Vapor intrusion assessments performed during site investigations

Petroleum Remediation Program

I. Introduction

This document describes the methodology for completing a vapor intrusion (VI) assessment at a site in the Minnesota Pollution Control Agency's (MPCA) Petroleum Remediation Program (PRP). Vapor intrusion is the migration of volatile organic compounds (VOCs) from an underground source through soil or other pathways into buildings. A VI assessment is required when completing a site investigation within the PRP.

The goal of a VI assessment is to evaluate the VI pathway associated with a petroleum release. The VI pathway has three elements: receptor, vapor source, and subsurface migration route. A receptor is a person potentially affected by VI, generally an occupant of a building. A vapor source is the supply of VOCs, such as contaminated soil or groundwater or light non-aqueous phase liquids (LNAPL). A subsurface migration route is the path that vapors travel through soil or other pathways in the unsaturated zone. The VI assessment uses field-based methods to evaluate the VI pathway, including a receptor survey, soil gas sampling, sub-slab sampling, and indoor air sampling. For additional background information, see the Environmental Protections Agency's (EPA) Technical Guide For Addressing Petroleum Vapor Intrusion At Leaking Underground Storage Tank Sites and the Interstate Technology Regulatory Council's (ITRC) Petroleum Vapor Intrusion Fundamentals of Screening, Investigation, and Management.

II. Step 1 - Soil gas assessment

Complete a soil gas assessment while defining the extent and magnitude of soil and groundwater impacts. There are limited situations in which the MPCA will preapprove a different scope of work than what is described here. This may include waiving specific requirements, expediting an investigation, or adjusting the assessment to site-specific conditions.

A. Receptor survey

Start the soil gas assessment by identifying VI receptors within a 100-foot radius of the source area(s), or the area(s) of highest known or suspected petroleum contamination. If there are no receptors within 100 feet of the source area(s), contact the MPCA to determine if a soil gas assessment is required. If it is not required, provide sufficient information in the Investigation report to document that receptors are not present.

Soil gas monitoring points

Permanent soil gas monitoring points to monitor contaminant concentrations over time may be required in certain situations. These may include recent releases, unstable groundwater plumes, migrating LNAPL, and highly fluctuating water tables. See Section V for construction details.

B. Soil gas sampling

Once receptors and source area(s) are identified, collect soil gas samples and submit them for analysis by EPA Method TO-15 for compounds on the Minnesota Soil Gas List and for fixed gases (methane, oxygen, and carbon dioxide) via either EPA Method 3C or ASTM method D1946. Collect soil gas samples from the following locations using the procedures in Section V:

A. **Source area(s):** Collect one soil gas sample from a direct push boring advanced close to the source area(s) to the required depth (Table 1). The highest contamination is often found at the source of the release, such as tank basin, but other situations may exist and should be assessed to ensure that soil gas associated with the most heavily contaminated soil or groundwater is sampled.

   If a source area is adjacent to, or underneath, a receptor, you may need to collect seasonal sub-slab samples with, or instead of, an exterior soil gas sample. If your site fits this situation, contact the MPCA for approval before collecting samples.

B. **Receptor-specific:** Collect up to four soil gas samples near receptors that are within 100 feet of the source area sample(s). Use Table 1 to determine the required depth. Collect receptor-specific samples under the following scenarios:

   - Fewer than four receptors: If four or fewer receptors, including onsite receptors, are located within 100 feet of the source area sample, collect one soil gas sample near each receptor.
   - More than four receptors: If more than four receptors, including onsite receptors, are within 100 feet of the source area sample, collect samples that are evenly distributed near receptors.

Table 1. Soil gas sample collection depths

Sample location	Sample collection depth
Source area(s)	8–10 feet below grade, at least 2 feet above the water table and at a minimum depth of 3 feet. If the water table or bedrock prevent sample collection below 3 feet, the sample does not need to be collected at this time, but the MPCA may request other means of assessing VI.
Receptor-specific	Buildings with basements: 8–10 feet below grade. Buildings with slab-on-grade or crawl space: 3–5 feet below grade. All samples must be at a minimum depth of 3 feet. If the water table or bedrock prevent sample collection below 3 feet, the sample does not need to be collected and the MPCA may request other means of assessing VI.

If contaminated groundwater or LNAPL extends 100 feet beyond the source area, you may need to collect additional soil gas samples near receptors within 100 feet of the groundwater plume or LNAPL body.

Use professional judgment to decide if a receptor-specific soil gas sample is needed. For example, consider not sampling a building with low human exposure, such as a storage garage. Conversely, consider sampling near subsurface structures such as utility corridors, utility service lines, fractured bedrock, or other subsurface anomalies because they may be preferential migration routes for soil gas if they are close to buildings.

