99.5%	<0.25	<0.25	<0.25	<0.25	0.41	200	100.0%	<0.25	<0.25	<0.25	<0.25	0.38
CHLOROETHANE	400	90.3%	<0.25	<0.25	<0.25	<0.25	0.39	200	94.0%	<0.25	<0.25	<0.25	<0.25	0.40
CHLOROFORM	400	53.0%	<0.25	<0.25	0.54	1.4	1.2	200	84.0%	<0.25	<0.25	<0.25	0.39	0.48
CHLOROMETHANE	400	46.0%	<0.25	0.50	1.8	3.3	4.2	200	48.0%	<0.25	0.51	1.8	3.2	4.3
CIS-1,2-DICHLOROETHENE	400	91.0%	<0.25	<0.25	<0.25	<0.25	0.41	200	96.5%	<0.25	<0.25	<0.25	<0.25	0.38
CIS-1,3-DICHLOROPROPENE	400	97.0%	<0.25	<0.25	<0.25	<0.25	0.38	200	97.5%	<0.25	<0.25	<0.25	<0.25	0.40
CYCLOHEPTANE	400	39.8%	<0.25	0.52	1.3	3.1	2.9	200	74.0%	<0.25	<0.25	0.28	0.68	0.56
CYCLOHEXANE	400	31.3%	<0.25	0.81	2.6	8.1	6.3	200	68.5%	<0.25	<0.25	0.43	1.3	0.94
DICHLORODIFLUOROMETHANE	400	53.8%	<0.25	<0.25	4.1	15	10	200	54.0%	<0.25	<0.25	4.2	7.5	10
d-LIMONENE	400	19.3%	0.50	2.8	8.4	24	20	199	77.9%	<0.25	<0.25	<0.25	0.83	0.48
ETHYL ALCOHOL	227	1.3%	27	160	540	1400	1300	114	0.9%	3.3	6.9	16	31	34

Table 6-2: Detailed Data 1997-3003 NYSDOH Study – All data $\mu\text{g}/\text{m}^3$

Chemical	Indoor							Outdoor						
	N	ND(%)	25 th Pctl	50 th Pctl	75 th Pctl	90 th Pctl	Upper F	N	ND(%)	25 th Pctl	50 th Pctl	75 th Pctl	90 th Pctl	Upper F
ETHYLBENZENE	400	14.5%	0.41	1.0	2.8	7.4	6.4	200	53.5%	<0.25	<0.25	0.48	1.1	1.0
ETHYLCYCLOHEXANE	400	37.3%	<0.25	0.44	1.2	2.6	2.8	200	82.0%	<0.25	<0.25	<0.25	0.46	0.45
ETHYLMETHACRYLATE	227	94.7%	<0.25	<0.25	<0.25	<0.25	0.39	114	100.0%	<0.25	<0.25	<0.25	<0.25	0.38
HEXACHLORO-1,3-BUTADIENE	400	76.0%	<0.25	<0.25	<0.25	4.6	0.49	200	81.0%	<0.25	<0.25	<0.25	2.3	0.46
ISO-OCTANE	400	32.5%	<0.25	0.56	2.1	6.5	5.0	200	69.5%	<0.25	<0.25	0.33	0.87	0.67
ISOPRENE	400	11.0%	0.81	2.0	4.3	8.8	9.5	200	55.5%	<0.25	<0.25	0.86	2.8	2.0
ISOPROPYLBENZENE	400	64.8%	<0.25	<0.25	0.39	0.88	0.82	200	91.0%	<0.25	<0.25	<0.25	<0.25	0.38
M,P-XYLENE	400	13.5%	0.50	1.5	4.6	12	11	200	55.0%	<0.25	<0.25	0.48	1.4	1.0
METHYL ETHYL KETONE	227	8.8%	1.4	3.4	7.3	16	16	114	7.0%	0.76	1.3	2.6	6.3	5.3
METHYL ISOBUTYL KETONE	227	44.9%	<0.25	0.33	0.86	2.2	1.9	114	75.4%	<0.25	<0.25	<0.25	0.94	0.50
METHYLCYCLOHEXANE	400	28.0%	<0.25	0.68	1.9	6.4	4.5	200	70.5%	<0.25	<0.25	0.34	0.78	0.70
METHYLENE CHLORIDE	400	22.3%	0.31	1.4	6.6	22	16	200	50.5%	<0.25	<0.25	0.73	1.6	1.6
METHYLMETHACRYLATE	227	86.8%	<0.25	<0.25	<0.25	0.45	0.43	114	96.5%	<0.25	<0.25	<0.25	<0.25	0.41
METHYL-tert-BUTYL ETHER	227	30.4%	<0.25	0.79	5.6	27	14	114	46.5%	<0.25	0.27	0.86	2.1	1.9
n-BUTYLBENZENE	400	55.5%	<0.25	<0.25	0.49	1.2	1.1	200	87.0%	<0.25	<0.25	<0.25	0.33	0.41
n-DECANE	400	10.0%	1.2	2.7	6.6	16	15	200	32.5%	<0.25	0.84	2.0	2.6	4.7
n-DODECANE	400	18.3%	0.42	1.5	3.9	11	9.2	200	47.0%	<0.25	0.45	1.9	4.5	4.5
n-HEPTANE	400	4.8%	1.0	2.8	7.6	19	18	200	28.5%	<0.25	0.49	1.0	2.6	2.2
n-HEXANE	400	12.5%	0.63	1.6	6.0	18	14	200	39.5%	<0.25	0.42	0.88	1.6	2.0
n-NONANE	400	16.3%	0.37	1.3	3.4	8.8	7.9	200	65.5%	<0.25	<0.25	0.37	0.78	0.74
n-OCTANE	400	21.0%	0.33	0.89	2.3	4.2	5.2	200	56.0%	<0.25	<0.25	0.65	1.2	1.5

