Vapor Intrusion Assessments Performed During Site Investigations

Guidance Document 4-01a
Petroleum Remediation Program

This guidance document describes the process used to assess the risk posed by vapor intrusion at petroleum release sites. It also outlines the necessary procedures and requirements for conducting soil gas, sub-slab soil gas, and indoor air investigations, including sampling, data interpretation, reporting, and Quality Assurance/Quality Control (QA/QC) procedures.

The Minnesota Pollution Control Agency's (MPCA) Remediation Division has recently issued a supplementary document titled, *Vapor Intrusion Technical Support Document*. This document provides additional information on using multiple lines of evidence for evaluating the vapor intrusion pathway, development of a site conceptual model for vapor intrusion, data interpretation methods, remediation strategies, and other topics related to vapor intrusion. The *Vapor Intrusion Technical Support Document* should be used as a supplemental resource for completing vapor intrusion investigations in addition to the guidance described in this document for the Petroleum Remediation Program (PRP).

Vapor intrusion is the migration of Volatile Organic Compounds (VOCs) from the subsurface into buildings. VOCs, such as those found in petroleum, can migrate as soil gas through the subsurface and into overlying or adjacent buildings. In extreme cases, vapors may accumulate in dwellings or occupied buildings at hazardous levels. Fortunately, people may be able to smell high concentrations of vapors, especially those from petroleum. Field instruments such as organic vapor meters or explosimeters are also able to identify such instances.

There are concerns regarding the health effects of long-term exposure to petroleum vapors in indoor air. At low levels, odors may not be observed to warn people that contaminants are present, and conventional field instruments are unlikely to detect impacts. Long-term exposure to petroleum vapors may increase the risk of developing adverse health conditions, including cancer. Though these risks are usually low, they are avoidable by identifying and then reducing or eliminating the vapor intrusion pathway.

The PRP's vapor intrusion assessment is a field-based procedure used to identify vapor sources, receptors and subsurface migration routes associated with a petroleum release. This is accomplished by completing a detailed evaluation of receptors within a 100-foot radius from the "worst case" sample area; or the area of known or suspected highest petroleum contamination, accompanied by the collection and analysis of soil gas samples.

A vapor intrusion receptor is defined as human occupants of an inhabitable building. A vapor source is defined as contaminated soil, contaminated groundwater, or Non-Aqueous Phase Liquids (NAPL). A subsurface migration route is defined as soils in the unsaturated zone through which vapors are transported. Receptor, vapor source, and migration route are the three elements that make up the vapor intrusion pathway. Evaluation of the vapor intrusion pathway is required for site investigations completed in the PRP.

I. Preliminary Soil Gas Assessment During Limited Site Investigation or Remedial Investigation

The following procedures and information for investigating the vapor intrusion pathway should be completed as part of all standard site investigations for the PRP unless the exclusion of some or all of the work is specifically pre-approved by PRP staff. **If no receptors of concern are identified within 100 feet of the "worst case" sampling area, contact PRP project staff to determine if a vapor intrusion investigation will be required.** In such situations, the Limited Site Investigation (LSI) or Remedial Investigation (RI) report should provide sufficient supporting documentation that receptors were not present.

At PRP sites with receptors, a preliminary soil gas assessment will take place during the LSI or RI phase of a site investigation as described below. This preliminary soil gas assessment should take place based upon an evaluation of receptors within a 100-foot radius from the "worst case" sample defined below.

Minnesota Pollution Control Agency • 520 Lafayette Rd. N., St. Paul, MN 55155-4194 • www.pca.state.mn.us
651-296-6300 • 800-657-3864 • TTY 651-282-5332 or 800-657-3864 • Available in alternative formats

Required investigation steps for completing a preliminary soil gas assessment at PRP sites:

A. **"Worst case" soil gas sample:** One (1) soil gas sample should be collected from a direct push boring placed close to the area of the known or suspected highest petroleum contamination. While the highest contamination is often found at the release source, (e.g. tank basin), alternate situations may exist and should be accounted for to ensure that soil gas associated with the most heavily contaminated soil or groundwater is sampled. See Table 1 below for recommended sampling depths.

If a petroleum release source is immediately adjacent to or underneath a receptor it may be appropriate to collect sub-slab soil gas samples in addition to or instead of collecting an exterior "worst case" soil gas sample during the preliminary soil gas assessment. If such conditions are apparent contact the MPCA project team for prior approval.

B. **Receptor-specific soil gas samples:** Up to four (4) additional subsurface soil gas samples should be collected near receptors within 100 feet from the "worst case" sample. See Table 1 below for sampling depths. This sampling has two objectives: The first is to obtain a representation of soil gas concentrations near receptors to provide a reliable basis for risk-based decisions. The second is to assess the accumulation of soil gas around receptors nearest to the "worst case" sample. To balance these objectives, and to account for limiting factors such as property boundaries and access issues, here are two scenarios for the collection of soil gas samples:

1. Less than four receptors: If four or less receptors are located within 100 feet from the "worst case" sample, including on-site receptor(s), the soil gas samples should include one sample collected near each receptor.
2. More than four receptors: At sites where the number of receptors within 100 feet from the "worst case" sample exceeds four, including on-site receptors(s), samples should be evenly distributed near receptors within the defined sampling area.