C. Data evaluation

Data comparison

For VOCs, compare soil gas results to the applicable vapor screening levels based on the receptor type: residential versus commercial/industrial buildings. For a soil gas sample, the vapor screening level is the intrusion screening value (ISV) divided by the U. S. Environmental Protection Agency's (EPA's) default VI attenuation factor of 0.03, or 33X ISV for short. ISVs are found in the MPCA's Intrusion screening values (ISVs) for vapor intrusion risk evaluation document. Derivation of 33X ISVs and supporting information are in the MPCA's Intrusion screening values technical support document.

Receptor type examples

Residential: Single-family homes, multi-family homes, long-term care facilities, correctional housing, hospitals, childcare centers, churches, schools

Commercial/industrial: Restaurants, retail stores, shopping malls, hotels, non-retail businesses, manufacturing facilities, warehouses, public utilities

For fixed gases, if the results show a high methane concentration in soil gas, contact the MPCA. A high methane concentration exceeds 10% of the lower explosive limit, or 0.5% methane by volume (5000 ppmv), within 100 feet of a receptor.

Pathway evaluation
Determine if additional pathway evaluation is required based on the following conditions:

- If a contaminant concentration from a receptor-specific sample exceeds a 33X ISV and/or there is a high methane concentration, a building-specific investigation or additional soil gas sampling closer to the receptor is required. See Section III for more information on conducting a building-specific investigation.
- If no 33X ISVs are exceeded and there are no high methane concentration(s), no further pathway evaluation is required.

Please note that these requirements apply to PRP and may differ from other MPCA programs such as the Superfund or Voluntary Investigation and Cleanup Programs.

Conceptual site model
Integrate the results of the soil gas assessment into the conceptual site model (CSM) in the Investigation report. For the VI pathway, describe how quantitative and qualitative factors affect the fate and transport of subsurface vapors and their relationship to identified receptors. Information on developing a CSM is in Soil and groundwater assessments performed during site investigations.

For Investigation report submittal, do not complete any additional VI assessment beyond the soil gas assessment without preapproval from the MPCA.

III. Step 2 - Building-specific investigation

A building-specific investigation further characterizes the VI pathway and provides direct evidence regarding the risk associated with petroleum vapors. A building-specific investigation is required if the pathway evaluation completed during the initial soil gas assessment shows a contaminant concentration from a receptor-specific sample above a 33X ISV and/or there is a high methane concentration (See Section II subsection C). The building-specific investigation includes completing a VI building survey and sub-slab sampling.

A. Vapor intrusion building survey

Complete a Vapor intrusion building survey form before sub-slab sampling. The survey provides information on general building characteristics, points where soil gas may enter the building, and potential indoor contaminant sources. Inspect the building floor and document penetrations (e.g., cracks, floor drains, utility perforations, sumps, other preferential pathways) where soil gas may enter the building. Survey results determine the location and number of sub-slab sampling points (Table 2) and whether the default VI attenuation factor is valid (See the Data comparison part of Section III subsection C).

B. Sub-slab sampling

Collect sub-slab samples in a location away from foundation footings and submit them for analysis following the procedures in Section V. Install sampling points at locations where indoor air is unlikely to infiltrate through floor penetrations. If a significant floor penetration is near a sampling location, temporarily seal the penetration to avoid short-circuiting during sample collection.

Sub-slab sampling alternatives
Sub-slab sampling may not be feasible due to physical access, a dirt floor, or a highly deteriorated slab or foundation. See Section III subsection D for alternative investigation methods.

Complete two sub-slab sampling events, at least 30 days apart, in the following seasonal conditions:

- One sampling event in the heating season (November 1 through March 31).
- One sampling event in the non-heating season (April 1 through October 31).

Two sub-slab sampling events are needed to evaluate risk because seasonal variability, such as soil moisture levels, depth to groundwater, changes in the building's heating and cooling system, can lead to fluctuating vapor concentrations and distribution in the vadose zone. The MPCA recommends completing sub-slab sampling points as permanent points to facilitate multiple sampling events.

The number of sub-slab sampling locations is dependent on the area of the building foundation and/or slab-on-grade (Table 2).

Table 2. Number of sub-slab sample locations

Building foundation area and/or slab-on-grade (square feet)	Minimum number of sub-slab samples[1]
Up to 500	1
501 to 1,000	2
1,001 – 2,500	3
2,501 – 5,000	4
5,001 – 10,000	5
10,001 – 20,000	6
20,001 – 30,000	8
30,001 – 40,000	10
40,001 – 50,000	12
50,001 – 60,000	14
60,001 – 70,000	16
70,001 – 80,000	18
80,001 – 90,000	20
90,001 – 100,000	22
>100,000	22 + 2 samples for every 10,000 square feet above 100,000

[1]Includes sub-slab samples within an existing building. Building conditions that may affect the total number of sub-slab samples include the following:

- If the sub-surface or at-grade slab is divided by a footing or foundation structure, collect at least one sub-slab sample on both sides of the slab divide.
- If a building addition is present, collect sub-slab samples from the original building floor slab and the addition's floor slab.

C. Data evaluation

Data comparison

Compare sub-slab sampling results to the applicable vapor screening levels based on the following conditions:

1. Receptor type: Compare to the applicable residential or commercial/industrial or ISV. See Section II subsection C.
2. Building integrity: Determine if the 33X ISV is valid for the building's construction and condition.

