8.0 Soil Gas Survey and Evaluation

8.1 Introduction

Soil gas monitoring in the vadose zone is a method used to directly measure characteristics of the soil atmosphere that are frequently used as an indirect indicator of processes occurring in and below a sampling horizon. Soil gas monitoring is used as a method to suggest the presence, composition, and origin of contaminants in and below the vadose zone.

A soil gas survey is very effective as a rapid and relatively inexpensive method of detecting volatile contaminants in the vadose zone. Soil gas measurements can be used to both determine the presence or absence of a volatile material in the subsurface and to determine relative concentrations. Volatile materials diffuse through unsaturated soils to the surface, achieving an equilibrium with other soil gases. Their equilibrium concentration will be a function of their source concentration (separate phase product, soils, and groundwater), their volatility, and the distance they have to travel. Once the soil gas over a contaminant source has equilibrated, its composition is fairly stable as the only active exchange of soil gas with the atmosphere occurs in the top 12 to 18 in. of soil. Thus sampling of the soil gas below this depth can provide useful information about subsurface contamination.

8.2 Purpose

A soil gas survey (SGS) is a simple procedure that can provide a qualitative indication of the presence and delineation of volatile subsurface contaminants. The purpose of this document is to provide standard procedures for conducting soil gas surveys in the field.

8.3 References

The following ASTM Standard was consulted in the preparation of this SOP:

D 5314-93 Standard Guide for Soil Gas Monitoring in the Vadose Zone.

8.4 Overview of Methods

Soil gas surveys are generally used to indicate presence and horizontal delineation of subsurface volatile contaminants. It is a survey method which is qualitative, not quantitative. The quantity of data is more important than the quality in that an individual soil gas reading is not reliable by itself, but becomes a reliable indicator when supported by surrounding readings. The more data generated, the more reliable the delineation will be. In a soil gas survey the concentrations of specific compounds is irrelevant; it is the relative levels of a general class of contaminant (e.g., gasoline, chlorinated organics, etc.) that are important. One should therefore choose the simplest system that provides adequate confirmation of the type of contaminant being monitored.

Six basic soil gas sampling systems have been identified:

1. Collection of soil gas using a whole-air active approach:
   - involves the forced movement of bulk soil atmosphere from the sampling horizon to a collection or analyzing device through a probe; and

- best where contaminant concentrations are expected to be high and the vadose zone is highly permeable to vapor.

2. Collection of soil gas using a sorbed contaminants active approach:
   - involves the forced movement of bulk soil atmosphere from the sampling horizon through a probe to a collection device designed to extract and trap sample stream contaminants by adsorption;
   - well suited to sites where soil is highly permeable to vapor and where contaminant concentrations may be lower than required for successful whole-air surveys; and
   - contaminant trapping is accomplished by use of an adsorbent collection medium such as charcoal.

3. Collection of soil gas using a whole-air passive approach:
   - involves the entry of bulk atmosphere or soil atmosphere components from a near-surface sampling horizon to a collection or containment device through a flux chamber or similar apparatus; and
   - useful to some very specific applications such as monitoring soil contaminant emissions from soil or water to assess the health hazard risk to the general public.

4. Collection of soil gas using a sorbed contaminants passive approach:
   - involves the passive movement of contaminants in soil to a sorbent collection device over time;
   - samplers are placed into shallow holes, backfilled and left in place for two to ten days; and
   - charcoal is generally used as the adsorbent.

5. Collection of soil samples for subsequent headspace atmosphere or extraction sampling:
   - examines contaminants that are present in a headspace atmosphere above a contained soil sample; and
   - can be a relatively poor method for determining many of the more volatile contaminants, so is therefore limited in value.

6. Collection of soil pore liquid headspace gas:
   - uses a suction lysimeter or other device to sample soil pore liquid;
   - soil vapor that collects in the soil pore liquid sampling device is extracted and analyzed; and
   - limited by the expense and complexity of installing the sampling devices.