If the horizontal extent of impacted groundwater or NAPL extends beyond 100 feet from the "worst case sample", it may be necessary to collect additional soil gas samples beyond this preliminary assessment area. In these situations, additional soil gas sampling may be required near receptors within 100 feet of the defined groundwater or NAPL plume's edge.

Professional judgment should be used to decide whether receptors require a soil gas sample. Buildings with low human exposure can be considered for exclusion from this sampling. Subsurface structures such as utility corridors, utility service lines, fractured bedrock, or other subsurface anomalies may act as preferential migration routes for soil gas and should be considered for sampling if buildings are located in close proximity.

Table 1. Soil gas sample collection depths

Soil gas sample	Sample collection depth
"Worst Case" soil gas sample	8-10 feet below grade, minimum of 2 feet above the water table. Minimum depth of 3 feet. If water table or bedrock does not permit collection at minimum 3 feet, sample does not need to be collected.
Receptor-specific soil gas sample	Buildings with basements: 8-10 feet below grade. Buildings with slab-on-grade or crawl space: 3-5 feet below grade. Minimum depth of 3 feet. If the water table or shallow bedrock does not permit collection at a minimum of 3 feet, the sample does not need to be collected.

Note: If site conditions prevent the collection of samples at 3 feet and greater depths, the MPCA PRP staff may request other means of assessing vapor intrusion.

A field instrument (e.g., Photoionization Detector (PID) organic vapor measurement should be collected from each boring at the soil gas sampling interval and recorded on the chain-of-custody form. Soil gas, sub-slab, indoor air and ambient air samples should be analyzed by U.S. Environmental Protection Agency (EPA) method TO-15 (full-scan) for compounds in the Minnesota Soil Gas List (Appendix A). In situations where high contamination levels are found the use of EPA method TO-14 will be allowable. This determination should only be made by the laboratory.

Beyond this, no additional field work related to soil gas or vapor intrusion investigations are required as part of an LSI or RI, and none should be conducted without pre-approval from the PRP project team.

Data evaluation and recommendations

Evaluation of soil gas and sub-slab soil gas results should be completed using multiples of the MPCA Intrusion Screening Values (ISVs) as screening factors described below:

- Contaminant concentrations are less than 10 times (10x) ISVs.
- Contaminant concentrations are between 10 times (10x) and 100 times (100x) ISVs.
- Contaminant concentrations are greater than 100 times (100x) ISVs.

Direct comparison of indoor air samples to the compound-specific ISV should be made when completed. Appendix B contains additional information describing the ISVs for use in PRP vapor intrusion investigations.

Recommendations as part of the preliminary soil gas assessment should be based on the presence of receptors, geology and soil characteristics, the contaminant concentrations in "worst case" area, and contaminant concentrations in receptor-specific soil gas samples. The LSI/RI report should include recommendations based on the following general criteria:

A. If the concentrations from a "worst case" soil gas sample or a receptor-specific sample do not exceed the 10x screening values for petroleum compounds, no further vapor intrusion actions would be required.

B. If the concentrations from a receptor-specific sample fall between the 10x and 100x screening values for petroleum compounds, the vapor intrusion pathway will need to be further characterized. An appropriate recommendation for completing further assessment should be included in the investigation report form. Additional assessment of the vapor intrusion pathway may include: confirmation soil gas samples, completion of a Vapor Intrusion Interior Building Survey Form (Appendix C) to evaluate the receptor for preferential soil gas entry points, or the direct measurement of sub-slab soil gas concentrations by collecting sub-slab samples. A recommendation for no further investigation to the receptor must be supported through a site conceptual model (SCM) indicating that the vapor intrusion pathway is either incomplete, or that the pathway may be complete but does not present a risk to building occupants based on additional pathway assessment information.

C. If soil gas concentrations from a receptor-specific sample are greater than the 100x screening values for petroleum compounds, a building-specific investigation will be required to further characterize the vapor intrusion pathway. Examples of building-specific investigation techniques would include completion of a Vapor Intrusion Interior Building Survey Form, sub-slab soil gas or sub-slab soil gas in conjunction with indoor air sampling to provide direct evidence that elevated petroleum vapors beneath the building slab are not migrating into the receptor.

The need for additional vapor intrusion investigation, and possible corrective action, is based on the results of the risk assessment procedure conducted as part of the LSI or RI. If the assessment detects a soil gas cloud from a petroleum release site, and the soil gas contaminant concentrations near receptors exceed the compound-specific screening levels, a building-specific investigation of the vapor intrusion pathway may be required. This investigation may include evaluating soil gas entry points by completing a *Vapor Intrusion Interior Building Survey Form*, confirmation sampling of soil gas samples, sub-slab soil gas sampling beneath the building slab, or indoor air sampling may be required for evaluating the existence of a completed pathway to the interior of a structure. If a completed vapor intrusion pathway is established, appropriate corrective action measures will be required. **Additional soil gas/vapor intrusion investigation and corrective action should be conducted only after MPCA PRP project staff approval of the recommended actions**.