To determine if the attenuation factor is valid, refer to the VI building survey. The attenuation factor may not be valid if the building is susceptible to soil gas entry, including, but not limited to, the following situations:

- Buildings with significant openings to the subsurface (e.g., sumps, unlined crawl spaces, dirt floors) other than typical utility penetrations.
- Buildings with deteriorating foundation walls or slabs.

When comparing sub-slab sampling results, pay attention to whether any contaminant concentration exceeds 33 times an expedited intrusion screening value (33X EISV). An exceedance of 33X EISVs for sub-slab sampling requires expedited action, see Section III subsection E.

Pathway evaluation

Use Table 3 or Table 4 depending on whether or not the attenuation factor is valid to determine if corrective action or further pathway evaluation is required.

Note that two seasonal sampling rounds are required for sub-slab sampling (See Section III subsection B). If a 33X ISV or EISV is exceeded in the first sampling event, you can go directly to corrective action. If there was a 33X ISV or EISV exceedance in the second sampling round but not the first, corrective action is necessary.

Table 3. 33X ISV is valid[1] Pathway evaluation decisions based on sub-slab sampling results – when 33X ISV is valid.

Sub-slab Contaminant Concentration (CC)	Action
CC from both seasonal sampling events < 33X ISV	Corrective action is not necessary. Additional sampling is not necessary unless site conditions change[2].
CC from one or both seasonal sampling event(s) > 33X ISV and < 33X EISV	Corrective action is necessary.
CC from one seasonal sampling event > 33X EISV	Corrective action is necessary—contact the MPCA to determine the need for expedited action.

[1]Based on building conditions evaluated while completing the Vapor Intrusion Building Survey Form. See the Data comparison part of Section III subsection C.

[2]Examples of changed site conditions include but are not limited to migration of a plume, changed building conditions, such as cracks in floor, building additions, or HVAC changes.

If a completed VI pathway is identified, corrective action is required (see Section IV). In certain situations, you may need to complete concurrent sub-slab and indoor air sampling to provide a line of evidence for pathway evaluation. Do not complete any additional VI assessment or corrective action without preapproval from the MPCA.

D. Alternative building-specific investigation methods

For buildings where sub-slab sampling is not possible or the attenuation factor is not valid, pathway evaluation is completed by soil gas beneath a building or indoor air and outdoor air sampling.

Sampling requirements
There are two sampling scenarios for an alternative building investigation:

1. Soil gas sampling below the building is feasible.

Collect soil gas samples from a depth of three feet below the building floor level following the procedures in Section V. The number of soil gas samples depends on the area of the building foundation (Table 2).

2. Soil gas sampling below the building is not feasible.

If collecting soil gas samples from a depth of three feet is not feasible due to groundwater, bedrock, or other restrictions, collect concurrent 24-hour indoor air and outdoor air samples to evaluate risk as described below and following the procedures described below and in Section V.

In both scenarios, at least two seasonal sampling events are required as described in Section III subsection B.

Indoor air sampling
Before sampling, complete a Vapor intrusion building survey form with assistance from the building owner or other designated representative to evaluate building layout and conditions. Identify conditions that may affect sampling and require temporary mitigation. Complete the survey at least **two weeks** before sampling to allow building occupants time to change building use or behaviors that could compromise sample results. Refer to Appendix A for instructions that building occupants should follow before and during indoor air sampling. Include the survey form with all indoor air sampling results, documenting all modifications that building occupants were requested to make and to what extent they complied.

Collect samples over a 24-hour period using a special low-flow precision regulator. There may be sites where a grab sample is appropriate, but contact the MPCA for approval before collecting a grab sample.

Select a representative sampling location following these guidelines:

1. Place the canister in the breathing zone, approximately three to five feet from the floor.
2. Collect samples from the basement or lowest level near suspected vapor entry points to assess the worst-case exposure.
3. Collect samples away from windows or other sources of exterior air leakage.
4. If direct preferential pathways are identified, such as earthen floors, unsealed crawl spaces, or sumps, collect samples from those areas.

Collect samples under conditions that represent the building use, such as doors open or closed depending on their typical condition and if heating system is in use. In summer months, close windows at least 24 hours before sampling to minimize the contribution of outside air.

Site-specific, high-risk situations identified during the site investigation may warrant indoor air sampling to assess indoor air conditions before characterizing soil gas, with or without concurrent sub-slab sampling. Notify the MPCA before initiating immediate indoor air sampling. Examples may include, but are not limited to, the following situations:

- Measurable organic vapors observed in a building when screening with a field meter, such as a photoionization detector (PID) or explosimeter, and the source is unknown.
- Soil or groundwater contamination is beneath the building, the building is prone to groundwater intrusion or flooding, such as from sump pit overflows, and sub-slab sampling is not feasible.
- Residents complain of being able to smell petroleum vapors frequently, but field meters do not show detections. **Please note that this may be an emergency situation that should be reported to the Minnesota Duty Officer.**

Outdoor air sampling

Outdoor air samples are collected to characterize site-specific outdoor air conditions. Concurrent indoor and outdoor sampling results with the findings of the building survey are used to distinguish indoor air contaminants from VI versus those originating from background contaminant sources.