Table 6-2: Detailed Data 1997-3003 NYSDOH Study – All data $\mu\text{g}/\text{m}^3$

Chemical	Indoor							Outdoor						
	N	ND(%)	25 th Pctl	50 th Pctl	75 th Pctl	90 th Pctl	Upper F	N	ND(%)	25 th Pctl	50 th Pctl	75 th Pctl	90 th Pctl	Upper F
n-PROPYLBENZENE	400	51.5%	<0.25	<0.25	0.69	1.7	1.5	200	92.0%	<0.25	<0.25	<0.25	<0.25	0.39
n-UNDECANE	400	14.8%	0.57	1.8	5.0	12	12	200	52.5%	<0.25	<0.25	0.67	1.7	1.5
O-XYLENE	400	17.8%	0.39	1.1	3.1	7.6	7.1	200	60.0%	<0.25	<0.25	0.56	1.7	1.2
sec-BUTYLBENZENE	400	56.3%	<0.25	<0.25	0.55	1.2	1.2	200	80.0%	<0.25	<0.25	<0.25	0.44	0.46
STYRENE	400	43.8%	<0.25	0.30	0.64	1.3	1.4	200	79.0%	<0.25	<0.25	<0.25	0.43	0.45
tert-BUTYLBENZENE	400	57.0%	<0.25	<0.25	0.60	1.6	1.3	200	88.5%	<0.25	<0.25	<0.25	0.27	0.44
TETRACHLOROETHENE	400	46.8%	<0.25	0.34	1.1	2.9	2.5	200	71.5%	<0.25	<0.25	0.34	0.81	0.68
TETRAHYDROFURAN	227	72.2%	<0.25	<0.25	0.35	3.3	0.78	114	94.7%	<0.25	<0.25	<0.25	<0.25	0.40
TOLUENE	400	6.3%	3.5	9.6	24.8	58	57	200	6.0%	0.60	1.3	2.4	5.9	5.1
TRANS-1,3-DICHLOROPROPENE	400	100.0 %	<0.25	<0.25	<0.25	<0.25	0.40	200	100.0%	<0.25	<0.25	<0.25	<0.25	0.41
TRICHLOROETHENE	400	80.8%	<0.25	<0.25	<0.25	0.48	0.46	200	88.5%	<0.25	<0.25	<0.25	0.32	0.43
TRICHLOROFUOROMETHANE	400	10.5%	1.1	2.9	5.4	17	12	200	35.0%	<0.25	0.78	2.2	3.6	5.1
VINYL CHLORIDE	400	96.8%	<0.25	<0.25	<0.25	<0.25	0.37	200	98.5%	<0.25	<0.25	<0.25	<0.25	0.39