Methods 1, 2 and 4 are explained in detail in this document as they are the methods most commonly used by FDGTI for conducting soil gas surveys. Method 5 is commonly used for monitoring soil headspace in collected samples during drilling. The procedure for method 5 is presented in SOP No. 7.

Soil gas samples can be obtained using the following methods of penetration:
shallow driven points (less than 3 ft.) using a slam bar and ¼ in. probe; can drive 30 or more points per day; good for contamination above about 30 ft. depth; must pre-drill through sealed surfaces such as concrete;
hydraulically driven points using ¾ in. tube; slow method (10 to 15 points per day); good for deep contamination or complex geology; can cause filter cake that blocks soil vapor readings; and

drilled hole using a charcoal collection tube; slow method (10 to 15 points per day); eliminates filter cake problem; can be used as a permanent monitoring point.

The following sampling methods are used to retrieve soil gas samples:
syringe samples/direct injection into a field instrument (PID, FID, field GC or detector tubes); fast method for whole air sampling (field use only); requires a sampling pump (or can use suction pump in the field instrument to draw in the sample);
bag samples; good for moderate to high concentrations; limited holding time; requires a sampling pump; good for laboratory analysis; not appropriate for use with field instruments;
evacuated (Scott Air) bottle; good for low to moderate concentrations; moderate holding times; no sample pump required; not appropriate for field instruments; and
collector tubes (Tenax, charcoal, Petrex); slow sampling method; good for low concentrations; good holding time; requires laboratory analysis.

8.5 Limitations

The following limitations apply to soil gas surveys:
a soil gas survey is only applicable to volatile contaminants;
any barrier that interferes with vapor migration such as perched water, clay or made-made structures can lead to a low or false negative reading;
soil gas readings taken within 24 to 48 hours of heavy precipitation can produce drastically reduced or non-existent readings;
biodegradation can reduce the vapor levels of many hydrocarbons, including BTEX compounds;
the deeper the contamination relative to the soil gas sample point, the more the impact of biodegradability is likely to be; and
soil gas surveys are qualitative at best, do not provide repeatable quantitative information over time, and data must be confirmed by hard sampling methods (i.e., ground truth sampling).

8.6 Survey Design Considerations

The likelihood of the success of the soil gas sampling technique selected is controlled in part by the methodology in application of that sampling technique. This methodology should be guided by the project objectives and by the perceived spatial and temporal array of the potential sampling targets. In order to design a successful soil gas survey, the following considerations must be taken into account:

8.6.1 Development of a sampling grid:

- collected data must be distributed over a geographical area;
- the selection of grid size is strongly dependent on the relationship between project confidence level requirements and cost budget;
- small survey targets and complex vadose zone geology require decreased spacing between samples;
- overly large grid cell spacings result in inadequate, over-interpreted data; and
- grid arrays can be designed as regularly spaced, predetermined locations or they can be irregularly spaced and continually field modified.

8.6.2 Contaminant profiling:

- consists of sampling at closely spaced intervals in a linear array, the results being displayed as contaminant concentration versus distance on an *X - Y* plot; concentration data is often displayed logarithmically;
- profile intervals (i.e., spacing between samples) can range from about 25 to 100 feet; and
- useful as a corroborative tool for other monitoring methods.

8.6.3 Multiple depth sampling:

- allows monitoring of changes in soil gas contaminant fractions with depth;
- some sampling systems can recover soil gas samples as probes are advanced deeper into the vadose zone;
- this practice is helpful in determining the optimum sampling depth for a particular site or to demonstrate the presence or absence of soil atmosphere contamination in a certain horizon; and
- cross-contamination is unavoidable, so quality control is limited.

8.6.4 Time variant methodologies:

- consists of monitoring soil gas in the vadose zone over time;
- can help monitor the effectiveness of remedial air-injection or suction systems as well as the migration of contaminants from a source such as an underground storage tank; and
- proper maintenance of long-term monitoring systems is essential.