Possible corrective action design scenarios

A. If there is direct evidence or significant indirect evidence that a vapor intrusion pathway is complete, corrective action will likely be required and a conceptual Corrective Action Design Scenarios (CAD) must be submitted to the PRP. The corrective action objectives will be to mitigate the vapor source or interrupt the migration route between the vapor source and the receptor minimizing risk of exposure to building occupants. Building control technologies, such as sub-slab depressurization systems, commonly used in the radon mitigation industry, can be highly effective building controls for vapor intrusion. Building pressurization or heating, ventilating, and air conditioning modifications at larger commercial or industrial buildings may be appropriate as well. Section 6.0 of the *Vapor Intrusion Technical Support Document* provides additional information on building control technologies along with other corrective action options that may be applicable for vapor intrusion CAD situations.

B. Additional soil gas investigation may be required if the soil gas cloud has continued to migrate beyond the impacted building(s) towards other receptors.

C. In cases where buildings overlie or are adjacent to contaminated groundwater or NAPL, it may be necessary to monitor the soil gas cloud along with the groundwater plume to demonstrate that they are either stable or declining. If deemed necessary, a recommendation for completing this work should be included in a monitoring-based CAD.

Site conceptual model

Information used for investigating the vapor intrusion pathway must be interpreted through constructing an SCM that describes the risks associated with the vapor intrusion pathway. An SCM should be viewed as a descriptive and interpretative tool for understanding how quantitative and qualitative factors affect the fate and transport of subsurface vapors, sources of vapors and their relationship **to** identified receptors. It is understood that the refinement of information within an SCM may occur over the lifetime of a site. Discussion of the vapor intrusion risk assessment should be included in Guidance Document 4-06 *Investigation Report Form* or 4-08 *Monitoring Report* when applicable. For additional information on developing SCMs refer to PRP Guidance Document 1-01 *Petroleum Remediation Program General Policy*; Section 2 of the *Vapor Intrusion Technical Support Document*; and *Vapor Intrusion Pathway: A Practical Guideline,* VI-1, Interstate Technology & Regulatory Council, Washington, D.C.

II. PRP Recommended Sampling Methodologies and Field QA/QC

Recommended field methods and procedures for soil gas, sub-slab vapor, indoor air, and outdoor (ambient) air sampling are described below as well as in Appendix D of the *Vapor Intrusion Technical Support Document*. While it is understood that different practitioners will employ various methods based on their experience and equipment, it is expected that due care will be taken to ensure the integrity of the samples and data quality. The procedures recommended here may be varied or changed with PRP project staff approval, depending on site-specific conditions or emerging technologies and methodologies. In all cases, the methodologies used in the field must be thoroughly described and documented in the final report accompanying the sampling results. Field work should be completed using the same methods and procedures at all sampling locations throughout the site investigation.

A. **Soil gas:** The method for soil gas sampling involves the collection and analysis of a sample from an evacuated canister using the EPA TO-15 method (full-scan). Soil gas sampling point installations may be permanent or temporary. The following basic procedures should be included in any sampling protocol:

1. Advance the soil gas sampling point to the necessary depth (see Table 1) using direct push technology, or manual probes if site conditions permit.
2. An appropriate sealing material (e.g. bentonite slurry) should be placed around the probe rod at the ground surface to avoid sample short circuiting to the atmosphere.
3. Soil gas sampling points should be fitted with inert tubing (e.g., polyethylene, stainless steel, or Teflon®) of the appropriate size.
4. Prior to collecting the sample, a minimum of two volumes (i.e., total volume of the sampling point and tube) must be purged. This can be accurately completed using a graduated syringe. This process is to ensure samples collected are representative of sub-surface vapors.
5. An in-line particulates trap should be installed to prevent particulates and moisture from entering the evacuated canister.
6. Collect a sample by attaching the top end of the tubing to a sampling canister instrumented with a vacuum gauge.
7. Note and record the initial vacuum gauge reading, open the sampling canister valve, and monitor the vacuum gauge to check progress of canister filling.
8. Close the sampling canister valve after the required time has elapsed for an adequate volume of soil gas to be collected, or the vacuum gauge indicates that the canister is full. Record the time required for sampling and the final pressure onto the reporting form and chain of custody form. Sampling with a vacuum gauge is required for each sampling canister to ensure that an adequate volume of sample was collected. Without an adequate sample volume, the laboratory may not be able to meet the reporting limits needed to determine if the compound-specific action levels are being exceeded. **If reporting limits prove to be consistently higher than the screening levels, a decision regarding vapor intrusion risk may not be possible and re-sampling may be required.** Consult with the laboratory supplying the canisters to obtain the vacuum gauge readings corresponding to an acceptable canister volume.

9. Record the time required for sampling and final pressure onto the reporting form and chain-of-custody form.
10. Connect the inert tubing that was used to fill the canister to a field instrument and record the organic vapor measurement onto the laboratory chain-of-custody form and field sample log sheet, and submit the canisters for laboratory analysis.
11. If the soil gas sampling point is a permanent installation, which may be the case where soil gas monitoring is included as part of a CAD, an above grade protective casing should be set around the point tubing and grouted in place to the surface to minimize infiltration of water or outdoor air, as well as to prevent accidental damage. The construction of any such permanent sampling point must also be such that the sampling interval is adequately sealed off from both the casing air and external surface air.