N: Total Number of Samples

ND(%): % of nondetects

Upper F: Upper Fence, see accompanying text for this calculation

Most homes near Albany NY. All homes pre-inspected to verify no history of oil spills or use of VOC products. Analysis by Summa® canister and EPA Method TO 15; Detection Limit 0.25 $\mu\text{g}/\text{m}^3$; Reporting Limit 1 $\mu\text{g}/\text{m}^3$. To develop the descriptive statistics, randomly generated numbers between 0.00 and 0.25 were substituted for levels below the detection limit of 0.25 $\mu\text{g}/\text{m}^3$.

Table 6-3
Preliminary & Partial Data - Haley & Aldrich
Typical Indoor Air Concentrations of VOCs and APH in Massachusetts Residences (2004 - 2005)
[http://www.newmoa.org/cleanup/cwm/vapor/Rago_NEWMOA_\(TO%20POST\)-final.pdf#search=%22Haley%20Aldrich%20indoor%20air%20NEWMOA%22](http://www.newmoa.org/cleanup/cwm/vapor/Rago_NEWMOA_(TO%20POST)-final.pdf#search=%22Haley%20Aldrich%20indoor%20air%20NEWMOA%22)

Table 6-3: Haley & Aldrich – Massachusetts Residences – 2006 All Data µg/m3						
Chemical Compound	Frequency of Detection	Minimum Detected Conc	Maximum Detected Conc	Median	75 th Pctl	90 th Pctl
Acetone	97/100	4.89	257	26.5	41.4	61.6
Benzene	31/100	1.6	28.1	2.0	1.9	6.8
C5 - C8 Aliphatic Hydrocarbons	83/100	24.9	1240	58	125	329
C9 – C12 Aliphatic Hydrocarbons	80/100	28.4	3480	68	110	222
Chloromethane (Freon)	79/100	1.04	4.21	1.2	1.4	1.8
Ethyl Acetate	52/100	1.96	32	2.3	5.9	9.8
Ethyl Alcohol	100/100	16.8	7290	286	676	1673
Ethylbenzene	19/100	2.01	30	2.2	2.1	4.6
Isopropyl alcohol	92/100	1.26	443	10.1	29.5	89.7
Methyl Ethyl Ketone (MEK)	79/100	?	3270	2.7	4.0	9.6
MtBE	46/100	2.54	155	1.8	6.9	38
O-Xylene	29/100	2.2	23	2.2	2.4	6.8
Tetrachloroethylene (PCE)	5/100	6.2	27.6	3.4	3.4	3.4
Toluene	90/100	1.99	944	7.6	17.9	42.5
Trichloroethylene (TCE)	2/100	3.84	110	2.7	2.7	2.7
Xylenes M & P	52/100	2.54	81.9	3.0	7.4	21
Xylene, O	29/100	2.2	23	2.2	2.4	6.8

100 homes in Massachusetts; LSPs and MassDEP employees; Summa® canister and EPA TO-15, Reporting Limit generally between 2 – 4 µg/m3