8.6.5 Combining with other vadose zone monitoring systems:

- SGS is commonly used as a reconnaissance tool for determining the best location for other monitoring devices such as monitoring wells.

8.6.6 Field Quality Assurance/Quality Control:

- essential for establishing support for any interpretation of measurement data;
- QA/QC requirements are dependent upon the data quality objectives defined in the planning phase of the survey;
- Persons collecting data should not be varied during a soil gas survey as changes in field personnel can translate into apparent changes in soil lithology that are merely functions of subjectivity;
- Field personnel should closely follow a standard operating procedure (i.e., one of the procedures documented below). Any deviations in the SOP should be recorded in the field notes;
- it is essential to follow the SOP for equipment decontamination (see SOP No. 12 for that procedure);
- bias of soil gas data (i.e., consistently lower-than-actual or higher-than-actual concentrations related to the measurement process) can occur for a number of reasons (malfunction of the field instrument, subsurface barriers to vapor diffusion, etc.) and must be considered in data evaluation;
- QA/QC samples must be taken, the type and magnitude of which depends upon the purpose of the soil gas survey and the requirements for data quality attendant to it. At a minimum, the following QA/QC samples should be taken when collecting samples for laboratory or field

GC analysis (variations of these sampling techniques can be used to check field equipment when taking only field readings) :

field blanks: samples of ambient air or nitrogen recovered from the sampling system to determine sample contamination by ambient air or to test for contamination of the sampling system; collect at least one field blank for each ten soil samples or one per sample batch;

travel blanks: the contents of a sample container containing no sample handled in the same manner as those containers holding samples, to audit sample integrity for loss due to sample handling and transport; include one travel blank in each batch of samples;

sample container blanks: obtained by sampling the contents of a clean container to ensure that residual contaminants are not present in the container prior to sampling; should be collected and analyzed prior to each use of a sample container;

sample probe blanks: carrier gas or atmospheric air drawn through the sampling device and recovered in the same manner as soil gas to check for the presence of sample train contaminants; should be collected and analyzed prior to each use of a probe and/or other components of the sampling system;

field replicates: separate soil gas samples collected from the sample site into multiple containers, can be used to estimate the precision of sampling and analysis; collect at least 10% of the total number of soil gas samples; and

sample spiking: the addition of a known quantity of a known compound or mixture to the soil gas sample to provide internal checks of analytical quality; generally done in the lab, not recommended in the field;

- a paperwork audit should be done at the end of each working day or at the conclusion of sample collection, and should include evidence of an equipment inventory, sample inventory including QA/QC samples, review of field notes and chain-of-custody (COC) documentation; and
- COC documentation is mandatory when samples are transmitted to an off-site laboratory (see SOP No. 12 for standard COC documentation procedures).

8.6.7 Sample handling and transport:

- the period of sample handling and transport represents the greatest opportunity for loss or gain of contaminants from or to sample containers;
- minimize the time between sample collection and analysis: pre-arrange analysis with the selected laboratory when samples are analyzed off site;
- protect samples against light and heat and exercise precautions against leaks;
- select materials for soil gas sampling, transfer and containment that will not impact sample integrity; avoid porous rubbers and plastics and corrosive metals;
- problems of sample handling and transport are minimized by integration of the sampling and analytical system (i.e., by feeding the sample stream directly into the intake port of the analyzer when doing field analysis);
- cross contamination is a concern with integral systems;
- when recovering samples by syringe, syringes must be either disposed of after each sample collection (if plastic) or decontaminated between each sample collection (if glass); syringe samples should be injected into the analyzer immediately upon sample collection;

- hand pumps and mechanical pumps can contribute to sample contamination, and should only be installed behind the analyzer or container in the sample train;
- if samples are to be transported to an off-site laboratory, they must be properly packaged to avoid damage to sample containers; take care to keep samples from becoming overly warm or agitated during transport; and
- archiving (i.e., storing) of soil gas samples should not be done due to the likelihood of degradation of stored samples.