Collect outdoor air samples concurrently with indoor air samples over a 24-hour period using a special low-flow precision regulator.

Select a representative sampling location following these guidelines:

1. Place the canister in the breathing zone, approximately three to five feet from the ground.
2. Collect outdoor air samples from a representative upwind location, away from obstructions, such as trees or buildings.
3. Avoid locations near localized sources, such as running single-cylinder engines or oil storage tanks, that may influence the sample.

Document the following items to help with data evaluation:

- The building site, area street, outdoor air sample locations, location of potential interferences, such as gasoline stations, factories, or lawn mowers, and compass orientation on outdoor plot sketches.
- Weather conditions, including precipitation, indoor and outdoor temperature, barometric pressure, and ventilation conditions, such as heating system active and windows closed.
- Any relevant observations such as odors, field meter readings, and significant activities in the vicinity, such as heavy equipment operation or dry cleaners nearby.

Data comparison

Compare soil gas or indoor air results directly to the appropriate ISVs and EISVs to determine the need for corrective action.

Pathway evaluation

If soil gas samples beneath the building are collected, use Table 4 to determine the need for corrective action. If soil gas samples beneath the building cannot be collected, corrective action is necessary if sampling results show an ISV exceedance in indoor air that cannot be attributed to an indoor or outdoor ambient source. If an ISV is exceeded in the first sampling event, corrective action can proceed without a second event. If an EISV is exceeded, contact the MPCA to determine the need for expedited action.

Table 4. 33X ISV is NOT valid[1] Pathway evaluation decisions based on soil gas beneath a building sampling results – when 33X ISV is not valid.

Soil gas beneath a building Contaminant Concentration (CC)	Action
CC from both seasonal sampling events < ISV	Corrective action is not necessary. Additional sampling is not necessary unless site conditions change[2].
CC from one or both seasonal sampling event(s) > ISV and < 33X ISV	Corrective action is necessary. OR Complete concurrent sub-slab (or soil gas below building), indoor air, and outdoor air sampling – contact the MPCA before performing for approval. Report results to the MPCA immediately to determine corrective action need. OR Address building conditions so 33X ISV screening level is valid, then repeat seasonal sub-slab sampling to determine corrective action need.
CC from one seasonal sampling event > 33X ISV and < 33X EISV	Corrective action is necessary—contact the MPCA to determine the need for expedited action[3].
CC from one seasonal sampling event > 33X EISV	Corrective action is necessary—contact the MPCA to determine the need for expedited action.

[1]Based on building conditions evaluated while completing the Vapor intrusion building survey form. See the Data Comparison part of Section III subsection C.

[2]Examples of changed site conditions include, but are not limited to: migration of a plume, changed building conditions, such as cracks in floor, building additions, or HVAC changes.

[3]For residential buildings, contact the MPCA to determine the need for expedited action.

If a completed VI pathway is identified, corrective action is required (see Section IV). **Do not complete any additional VI assessment or corrective action without preapproval from the MPCA.**

E. Expedited action

If expedited action is necessary, it should begin as soon as possible but no later than 30 days after receiving laboratory analytical results. Expedited action options include the following:

- Expedited mitigation: Install a mitigation system as soon as possible but no later than 30 days from receipt of laboratory analytical data. The standard mitigation installation timeframe is generally 60 to 90 days.
- Expedited sampling: Sub-slab or indoor air sampling paired with outdoor air sampling and pressure differential measurements at sub-slab sampling points, if applicable. The expedited sampling timeframe is sample as soon as possible with a rush laboratory analysis (i.e., three-day turnaround time) and results reported to the MPCA immediately upon receipt.

IV. Step 3 - Evaluating corrective actions

If the VI assessment shows direct or significant indirect evidence that a VI pathway is complete, the MPCA will require corrective action to minimize the risk of exposure to building occupants. Corrective action may include remediating the vapor source, interrupting the migration route between the vapor source and the receptor, or a combination of both approaches. Building control technologies, such as sub-slab depressurization systems, can

be highly effective at mitigating VI impacts. Building pressurization or heating, ventilating, and air conditioning modifications at larger commercial or industrial buildings may be appropriate as well. See Vapor investigation and mitigation decision best management practices for additional information regarding corrective actions.

When corrective action is required, refer to Corrective action design and implementation for instructions on how to proceed. The first step is to contact the MPCA to discuss corrective action requirements and potential alternatives before completing a Conceptual corrective action design report. When expedited action is needed, the MPCA may modify the approval process to accelerate the mitigation response.

If petroleum vapors have migrated beyond an impacted building(s) toward other receptors, the MPCA may require additional soil gas assessment. You can make recommendations for additional assessment any time in a subsequent investigation or corrective action design report.