B. **Permanent soil gas monitoring point:** Permanent soil gas monitoring points may be installed when multiple exterior samples are necessary at a site. Such sampling may be required to evaluate soil gas concentrations resulting from unstable vapor sources near receptors. The following basic procedures should be included in any sampling protocol:

1. **Single sampling port at depth**
   a) Advance the soil gas sampling point to its necessary depth using direct push technology or manual probes if site conditions permit.
   b) Soil gas sampling points should be fitted with inert tubing (e.g., polyethylene, Teflon®, stainless steel, etc.) of the appropriate size and length along with an inert screen material approximately six inches in length comprised of stainless steel, slotted polyethylene, or polyethylene mesh).
   c) A valve should be installed on the surface end of the inert tubing. The valve used must not allow ambient air to enter the tubing.
   d) An artificial filter pack should be placed in the annular space between two to four inches below the screen tip to six inches above the screened interval.
   e) The remaining annular space should be grouted to the surface using bentonite or other appropriate material.
   f) Monitoring points should be fitted with at grade covers or above grade protective casings set in place with cement.
   g) Wait 30 to 60 minutes at a minimum before purging and sampling if a sample is to be collected during the installation mobilization.
2. **Nested sampling ports**
   a) Complete steps a through d as listed in Part 1 above.
   b) A seal of at least two feet of bentonite should be used between individual screened intervals.
   c) Step d) should again be completed to set the second sampling screen in filter pack. Repeat steps b) and c) as needed for the number of nested points required.
   d) Cut the protruding lengths of tube successfully shorter so that the deepest screened interval tube is the longest length with other tubes becoming progressively shorter. Each tube should be labeled clearly upon completion.
   e) Surface ends of each tube should be completed with an airtight check valve or cap to prevent ambient air from entering each tube.
   f) Wait 30 to 60 minutes at a minimum before purging and sampling if a sample is to be collected during the installation mobilization.

C. **Sub-slab sampling:** The method for sub-slab soil gas sampling involves the collection and analysis of a sample from an evacuated canister using the EPA TO-15 method (full-scan). Sub-slab samples are collected to characterize the nature and extent of soil gas contamination immediately beneath a building footprint. These samples are collected after soil gas sampling near receptors or other sampling (e.g., soil/groundwater sampling) indicate a need. In addition, a *Vapor Intrusion Interior Building Survey Form* should be completed prior to the completion of sub-slab soil sampling (Appendix C). The building floor should be inspected and any penetrations (i.e. cracks, floor drains, utility perforations, sumps, and other preferential pathways) for sub-slab soil gas to enter the building should be noted and recorded using the *Vapor Intrusion Interior Building Survey Form* (Appendix C).

1. Sub-slab vapor samples should be collected in a central location away from foundation footings and from the soil or aggregate immediately below the basement slab or slab-on-grade. Significant floor penetrations near a sampling location may require temporarily sealing to avoid short circuiting during sample collection. Probes should be installed at locations where the potential for ambient air infiltration via floor penetrations is minimal.
2. Typically the MPCA PRP will require a minimum of two sub-slab sampling events be conducted during differing seasonal conditions. For example, winter and spring/summer, with a winter round being mandatory. Certain conditions may warrant more frequent sampling and should be discussed with the PRP project staff.
3. Sub-slab sampling points should be constructed in the same manner at all sampling locations for the investigation to minimize possible discrepancies. The following procedures should be included in any construction protocol:
   a) Advance a boring into the sub-slab material using a rotary hammer drill or other device.
   b) Soil gas sampling probes should be fitted with inert tubing (e.g., polyethylene, stainless steel, or Teflon®) of the appropriate size.
   c) Insert a vapor sampling point into the material immediately below the slab.
   d) Coarse sand or glass beads should be added to cover the point tip.
   e) The boring should be sealed at the surface with grout, cement or other non-VOC-containing and non-shrinking products to prevent infiltration of air from above the slab.
   f) Prior to collecting the soil gas sample, a minimum of two volumes (the volume of the sample point and tube) must be purged with a graduated syringe or other device.
   g) An in-line particulates filter should be installed to prevent particulates and moisture from entering the evacuated canister. The canister filling rate must be limited to a maximum flow rate of 200 milliliter per minute (mL/minute) using a flow controller.
   h) Collect a sample by attaching the top end of the tubing to a sampling canister instrumented with a vacuum gauge.
   i) Open the sampling canister valve and monitor the vacuum gauge to check progress of canister filling for the same reasons as listed above.
   j) After an adequate volume of air has been filled close the sampling canister valve and record the final canister pressure and time required for sampling on the chain-of-custody form and sample sheets and submit the canister for laboratory analysis.
   k) Connect the inert tubing that was used to fill the canister to a field instrument and record the measurement onto the chain-of-custody form and sample log sheet.
   l) For permanent monitoring points, seal the monitoring point tight with a hex wrench to allow for follow up sampling.
   m) After sampling activities are completed, properly seal the sub-slab slab hole opening.