8.6.8 Analysis of samples:

- soil gas analysis procedure is based upon pre-existing protocol established for the analysis of contaminants in ambient air;
- soil gas surveying as a field screening technique can be effective without the expenditure for highly sophisticated analytical techniques;
- portable field instruments (PIDs, FIDs and infrared detectors) are the most commonly used analyzers when performing an SGS as a field screening technique; limitations of these instruments include measurement capabilities for relatively low concentrations only, limited selectivity, inability to separate contaminant compounds, and limited accuracy (see SOP No. 7 regarding the use of field monitoring instruments);
- use of a field gas chromatograph (GC) provides much greater analytical capabilities than portable field instruments but it is very costly and is generally not warranted for a field screening survey (see SOP No. 7 regarding the use of a portable GC); and
- detector tubes (e.g. Draeger Tubes) can be used for field analysis, particularly if compound-specific detection is required; they are relatively inexpensive and provide immediate results, but are restricted to applications with few interfering compounds (see SOP No. 7 regarding the use of detector tubes).

8.6.7 Data interpretation:

- soil gas data interpretation is an iterative process including the examination of the raw data, selection of appropriate and useful data displays, an establishment of correlation of the data set to other vadose zone monitoring data and ground truth;
- soil gas data cannot be consistently interpreted in a manner that establishes direct correlation between contaminants in a soil gas horizon and contaminants in other horizons, however the detection of contaminants in soil gas does suggest the existence of a contaminant source, and increase in contaminant concentration can suggest close proximity to the source;
- it is the responsibility of the interpreter to examine soil gas data in context of other site characteristics, and provide an interpretation based upon sound judgement and thorough yet practical data treatment;
- soil gas data is normally interpreted as raw data; the application of correction factors is not recommended;
- statistical treatment of soil gas monitoring data allows the interpreter to estimate the amount of variation noted in the survey data due to errors, and can also be of use to define anomalous data subpopulations when the boundaries of a contaminated area are not clearly defined or if the

existence of multiple populations of data (i.e., contaminated and uncontaminated) within a single data set is in doubt;
- soil gas data from survey profiles displayed on an *X* - *Y* plot (see Section 8.6.2) can be used to examine the overall context for soil gas measurement data potentially indicating contamination; the profile can illustrate spatially significant groupings of data populations;
- soil gas data obtained by sampling at a single depth should be mapped to suggest the lateral extent of subsurface contamination; map suites of soil gas data obtained from multiple depths can sometimes aid in determining the depth to the contaminant source; and
- other vadose monitoring methods must be used to corroborate data obtained from a soil gas survey.

8.7 Whole-Air Active Approach

The following method is for the active collection of soil gas samples from shallow penetration holes (three feet or less) either by direct reading using a field meter or by collecting vapor samples into sample bags for laboratory analysis.

8.7.1 Bring the following equipment to the site to perform the SGS:
site plan and engineering scale for plotting sample locations,
tape measure or trundle wheel,
cable locating device,
impact drill (and generator if needed) if concrete must be penetrated,
slam bar or impact hammer,
one or more clean stainless steel vapor extraction rods,
field vapor monitoring instrument(s) (PID, FID, portable GC and/or detector tubes - see SOP No. 7 for details regarding these devices),
syringes, sample bags or a sample pump if needed,
cooler,
caulking gun and silicon rubber-based caulk (if sample points penetrate concrete), and
triple rinse equipment.

8.7.2 As with any subsurface investigation, locate underground utilities prior to beginning ground penetration. See SOP No. 6 for underground utility location procedures. It would also be prudent to use an underground cable locating device to use as a double check at each monitoring point location.

8.7.3 Begin in an area suspected of containing the highest concentrations of subsurface VOCs. The distance and direction of subsequent sampling locations will be based on consideration of the values measured at the previous locations.