In cases where buildings overlie or are adjacent to contaminated groundwater or LNAPL, the MPCA may require soil gas monitoring along with groundwater monitoring to demonstrate stable or declining contaminant concentrations. If you feel this work is necessary, include a recommendation for the specific activities that you will conduct in a monitoring-based corrective action design.

Note for commercial/industrial properties where one or both seasonal sampling events is greater than 33X ISV and less than 33X EISV, the MPCA may approve conducting an interim completed pathway evaluation to determine if sub-surface vapors are migrating into the indoor building air. This interim approach requires collecting paired sub-slab, indoor and outdoor air samples along with evaluating the existing building conditions to determine if sub-surface vapors are migrating into the indoor building air. Completed pathway evaluation is not considered a stand-alone, long-term vapor mitigation approach. However, completed pathway evaluation may be an appropriate interim measure for specific situations. See Vapor investigation and mitigation decision best management practices for completed pathway evaluation requirements. Contact the MPCA to determine if this approach is appropriate for your site.

V. Recommended sampling methods, procedures, and field quality assurance/quality control (QA/QC)

Below are recommended field methods and procedures for soil gas, sub-slab, indoor air, and outdoor air sampling to be included in any sampling protocol. Although you may use various field methods based on experience and available equipment, the MPCA expects that field staff take the utmost care to ensure sample integrity and data quality. You may change the procedures recommended below with MPCA approval depending on site-specific conditions or emerging technologies and methodologies. In all cases, you must thoroughly describe the methods and procedures used in the field in the final report accompanying the sampling results. Collect samples using an evacuated stainless-steel canister and analyze them by EPA Method TO-15 for compounds on the Minnesota soil gas list.

A. Methane analysis

For the soil gas assessment (Section II), in addition to EPA Method TO-15, also measure fixed gases methane, oxygen, and carbon dioxide. The measurement of fixed gases by EPA Method 3C or ASTM method D1946 will require a separate analysis, but a single canister will supply enough sample volume to complete the Method TO-15 and fixed gases analyses. Laboratory QA/QC requirements for Method TO-15 and fixed gases are provided in Section VI.

1. Analyze each sample for fixed gases (methane, oxygen, and carbon dioxide) via EPA Method 3C or ASTM method D1946.

2. Or analyze the source area sample by EPA Method 3C or ASTM method D1946 for fixed gases and collect field readings for methane, oxygen, and carbon dioxide using a direct reading methane field instrument, such as a landfill gas meter or multi-gas meter, from all soil gas sampling points. Follow the manufacturer's instructions for operation, maintenance, and calibration of the instrument. Keep calibration records in a bound book. The MPCA reserves the right to request these records.
   Please note that if you use this option and the reading from the field instrument for the source area do not correlate with the lab analysis resampling for methane, oxygen, and carbon dioxide may be required.

B. Temporary soil gas sampling point installation

1. Advance the soil gas sampling point(s) to the necessary depth from Table 1 using direct push technology or manual probes as site conditions permit.
2. Place an appropriate sealing material, such as bentonite slurry, at the ground surface around the probe rod to avoid the sample short-circuiting to the atmosphere.
3. Fit the soil gas sampling point(s) with appropriately sized inert tubing, such as polyethylene, stainless steel, or Teflon®.

C. Permanent soil gas monitoring point installation

Single sampling point

1. Advance the soil gas monitoring point to the necessary depth from Table 1 using direct push technology or manual probes as site conditions permit.
2. Fit the soil gas monitoring point with appropriately sized inert tubing, such as polyethylene, stainless steel, or Teflon®, and a screen approximately six inches long comprised of stainless steel, slotted polyethylene, or polyethylene mesh.
3. Install an airtight check valve or cap on the surface end of the tubing. The valve must not allow ambient air to enter the tubing.
4. Place an artificial filter pack in the annular space between two to four inches below the screen tip to six inches above the screened interval.
5. Grout the remaining annular space to the surface using bentonite or other appropriate material.
6. Fit the soil gas monitoring point with an at-grade cover or above-grade protective casing grouted in place to minimize infiltration of water or atmospheric air and prevent accidental damage. Proper construction will ensure the sampling interval is adequately sealed off from casing and atmospheric air.
7. If you are collecting a sample the same day as the installation, wait a minimum of 30 to 60 minutes before purging and sampling.

Nested sampling point

1. Complete steps 1 through 4 listed in the single sampling point instructions above.
2. Seal the space between individual screened intervals with at least two feet of bentonite.
3. Complete step 4 above to set the second sampling screen in filter pack.
4. Repeat steps 2 and 3 in this section as needed for the number of nested points required.
5. Cut the protruding tubing shorter so that the deepest screened interval has the longest tubing length, with shallower intervals becoming progressively shorter. Label each tube clearly upon completion. Varying the tubing length is a safeguard to prevent misidentification of the sampling interval.
6. Install an airtight check valve or cap on the surface end of each tube. The valve must not allow atmospheric air to enter the tubing.