Toolbox 7 - Internet Links to Useful Sites

	Identifier/Description	Link
MassDEP	MassDEP Home/School IRA SOP	http://intranet/bwsc/bwsc-docs/sop/sop0301.pdf
	MassDEP Indoor Air Sampling Guide	http://www.mass.gov/dep/images/indair.pdf
	MassDEP Risk Assessment Short Forms	http://www.mass.gov/dep/service/compliance/riskasmt.htm#air
US EPA	Chemical Fact Sheets	http://www.epa.gov/chemfact/
	EPA Vapor Intrusion Guidance	http://www.epa.gov/correctiveaction/eis/vapor.htm
	EPA "TO" Air Testing Methods	http://www.epa.gov/ttn/amtic/airtox.html
Toxicity	Air Toxics Website (EPA)	http://www.epa.gov/ttn/atw/techres.html
	IRIS (EPA)	http://www.epa.gov/iriswebp/iris/index.html
	ATSDR ToxFAQs	http://www.atsdr.cdc.gov/toxfaq.html
	Chem ID (toxicity and general data)	http://chem.sis.nlm.nih.gov/chemidplus/chemidheavy.jsp
Misc	NIST (chemical synonyms, CAS, info)	http://webbook.nist.gov/chemistry/name-ser.html
	Johnson & Ettinger Model (EPA)	http://www.epa.gov/athens/learn2model/part-two/onsite/JnE_lite_forward.htm
	ppbv to $\mu\text{g}/\text{m}^3$ units converter:	http://www.airtoxics.com/cclasses/unitcalc.html
	PID Response:	http://www.raesystems.com/~raedocs/App_Tech_Notes/Tech_Notes/TN-106_Correction_Factors.pdf
	Modeling subsurface transport of hydrocarbons	http://www.epa.gov/athens/learn2model/index.html
	OHM in household products	http://householdproducts.nlm.nih.gov/
	Interstate Technology & Regulatory Council	http://www.itrcweb.org/teampublic_Vapor.asp
	Vapor Intrusion Links	http://www.geosyntec.com/vi_links.asp

Toolbox 8 List of Acronyms

APH	Air-phase Petroleum Hydrocarbons
BOH	Board of Health
BTEX	Benzene, Toluene, Ethylbenzene & Xylenes
BWSC	Bureau of Waste Site Cleanup
CEP	Critical Exposure Pathway
CF	Calibration Factor
CMR	Code of Massachusetts Regulations
DCE	Dichloroethylene
DRD	Deputy Regional Director
ECD	Electron Capture Detector
ELCD	Electrolytic Conductivity Detector
ELCR	Excess Lifetime Cancer Risk
EPA	Environmental Protection Agency
EPH	Extractable Petroleum Hydrocarbons
ER	Emergency Response
eV	Electron-volt
FD	Fire Department
FEP	Fluorinated Ethylene Propylene
FID	Flame Ionization Detector
GC	Gas Chromatograph
GC/FID	Gas Chromatograph/Flame Ionization Detector
GC/MS	Gas Chromatograph/Mass Spectrometer
HDPE	High Density Polyethylene
HI	Hazard Index
HVAC	Heating Ventilation & Air Conditioning
I.D.	Inner Diameter

TOOLBOX 8 - LIST OF ACRONYMS

IAQ	Indoor Air Quality
IH	Imminent Hazard
IP	Ionization Potential
IRA	Immediate Response Action
L	Liter
LEL	Lower Explosive Limit
LNAPL	Light Non Aqueous Phase Liquid
LSP	Licensed Site Professional
MCP	Massachusetts Contingency Plan
mL	Milliliters
MtBE	Methyl tert-butyl ether
N/A	Not Applicable
NA	Not Available
NAPL	Non Aqueous Phase Liquid
ND	Not Detected
NIOSH	National Institute for Occupational Safety and Health
NL	Not Listed
NOR	Notice of Responsibility
NYSDOH	New York State Department of Health
O.D.	Outer Diameter
OHM	Oil and Hazardous Materials
ORS	Office of Research and Standards
OSHA	Occupational Safety and Health Administration
Pa	Pascals
PCE	Perchloroethylene (also known as Tetrachloroethylene)
Pctl	Percentile
PEL	Permissible Exposure Limits
PID	Photo ionization Detector
ppbV	Parts per billion by volume

TOOLBOX 8 - LIST OF ACRONYMS

ppmV	Parts per million by volume
Psi	Pounds per square inch
PVC	Polyvinyl chloride
QA/QC	Quality Assurance/Quality Control
RAO	Response Action Outcome
REL	Recommended Exposure Limits
RNF	Release Notification Form
SOP	Standard Operating Procedure
SSD	Sub Slab Depressurization
SSDS	Sub Slab Depressurization System
TCE	Trichloroethylene
UST	Underground Storage Tank
VC	Vinyl Chloride
VOA	Volatile Organic Analysis
VOC	Volatile Organic Compound
VPH	Volatile Petroleum Hydrocarbons
W	Watt
W.C.	Water column

TOOLBOX 8 - LIST OF ACRONYMS