D. **Indoor air sampling:** The method for indoor air investigation, when deemed necessary, involves the collection and analysis of a sample from an evacuated canister using the EPA TO-15 method (full-scan). Indoor air samples are collected after subsurface vapor characterization and other environmental sampling (e.g., soil and groundwater characterization) indicate a need and must be approved by the PRP project team.

1. At a minimum, these general guidelines should be followed when selecting buildings to sample for indoor air:
   a) Buildings where elevated concentrations of contaminants were measured in sub-slab vapor samples or from adjacent soil gas probes.
   b) Buildings in which positive responses with field meters/equipment (e.g., PID) were obtained, suggesting a completed migration pathway.
   c) Buildings within, or in close proximity to, known or suspected areas of subsurface volatile chemical contamination that are used or occupied by sensitive population groups (e.g., daycare facilities, schools, nursing homes, etc.) should be given special consideration for sampling.

2. Prior to collecting sub-slab or indoor air samples, a *Vapor Intrusion Interior Building Survey Form* (Appendix C) should be completed to evaluate the physical layout and conditions of the building

3. g being investigated, to identify conditions that may affect or interfere with the proposed sampling, and to prepare the building for sampling by ensuring temporary mitigation of those conditions. The survey must be completed at least **two weeks** prior to sample collection so that cooperation can be requested from the building occupants in making alterations to building usage or their behaviors. This is required to provide adequate time for the reduction of potential background sources prior to sampling. A set of common instructions for building occupants to follow prior to and during the indoor air sampling is also found in Appendix C. All indoor air sampling results must be accompanied by a completed Vapor Intrusion Interior Building Survey as well as details of what modifications the occupants were requested to make and to what extent they complied with the request. The survey should be completed by an environmental professional with the assistance of the building owner or other designated representative.

4. Typically the MPCA PRP will require a minimum of two indoor air sampling rounds be collected during differing seasonal conditions. For example, winter and spring/summer, with a winter round being mandatory. Certain conditions may warrant more frequent sampling and should be discussed with the PRP project staff.

   Samples should be collected over a 24 hour period, which requires the use of a special low-flow precision regulator. There may be sites where a grab sample is appropriate, but contact the PRP Project Manager for approval prior to collecting a grab sample. The MPCA PRP may request that indoor air samples be collected along with sub-slab samples to evaluate constituents of petroleum hydrocarbons present in both the sub-slab and indoor air environment.

5. Instructions for using the sampling canister and regulator and for collecting the sample should be obtained from the canister supplier or laboratory. The sampling canister’s sample port should be placed in the breathing zone, approximately three to five above the floor. The sample should be collected at or near the center of the room. Ideally, samples should be collected from the lowest level of the structure (e.g., basement) near the suspected source and from the main floor and/or other commonly used spaces to assess worst-case exposures and the distribution of contaminants within the structure.

6. Samples should be collected under conditions representative of the use of the structure, (i.e., doors open or closed depending on their typical condition and if heating system is in use). In summer months, windows should be closed at least 24 hours prior to sampling in order to minimize the contribution of outside air. It is also useful to collect a sample directly from a point of suspected vapor entry such as a sump or other enclosed space to better define the potential route of entry and the maximum concentrations. An outdoor, ambient air sample should also be collected during the same time using the same sampling method as the indoor air sample (see below). In general, 24 hour indoor air samples should be collected in the following manner:

   a) Place a sampling canister in the appropriate sampling location.

   b) A flow controller must be affixed to the canister prior to sampling. The flow controller must be pre-set by the laboratory to collect the sample over a 24 hour period.

   c) An in-line particulates filter should be installed to prevent particulates and moisture from entering the canister.

   d) Open the valve on the canister to begin sample collection.

   e) After approximately 24 hours have passed, close the valve on the canister and record the time on the *Air Sampling Form* and on the chain-of-custody form.

   f) The canister(s) and flow controller(s) are then to be transported to the laboratory.

   g) If the MCPA requires that a grab sample be collected, the same procedure should be followed without the use of a flow controller.

7. In addition, site-specific high risk situations detected during the LSI or RI may warrant collecting indoor air samples prior to characterizing subsurface soil gas clouds with or without concurrent sub-slab sampling due to a need to immediately examine inhalation hazards. Notification to MPCA PRP project staff prior to initiating immediate indoor air sampling is required. Examples of such situations may include, but are not limited to, the following:

a) If high readings are obtained in a building when screening with field equipment (e.g., an organic vapor meter, or an explosimeter) and the source is unknown.
b) If soil or groundwater beneath the building is contaminated, the building is prone to groundwater intrusion or flooding (e.g., sump pit overflows), and subsurface vapor sampling is not feasible.
c) Residents complain of being able to frequently smell petroleum vapors but field instruments do not show any detects.

E. **Outdoor (ambient) air sampling:** Outdoor air samples are collected to characterize site-specific background outdoor air conditions. These samples should be collected simultaneously with indoor air samples and be collected in the same manner as the indoor samples (see above). Outdoor air sampling results are primarily used when evaluating the extent to which outdoor sources may be influencing indoor air quality to clearly distinguish any vapor intrusion from the subsurface from other sources.