7. Fit the soil gas monitoring point with an at-grade cover or above-grade protective casing grouted in place to minimize infiltration of water or atmospheric air and prevent accidental damage. Proper construction will ensure the sampling intervals are adequately sealed off from casing and atmospheric air.
8. If you are collecting a sample the same day as the installation, wait a minimum of 30 to 60 minutes before purging and sampling.

Sub-slab sampling methodology. For more information on the steps to collect a representative sub-slab sample, check out the MPCA's methodology video: https://www.youtube.com/watch?v=ub7m6KknVtU&feature=youtu.be

D. Sub-slab sampling point installation

1. Advance a boring into the sub-slab material using a rotary hammer drill or other device.
2. Fit soil gas sampling points with appropriately sized inert tubing, such as polyethylene, stainless steel, or Teflon®.
3. Insert a vapor sampling point into the material immediately below the slab.
4. Add coarse sand or glass beads to cover the point tip.
5. Seal the boring at the surface with grout, cement, or other non-VOC containing and non-shrinking product to prevent air infiltrating from above the slab.

E. Soil gas and sub-slab sampling

1. Before collecting the sample purge a minimum of two volumes, the total volume of the sampling point and tube, using a graduated syringe for volume accuracy. This ensures the sample is representative of sub-surface vapors.
2. Install an in-line particulates filter to prevent particulates and moisture from entering the canister.
3. Collect a sample by attaching the top end of the tubing to a canister equipped with a vacuum gauge.
4. Record the initial vacuum gauge reading on a sampling form.
5. Open the canister valve and monitor the vacuum gauge to check progress of canister filling. Avoid pulling groundwater into the tubing. If groundwater is pulled into the tubing, make note of it on the sampling form.
6. Close the canister valve after collecting an adequate volume of air or the vacuum gauge indicates the canister is full. Use a vacuum gauge on each sampling canister to ensure an adequate sample volume was collected. Make sure that the vacuum readings on the canister do not go all the way down to zero. Final vacuum readings should be between five and one inches of Hg. Without an adequate sample volume, the laboratory may not be able to meet the reporting limits necessary to compare to compound-specific ISVs. **If reporting limits are consistently higher than the ISVs, a decision regarding VI risk may not be possible and resampling may be required.** Consult with the laboratory supplying the canisters to obtain the vacuum gauge readings corresponding to an acceptable canister volume.
7. Record the required sampling time and final vacuum gauge reading on the sampling and chain-of-custody forms.
8. After disconnecting the canister, connect the sampling point tubing to a field meter (e.g., PID) and measure the organic vapor concentration. Record the PID reading on the sampling and chain-of-custody forms.
9. Submit the canister for laboratory analysis.

For sub-slab sampling only:

10. Use a certified clean canister.
11. For permanent monitoring points, seal the monitoring point tight with a hex wrench to allow for follow up sampling.
12. After sampling activities are completed, properly seal the slab hole opening.

Fixed gas note: Check with the MPCA if fixed gases (methane, oxygen, and carbon dioxide) analysis is required. A direct reading methane field instrument, such as landfill gas meter or multi-gas meter, may be all that is required.

F. Indoor and outdoor air sampling

1. Affix a flow controller to a canister equipped with a vacuum gauge. The flow controller must be pre-set by the laboratory to collect the sample over a 24-hour period.
2. Install an in-line particulates filter to prevent particulates and moisture from entering the canister.
3. Record the initial vacuum gauge reading.
4. Open the canister valve to begin sample collection.
5. After approximately 24 hours, close the canister valve. Record the sampling time and final vacuum gauge reading on the sampling and chain-of-custody forms.
6. Submit the canister for laboratory analysis.
7. If the MPCA requires a grab sample, follow the same procedure without the use of a flow controller.

G. Field QA/QC

Take extreme care during all aspects of sample collection to minimize sampling error. Sampling team members should avoid actions that can cause sample interference such as fueling/idling vehicles, using permanent marking pens, smoking, and wearing fragrances or freshly dry-cleaned clothing. Follow appropriate QA/QC protocols for sample collection and laboratory analysis, such as using certified clean sample devices, meeting sample holding times and temperatures, and proper completion of the chain-of-custody form. Deliver samples to the analytical laboratory as soon as possible after collection.

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

Field sampling personnel must maintain a field sampling log summarizing the following information **(Note: the field logs are required to be submitted as an appendix of the final report)**:

- Sample identification.
- Sample location.
- Date and time of sample collection.
- Sampling depth interval (soil gas or sub-slab).
- Sampling height (indoor or outdoor).
- Name(s) of samplers.
- Sampling methods and devices.
- Purge volumes and devices used.
- The vacuum (pressure) of the canister before and after sample collection and PID measurements must be recorded on chain-of-custody and sampling forms.
- Apparent moisture content, such as dry, moist, or saturated, of the sampling zone.
- Type of soil present in the sampling zone, such as clay, sand, and gravel.
- Chain-of-custody records to track samples from sampling point to analysis.