8.7.4 Once all underground utility locations are satisfactorily located, use the impact drill to penetrate any overlying sealed surface such as concrete.

8.7.5 use the slam bar or impact driver to drive a ½ in. hole to a depth of 18 to 24 in.

8.7.6 Place a clean vapor extraction rod into the hole and drive it to the desired depth into virgin soil.

8.7.7 If a sample pump is used, purge approximately one volume of air from the rod. Using the pump, extract a vapor sample into a syringe or into an air bag. a syringe sample can be injected directly into a portable GC or into an appropriate detector tube for analysis; a bag sample can be placed in a cooler for subsequent shipment to a laboratory. Bag samples should be kept in a closed cooler without ice that is kept out of out of direct sunlight.

If an FID or PID is used, use the instrument sample probe to draw air directly from the vapor extraction rod into the instrument and record the peak concentration that occurs as vapor is being drawn in.

If bag samples are collected for laboratory analysis, field readings must also be taken using a field instrument to help determine the best sampling locations.

8.7.8 When done sampling, withdraw the probe, wipe it with a clean, dry cloth, and decontaminate it according to standard protocol (see SOP No. 12 for triple rinse procedure). The probe should be allowed to dry before taking the next sample (a propane torch can be used to dry the probe quickly).

8.7.9 Using the tape measure or trundle wheel, measure the location of the sampling point and plot it along with the field reading on the site plan. As each point is plotted, observe any trends in the distribution of contaminant concentrations to determine the location of each subsequent sampling point.

8.7.10 When sampling has been performed through concrete or other sealed surfaces, the probe holes should be sealed with a durable, quick drying caulk, preferably of a color similar to the surface (particularly on active facilities where the presence of numerous open drill holes would not be acceptable). Squeeze a plug of caulk fully into the top several inches of the drill hole.

8.7.11 Move to the next location and repeat the above procedure. The survey is successfully completed when all areas showing significant vapor concentrations have been delineated out to where the vapor concentrations are very low or not detectable. This is not always possible if contamination extends to areas that are inaccessible (such as beneath structures or off site).

8.8 Sorbed Contaminants Approach

Presented below are two methods used for the collection of gas samples using the sorbed contaminants approach. The Petrex method is a passive collection approach and requires the burial of sample collection devices. Tenax Tube sampling is an active approach which involves the use of an air sampling pump to draw vapors from a pre-drilled hole into a sample collection device located at the surface.

8.8.1 Petrex Sampling Method

The Petrex method is accomplished by burying a series of sampling bottles containing an activated charcoal sample collector.

Sampling procedure:

1. Bury the sample collectors on 50 to 100 ft. centers in a grid pattern extending downgradient from the spill source area, each at a depth of 12 inches.

2. Leave the collectors in the ground for 3 to 7 days.

3. After the prescribed burial period, recover the charcoal collectors, seal them and ship them to a laboratory for analysis.

4. Have the laboratory analyze the samples using Curie effect mass spectrometry which provides both a mass spec “fingerprint” of the contaminant and a relative concentration (ion flux).

5. Use the laboratory results to plot a contour map of the contaminant plume.

8.8.2 Tenax Tube Sampling by Vacuum Pump

Collection of an accurately known volume of air is critical to the integrity of the results. For this reason, great care should be taken when setting up each piece of sampling equipment.

Sampling procedure:

1. Connect a ¼" swagelok fitting with urethane tubing from the top of the rotameter to a Gilian vacuum pump.

2. Connect the " swagelok fitting with urethane tubing to the bottom of the rotameter.

3. Insert a "dummy" tenax tube into the universal tube holder by placing the tenax tube into one end of the holder, then gently align the other end of the tenax tube with the inlet hole on the cap of the tube holder. Gently twist down the cap to get an airtight seal between the tenax tube and holder.

   Note: twisting the cap down too hard will result in a broken tenax tube.