1. Outdoor air samples should be collected from a representative upwind location, away from wind obstructions (e.g., trees or buildings), and at a height above the ground to represent breathing zones (three to five feet). A representative sample is one that is not biased toward obvious sources of volatile chemicals (e.g., automobiles, lawn mowers, oil storage tanks, gasoline stations, industrial facilities, etc.).
2. The following actions should be taken to document conditions during outdoor air sampling and ultimately to aid in the interpretation of the sampling results:

   a) Outdoor plot sketches should be drawn that include the building site, area streets, outdoor air sample locations (if applicable), location of potential interferences (e.g., gasoline stations, factories, lawn movers, etc.), and compass orientation (north).

   b) Weather conditions (e.g., precipitation, indoor and outdoor temperature, barometric pressure) and ventilation conditions (e.g., heating system active and windows closed) must be recorded.

   c) Any pertinent observations such as odors, field instrument readings, and significant activities in the vicinity (e.g., operation of heavy equipment or dry cleaners) should be recorded.

F. **Field QA/QC:** Take extreme care during all aspects of sample collection to ensure sampling error is minimized and high quality data are obtained. Sampling team members should avoid actions (e.g., fueling/idling vehicles, using permanent marking pens, smoking, wearing fragrances or freshly dry-cleaned clothing, etc.) which can cause sample interference in the field. Appropriate QA/QC protocols must be followed for sample collection and laboratory analysis, such as use of certified clean sample devices, meeting sample holding times and temperatures, proper completion of the chain-of-custody form, etc. Samples should be delivered to the analytical laboratory as soon as possible after collection.

Laboratory procedures must be followed for field documentation (sample collection information/locations), chain-of-custody form, field blanks, field sample duplicates and laboratory duplicates, as appropriate.

The field sampling personnel must maintain a field sampling log sheet summarizing the following:

1. sample identification
2. sample location
3. date and time of sample collection
4. sampling depth (soil gas or sub-slab)
5. sampling height (indoor or outdoor)
6. identity of samplers
7. sampling methods and devices
8. purge volumes and devices used
9. the vacuum (pressure) of the Summa canister before and after sample collection, and PID measurements must be recorded on the chain-of-custody form and sampling forms
10. apparent moisture content (dry, moist, saturated, etc.) of the sampling zone
11. type of soil present in the sampling zone (e.g., clay, sand, gravel, etc.)
12. chain-of-custody records to track samples from sampling point to analysis

G. **Supplemental sampling QA/QC:** The following methods may be used to provide added QA/QC when completing soil gas or sub-slab samples.

1. **Flow rate and vacuum**

   To minimize the potential for short circuiting air flow from the surface and desorption of contaminants from the soil under saturated conditions, techniques to control and minimize the flow and vacuum applied to the soil should be employed. In such cases, use of an in-line flow controller set at a flow of 200 mL/minute and vacuum less than 15 percent of atmosphere (≈ five inches of Hg) should be used. The PRP requires the use of 200 mL/minute flow controllers for sub-slab soil gas samples. Flow controllers may be required by PRP project staff for soil gas samples based on data quality objectives and site conditions.

2. **Leak check compounds**

   Leak check compounds can be used to evaluate if atmospheric breakthrough down the probe rod's annular space has occurred while sampling. At this time the PRP does not require the use of leak check compounds. However, these methods may be requested by project staff on a site-by-site basis based on data quality objectives and concerns. Several compounds can be used as leak check compounds during soil gas collection. Gaseous compounds using shrouds or liquids applied to paper towels can be used. Isopropyl alcohol, pentane, isobutene, and helium are some common compounds used in tracer analysis for soil gas samples. Additional information regarding leak check compounds can be found in *Vapor Intrusion Pathway: A Practical Guideline*, VI-1, Interstate Technology & Regulatory Council, Washington, D.C.

   Soil gas samples with concentrations of the leak check compound greater than five percent of the initial concentration (equal to 100 percent for gaseous compounds and to the partial pressure for liquid compounds) should not be considered reliable.

III. PRP Required Laboratory QA/QC

Each laboratory analyzing samples by method TO-15 shall follow the method as defined by the EPA in the EPA/625/R-96/010b dated January 1999 or subsequent updates or revisions.