H. Supplemental sampling QA/QC

Use the following methods to provide further QA/QC when conducting soil gas or sub-slab sampling.

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, use techniques to control and minimize the flow and vacuum applied to the soil. In these cases, use an in-line flow controller set at a flow of 200 mL/minute and vacuum less than 15% of atmosphere (≈ five inches of Hg). The MPCA may require flow controllers for soil gas samples based on data quality objectives and site conditions.

Leak check compounds

To determine if atmospheric breakthrough down the probe rod's annular space has occurred while sampling, use leak check compounds. At this time, the MPCA does not require the use of leak check compounds, but MPCA staff may request their use on a site-by-site basis based on data quality objectives and concerns. The fixed gas analysis serves as a surrogate to a leak check compound because results may indicate whether oxygen levels are near atmospheric levels suggesting that oxygen has entered sampling chain.

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. For additional information regarding leak check compounds, refer to the ITRC's Petroleum Vapor Intrusion Fundamentals of Screening, Investigation, and Management.

Soil gas samples with concentrations of the leak check compound greater than 5% of the initial concentration, equal to 100% for gaseous compounds and to the partial pressure for liquid compounds, are not considered reliable.

VI. Required laboratory QA/QC

A. EPA Method TO-15

Each laboratory analyzing samples by EPA Method TO-15 must follow the method described in the EPA's Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air – Second Edition (EPA 1999), including the following elements:

1. The laboratory must supply the following analysis with each report:
    a. 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% of the area response of the ISs in the mid-point standard of the most recent initial calibration. The retention time 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.
    b. Laboratory Control Sample (LCS): The laboratory will report the percent recoveries from all analytes spiked into the LCS. One LCS will be run within each 24-hour period of TO-15 samples analyzed.
    c. 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.
    d. The chromatogram for each analysis will be submitted with the data and have the compounds identified in the Minnesota Soil Gas List clearly labeled on the chromatogram.
    e. The laboratory shall report the results using the field sample ID and the associated laboratory sample number.

f. The laboratory shall report all compounds in units of µg/m^3.

g. 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/m^3, reporting limit, date of analysis, labeled sample chromatograms, method blank data for the batch, and a summary of applicable quality control.

2. The laboratory is required to maintain the data for a minimum of 10 years with the ability to reconstruct the data either electronically or on paper.

3. 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% of the true value.

4. 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.

5. Laboratories should run 10% laboratory duplicates. Duplicate samples should have less than or equal to 25% relative percent difference or corrective action should be initiated.

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

7. Reporting limits: The MPCA expects that for the following compounds: benzene, toluene, the xylenes, ethylbenzene, the trimethylbenzenes, trichloroethylene, and vinyl chloride will have reporting limits between 0.2-0.4 ppbv (reported as µg/m^3). The other compounds on the Minnesota Soil Gas List should have reporting limits between 0.5-1.0 ppbv (reported as µg/m^3). 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.

8. 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% certified canisters may be required upon request.

9. 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.

10. 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.

11. 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.

12. 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.

13. Method detection limit (MDL) studies must be performed at least annually. The MDLs should be ≤0.5 ppbv for all target analytes.

14. 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 Iss must be within ± 50% of the area response of the Iss in the mid-level standard of the most recent initial calibration.

15. 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% for each target analyte. Control charts should be maintained for the percent D values.

16. 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).

B. Fixed gases analysis

Fixed gases in soil gas: Soil gas samples may be analyzed for methane using a GC/FID. Other fixed gases including oxygen, and carbon dioxide may be analyzed using a GC/TCD (Thermal Conductivity Detector) technique based on EPA Method 3C. Laboratories analyzing samples for fixed gases in soil gas must also incorporate the following additional quality control procedures:

1. General considerations: Helium is used to prepare calibration gases. Use sample collection procedures described in EPA Method 3C or 25C. The sample loop must be Teflon® or stainless-steel tubing of the appropriate diameter. Peak height or peak area can be used for quantitation.

   EPA Method 3C requires that each sample must be analyzed in duplicate to calculate the average response. For the purposes of the MPCA PRP, a single analysis will be adequate.

2. Initial calibration: An external standard calibration technique is used. The concentration of the target analyte is calculated from the average response factor or from a standard curve. The initial calibration curves should contain at least five calibration points. The percentage RSD for average response factors must be less than or equal to 30% or the r^2 value for the curve must be greater than or equal to 0.995. The recovery (accuracy) for each point in the curve must be 70% to 130% except for the lowest point in the curve, which must be 60% to 140%. The lowest calibration point in the curve shall be at or below the analyte report level. If a sample concentration exceeds the highest calibration standard from the initial calibration, a smaller sample volume is injected into the GC and reanalyzed. If the instrument calibration results are outside the acceptance criteria, a number of actions can be taken:

   a. Check the instrument operating conditions. Instrument maintenance may be required.

   b. Review the response at each calibration level to ensure that the problem is not associated with one standard. If the problem appears to be associated with one of the standards, that standard can be reinjected. If the problem persists, remake the standard and reanalyze it.

   c. The last alternative is to delete calibration points from the curve. The MPCA will allow the removal of the lowest or the highest calibration point from the curve under the following provisions. If a non-linear calibration model is used in the initial calibration curve, a quadratic (second order) curve will require at least six non-zero standard levels while a polynomial (third order) curve will require at least seven non-zero standard levels. Care must be taken to ensure that there are enough remaining calibration points for the initial calibration curve. If the calibration criteria are now met, the analysis can proceed. However, there are ramifications in removing calibration points. If the top point is removed, the need for diluting samples and reanalyzing will occur at a lower concentration level. If the low point in the curve is removed, the sensitivity of the analysis has changed and thus the report level will need to change.