4. Check the system for leaks by turning on the vacuum pump; the ball in the flowmeter indicates flow throughout the system. Place your finger over the open end of the tube holder. The ball in the flowmeter will slowly drop to the bottom of the flowmeter to indicate no flow. If the ball does not slowly drop, this indicates leaks in the system. Reassemble the sampling configuration piece by piece, originating from the vacuum pump. After attachment of each piece of equipment, turn on the vacuum to check for leaks. Repeat this process until you're assured of no leaks.

   Note: The importance of assembling a leak-proof system is critical. a leaky system will result in erroneous analytical results.

5. To collect an air sample, the "dummy" tenax tube is removed from the tube holder and a treated tenax tube is **carefully** inserted into the tube holder for sample collection.

   Note: Polyethylene gloves must be worn when handling the tenax tubes. Cross contamination of hydrocarbon on your hands, clothing, or immediate sampling area will result in erroneous results. When removing the tenax tube from the storage container, keep the container inverted to minimize loss of helium.

6. Start the pump, verify air flow, and record the following parameters on the appropriate sheet:
   - project/project number: required for project identification and billing;
   - site: project site location;
   - sampling location: be as specific as possible, e.g., vapor monitoring well in west site of cafeteria;
   - sampling time required: flow rates recorded during sampling are generally consistent. The desired air sample volume is 1 liter, therefore, it is necessary to calculate the time required to collect a 1 liter sample by the flow rate Q, the sampling time requirement can be calculated:

     Example:
     If the flow rate recorded = 52.0 cc/min.
     and the sample volume desired = 1 Liter,
     then the sampling time is:
     (1 ltr/52.0 cc/min.) x (1000 cc./ltr) = 20 min;
   - ambient air temperature (^{O}C): this value can be obtained from either a hand carried thermometer or the local weather station;
   - barometric pressure (mm Hg): This value can be obtained from either a hand carried barometer or the local weather station;
   - relative humidity (%): This value can be obtained from either a hand carried relative humidity gauge or the local weather station; and
   - dry gas meter reading: This value will be calculated by the laboratory staff.

   Note: It is very important to document activities or chemicals that may affect the results of your air sampling.

7. Record the following information for proper analysis:
   - instrument model no., e.g., Hi Flow Sampler Model Hfs 113A up,
   - pump serial no.: e.g., S/N 7126,
   - date(s) sampled,
   - time period sampled,
   - operator: your name,
   - calibrated by: your name,
   - tenax tube no.: number indicated on the side of the tube,

- sample number: in chronological order from sample no. 1 through sample no. *n*. These numbers must be consistent with chain of custody form,
- rotameter reading: this value can be obtained directly from the F &P Lab Crest Flowrator meter during actual sampling, and
- flow rate Q (mL/min): this value can be obtained from the calibration curve supplied with the F&P Lab Crest Flowrator meter.

Note: The rotameter reading and flow rates should be recorded at least 4 times during sampling. Be sure the calibration curve is consistent with (a) air curve, and (b) float ball, e.g., sapphire, black grass, etc.

8. At the end of the sampling duration, remove the tenax tube from the tube holder and carefully insert into the storage and transport container. Label the storage container with the appropriate sample identification number.

9. Rewrap the storage containers with tenax tubes in bubble pack and place tubes in a cooler on ice for transport. (See "Tenax Tube Packaging Procedure")

10. Complete a chain of custody form. Place it in a plastic bag and then into the cooler with the tenax tubes.

    Note: Samples should be transported immediately to the laboratory for analysis. All samples should be pre-scheduled for analysis with the lab to accommodate desired turnaround time.

Packaging procedure

Use a cooler which can easily hold the tubes, wrapped in bubble pack, in a lengthwise manner.

Place a layer of ice in a plastic bag on the bottom of the cooler. Follow this with a layer of bubble pack.

Place the bag of tubes, containing the charcoal pack, which has been wrapped in bubble pack, in the cooler.

Place another layer of bubble pack on top of the tubes.