A. The laboratory shall supply the following data with each report:

1. Method blank (Zero canister): All results from analysis of the method blank should be less than the reporting limits. If concentrations are reported above the reporting limits, the laboratory will document this occurrence within the narrative and flag any concentration reported above the reporting limit for this compound up to 10 times the level measured in the blank. The area responses for the internal standards (IS) must be within ± 50 percent of the area response of the ISs in the mid-point standard of the most recent initial calibration. The RT for each IS must be within ± 0.33 minutes between the blank and the most recent calibration. Method blanks shall be run every 20 environmental samples or once per day, whichever is more frequent.
2. Laboratory Control Sample: The laboratory will report the percent recoveries from all analytes spiked into the Laboratory Control Sample (LCS). One LCS will be run within each 24 hour period of TO-15 samples analyzed.
3. The narrative of the laboratory report will define if the initial calibration curve, continuing calibration check sample (when appropriate), and internal quality assurance (such as internal standards, blanks, etc.) met the method requirements for each report.
4. The chromatogram for each analysis will be submitted with the data and have the compounds identified in Appendix C clearly labeled on the chromatogram.
5. The laboratory shall report the results using the field sample ID and the associated laboratory sample number.
6. The laboratory shall report all compounds in units of µg/m3.
7. The laboratory report must contain the following information: Coversheet with signature of a laboratory supervisor or designee, a narrative discussing the sample results and any irregularities that were found during the analysis, chain of custody and sample condition upon receipt forms, tables containing the VOC compounds, Chemical Abstract Service (CAS) number of each reported compound, measured concentration in µg/m3, reporting limit, date of analysis, labeled sample chromatograms, method blank data for the batch, and a summary of applicable quality control.

B. The laboratory is required to maintain the data for a minimum of 10 years with the ability to reconstruct the data either via a computer or paper.

C. Laboratories must verify their reporting limits by running a standard at the reporting limit once every month. The recovery of the reporting limit shall be +/- 40 percent of the true value.

D. Laboratories shall verify their calibration curve a minimum of every 24 hours. The 24 hour clock will begin at the injection of a standard for tuning the instrument (bromofluorobenzene is the suggested tuning standard). The calibration verification standard must be at the midpoint (or lower) of the calibration curve. The standard must meet TO-15 or laboratory generated limits for the compounds of interest/target compounds (as identified on the chain of custody), not a set of continuing calibration check compounds. If no direction is given to the laboratory for check compounds, then the laboratory Standard Operating Procedure (SOP) shall be followed.

E. Laboratories should run ten percent laboratory duplicates. Duplicate samples should have less than or equal to 25 percent Relative Percent Difference or corrective action should be initiated.

F. The MPCA accepts a holding time of 14 days for the TO-15 analysis.

G. Reporting limits: The MPCA expects that for the following compounds: benzene, toluene, the xylenes, ethylbenzene, the trimethylbenzenes, trichloroethene, and vinyl chloride will have reporting limits between 0.2-0.4 ppbv (reported as µg/m3). The other compounds on the Minnesota Soil Gas List (Appendix A) should have reporting limits between 0.5-1.0 ppbv (reported as µg/m3). The MPCA does recognize that some compounds will have issues with chromatography or interferences that will prevent the expected reporting limits from being met. Laboratories should clearly document these cases within their SOPs and on reports as necessary.

H. Canisters: The laboratory providing summa canisters shall verify each batch of 20 canisters by analyzing one container after cleaning. The canister chosen for post-cleaning analysis shall be the canister with the highest recorded VOC concentration from prior analyses. The container shall be verified by charging the canister with clean zero air, analyzing the container by TO-15, and verifying no compounds are found above the reporting limits required by the MPCA. Additionally, the supplier of summa canisters is expected to verify the operability of the canisters. The TO-15 SOP (or equivalent) should describe the preventative maintenance performed on the canisters. 100 percent certified canisters may be required upon request.

I. Whenever a high concentration sample is analyzed (sample with concentrations outside the calibration curves), a Zero canister analysis should be performed to check for carryover. If carry over is detected, column bake out shall be performed.

J. Tentatively identified compounds: The MPCA requires each TO-15 analysis to include the reporting of the top 10 Tentatively Identified Compounds greater than five ppbv that are not attributed to column breakdown, as compared to response of the nearest IS , when using full scan mode of the mass spectrometer. The laboratory will also report within the narrative if a hump is seen within the chromatogram such as is typical for gasoline, fuel oil, mineral spirits, etc.

   The laboratory is not required to quantify this as part of the analysis, although this may be requested of the laboratory at a later date for an additional cost.

K. Lab certification: At this time certification is available for the TO-15 method through the Minnesota Department of Health (MDH) Environmental Laboratory Accreditation Program. The MPCA requires that TO-15 analytical results submitted be completed by an MDH accredited laboratory.

L. MDL studies must be performed at least annually. The MDLs should be ≤0.5 ppbv for all target analytes.

M. Field samples can be analyzed after successfully meeting all criteria established for instrument performance checks, calibrations, and blanks. All target analyte peaks should be within the initial calibration range. The RT for each IS must be within ± 0.33 minutes of the IS in the most recent calibration. The area response for the IS's must be within ± 50 percent of the area response of the ISs in the mid-level standard of the most recent initial calibration.

N. Daily check standard must be analyzed every 24 hours. This standard is at the mid-point of the calibration curve (ten ppbv suggested). The percent D must be within ± 30 percent for each target analyte. Control charts should be maintained for the percent D values.

O. Internal standard: A suggested internal standard mixture of bromochloromethane, chlorobenzene-d5, and 1,4-difluorobenzene will be added to each sample as standard. The resulting concentrations are at ten ppbv (suggested).