3. Continuing calibration: The initial calibration curves are verified at the beginning and ending of an analytical sequence. The drift must be within 70% to 130%. If the instrument calibration results are outside the acceptance criteria, check the instrument operating conditions and/or perform instrument maintenance. Reanalyze the calibration standard. If the calibration criteria are still not met, a new initial calibration must be performed. All samples that were analyzed since the last passing calibration standard must be reanalyzed. There is one exception allowed for this QC criterion: if the recovery of the calibration verification standard is >130% of the true value and the environmental samples show no detection of the analyte, the "less than" value can be reported without reanalysis.

4. Method validation: The laboratory must perform an initial demonstration of low background for each matrix by analyzing instrument blanks and demonstrating that the analytical system is free of contamination and that the method analytes are not detected above one-half the report levels.

   The laboratory must also perform an initial demonstration of capability for the analysis of each matrix. Four to seven LCSs near the mid-range of the calibration curve must be prepared and analyzed. The samples must be processed through the entire preparation and analysis procedure. The average percent recovery of the replicate analyses must be ≥70% and ≤130% (with a relative standard deviation of ≤30%).

5. Method detection limit/report level: MDLs and Reporting Levels (RLs) are determined annually or after a major change to the instrument conditions. The RLs should be three to five times the MDLs. The lowest calibration point in the curve shall be at or below the analyte report level. If the accuracy of the RL standard does not meet the 60% to 140% criteria, new RL standards are chosen and analyzed until the accuracy criteria are met. Contact the MPCA for any required report level for each project. RLs depend on program needs. They can change as new information becomes available. RLs are verified after each calibration and at least monthly. For most analytical work for the MPCA, the RLs should be at or below 1% for reported fixed gases. The MPCA requires that final results be reported as a percentage for fixed gases.

6. Batch QC: A batch is defined as up to 20 environmental samples. At a minimum, each batch must contain a method blank and a LCS/Laboratory Control Sample Duplicate (LCSD) pair.

   The concentration of methane in the method blank must be less than the associated report level. If the method blank is contaminated, measures must be taken to eliminate the problem. Affected samples must then be reprocessed. If the contamination cannot be eliminated, the results must be qualified to indicate the problem. All concentration levels for the affected target analyte that are less than ten times the concentration in the blank should be qualified with a "B" to indicate that the sample results may contain a bias related to the blank contamination. Concentrations of the affected analyte that are above ten times the blank contamination will not need to be qualified.

   Methane is to be spiked into the LCS and LCSD. The spiking levels should be five to ten times the report levels. The LCS is made from reagent-grade helium that has been demonstrated to be methane-free. In a soil gas matrix, the percent recovery of methane in the LCS or LCSD must be ≥70% and ≤130%. The relative percent difference between the LCS/LCSD pairs in water must be ≤30%.

   Any QC failure that is not remedied by reanalysis or re-extraction/reanalysis must be flagged in the final report.

Appendix A: Instructions for occupants

Follow the instructions below to minimize the detection of background indoor air compounds during indoor air sampling. If possible, begin to follow these instructions at least 48 hours before starting indoor air sampling and during the event. Conduct normal building ventilation for the time of year, but ensure all windows are closed. Following these instructions may not completely eliminate the potential for background indoor air contamination but may help minimize its effects. Please inform field sampling staff whether these instructions were completed.

Building occupants should comply, to the extent practical, with the following instructions:

- Do not open windows, doors, fireplace dampers, openings, or vents.
- Do not keep doors open.
- Do not use air fresheners, scented candles, or odor eliminators.
- Do not smoke in building.
- Do not use wood stoves, fireplaces, or auxiliary heating equipment, such as a kerosene heater.
- Do not use paint or varnishes.
- Do not use cleaning products such as bathroom cleaners, furniture polish, appliance cleaners, all-purpose cleaners, floor cleaners.
- Do not store containers of gasoline, oil, or petroleum-based or other solvents within the house.
- Do not operate or store automobiles in an attached garage.
- Do not use cosmetics such as hair spray, nail polish, nail polish remover, perfume, cologne, etc.
- Do not partake in hobbies that use solvents or other volatile chemicals.
- Do not conduct lawn-mowing, snow blowing, or paving with asphalt.
- Do not use caulk, adhesives, or roofing tar.