Add two "ice-packs."

The cooler should be sealed securely and shipped overnight.

The only exception to the above procedure occurs when shipping syringes. These should be sent at room temperature after being securely packed in a cardboard box. The samplers should refer to the *"Air Sampling Certification Manual"* so that safe handling during the sampling procedure can be followed, and sample integrity maintained.

8.9 Interpretation of Results

Evaluation of soil gas survey results allows one to determine if the soil vapor contains volatile organics. Areas where subsurface contamination is most likely to exists can be identified as can areas where soils appear to be clean. Point sources may be identified as well as the general direction of contaminant spread. An SGS does not however provide the same level of quantification (or confidence) as obtained from soil sampling for laboratory analysis, nor does it indicate the vertical extent of contamination. SGS results can be used to develop a sampling plan for more definitive ground truth soil and groundwater testing.

Upon completion of collection and analysis of all soil gas samples, use the following procedure to incorporate the data into a Phase I or Phase II Subsurface Field Investigation (see SOP No. 5):

Complete the plotting of all survey points and associated vapor concentrations onto a site plan.

Draw interpreted vapor iso-concentration contour lines on the plan.
identify the areas that show the highest vapor concentrations as well as interpreted upgradient and downgradient locations.

Use the areas identified from the above plot along with other information gathered during pre-subsurface assessment to decide the locations of subsurface exploration points (boreholes, wells, test pits, etc.). You will want to further investigate areas where soil vapors are highest, and, if groundwater wells will be installed, place wells both upgradient and downgradient of the anticipated contaminant plume.

8.10 Reporting

Of primary concern in the reporting of findings pertaining to a soil gas survey is that the report includes the information necessary to describe the results of that survey performed for a particular application (e.g., monitoring SGS for environmental assessments). All reports should discuss data related to the QA/QC objectives and should include data comparability, representativeness, bias, precision accuracy, completeness and analytical detection limits wherever possible. A general discussion of the reliability of results and analytical detection limits is warranted. Reports of SGS findings should include the following elements:
the purpose of the soil gas study and the rationale for the selection of a particular monitoring technique;
a discussion of the sample array in three dimensions, sampling method employed and analytical scheme chosen;
a discussion on the impact of vadose zone (hydrogeologic) properties on survey design;
the characteristics of a contaminant source or spill, if known, and a list of the chemical compounds known or suspected to have been used at the site;
any unique characteristics of the site or the study that could provide a meaningful context in which to interpret the soil gas data;
a site plan showing sample locations, physical features, iso-concentration contours of specific compounds or groups and any other necessary information to guarantee map clarity;
cross-sections showing changes in contaminant concentration with depth or concentration profiles of more than one contaminant through several sample locations, if possible;
a discussion regarding the physical structures at the site that may impact the location of sampling points and the migration of soil gas (e.g., concrete pads, buried pipelines, etc.);
an evaluation of the impact of the regional and local hydrogeologic conditions within the survey area on the results of the survey.;
a detailed description of the type of soil gas survey conducted, including selection of method, sampling array, background sampling, decontamination procedure, field and/or laboratory analytical methods, and QA/QC procedures.

any unusual conditions that occurred during the survey (e.g., rainfall events, atmospheric conditions, visual observation of contamination at sampling points, etc.);

if the subject site is contaminated, a discussion of soil gas characterization of uncontaminated or non-anomalous contiguous property;

data collected during field sampling and field or laboratory analysis , compiled in tabular form; this data should include sampling and analysis dates, soil/rock description at each sampling point, depth and diameter of sampling point, quantity of soil gas purged prior to sampling, quantity of sample extracted, and tabulation of QA/QC samples recovered;

a discussion of the results of QA/QC efforts, establishing performance within limits set prior to the survey; systematic errors or bias can be detected in this review;

wherever possible, a discussion that correlates soil gas data to ground truth (e.g., monitoring wells); and

conclusions drawn from the results, and recommendations, if appropriate.