Appendix A: Minnesota Soil Gas List

Compound	CAS no.
Acetone	67-64-1
Benzene	71-43-2
Benzyl chloride	100-44-7
Bromodichloromethane	75-27-4
Bromoform	75-25-2
Bromomethane (Methyl Bromide)	74-83-9
1,3-Butadiene	106-99-0
2-Butanone (Methyl ethyl ketone, MEK)	78-93-3
Carbon disulfide	75-15-0
Carbon tetrachloride	56-23-5
Chlorobenzene	108-90-7
Chloroethane (Ethyl chloride)	75-00-3
Chloroform	67-66-3
Chloromethane (Methyl chloride)	74-87-3
Cyclohexane	110-82-7
Dibromochloromethane	124-48-1
1,2-Dibromoethane (Ethylene dibromide)	106-93-4
1,2-Dichlorobenzene	95-50-1
1,3-Dichlorobenzene	541-73-1
1,4-Dichlorobenzene	106-46-7
1,1-Dichloroethane	75-34-3
1,2-Dichloroethane	107-06-2
1,1-Dichloroethene (DCE)	75-35-4
cis-1,2-Dichloroethene	156-59-2
trans-1,2-Dichloroethene	156-60-5
Dichlorodifluoromethane (Freon 12)	75-71-8
1,2-Dichloropropane	78-87-5
cis-1,3-Dichloropropene	10061-01-5
trans-1,3-Dichloropropene	10061-02-6
Dichlorotetrafluoroethane (Freon 114)	76-14-2
Ethanol	64-17-5
Ethyl acetate	141-78-6
Ethylbenzene	100-41-4
4-Ethyltoluene	622-96-8
n-Heptane	142-82-5
Hexachloro-1,3-butadiene	87-68-3
n-Hexane	110-54-3
2-Hexanone (Methyl Butyl Ketone)	591-78-6

Compound	**CAS no.**
4-Methyl-2-pentanone (Methyl isobutyl ketone)	108-10-1
Methylene Chloride (Dichloromethane)	75-09-2
Methyl-tert-butyl ether (MTBE)	1634-04-4
Naphthalene	91-20-3
2-Propanol (isopropyl alcohol)	67-63-0
Propylene (Propene)	115-07-1
Styrene	100-42-5
1,1,2,2-Tetrachloroethane	79-34-5
Tetrachloroethylene (PCE)	127-18-4
Tetrahydrofuran	109-99-9
Toluene (Methylbenzene)	108-88-3
1,2,4-Trichlorobenzene	120-82-1
1,1,1-Trichloroethane (Methyl chloroform)	71-55-6
1,1,2-Trichloroethane	79-00-5
Trichloroethylene (TCE)	79-01-6
Trichlorofluoromethane (Freon 11)	75-69-4
1,1,2-Trichlorotrifluoroethane (Freon-113)	76-13-1
1,2,4-Trimethylbenzene	95-63-6
1,3,5-Trimethylbenzene	108-67-8
Vinyl acetate	108-05-4
Vinyl chloride	75-01-4
m&p-Xylene	108-38-3
o-Xylene	95-47-6

Appendix B: PRP Vapor Intrusion Screening Values and Exposure Scenarios

The MPCA's Remediation Division in cooperation with the MDH has developed compound-specific inhalation screening values, termed (ISVs), for volatile compounds associated with the vapor intrusion pathway. These values were developed using current toxicity information available from the EPA's Integrated Risk Information System database, the MDH, and other sources. ISV exposure scenarios have been developed for Residential and Industrial buildings. Commercial building settings should use the Industrial ISV values as they are based on the same exposure assumptions. Buildings with sensitive populations (e.g., daycare facilities, schools, nursing homes, etc.) should use the Residential ISVs. Additional information related to the ISVs can be found in Appendix B-1 and B-2 of the *Vapor Intrusion Technical Support Document*.

Direct comparison of each compound-specific ISV should be used when evaluating indoor air samples. Comparison of soil gas and sub-slab samples should be made using multiples of the ISVs as screening factors described below:

A. Compounds analyzed are less than 10 times (10x) intrusion screening values (ISVs).

B. Compounds analyzed are between 10 times (10x) and 100 times (100x) ISVs.

C. Compounds analyzed are greater than 100 times (100x) ISVs.

The PRP ISV table can be downloaded at the following internet address:

AdobePDF format:

http://www.pca.state.mn.us/index.php?option=com_docman&task=doc_download&gid=3021

Microsoft Excel format:

http://www.pca.state.mn.us/index.php?option=com_docman&task=doc_download&gid=3022

Appendix C: Vapor Intrusion Interior Building Survey Form

The *Vapor Intrusion Interior Building Survey Form* provides important information concerning potential soil gas entry points to the indoor air environment in addition to general building characteristics and potential indoor contaminant sources. These details can be important when evaluating indoor air analytical samples, sampling locations and analytical data from sub-slab soil gas samples.

Copies of this form can be downloaded at the following internet addresses:

AdobePDF

http://www.pca.state.mn.us/index.php?option=com_docman&task=doc_download&gid=14170&Itemid=

Microsoft Word

http://www.pca.state.mn.us/index.php?option=com_docman&task=doc_download&gid=14166&Itemid=