

**BASIC REMEDIATION COMPANY
STANDARD OPERATING PROCEDURES
BMI COMMON AREAS
CLARK COUNTY, NEVADA**

SOP-37

ACTIVE SOIL GAS INVESTIGATION

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DISCLAIMER

THE FOLLOWING STANDARD OPERATING PROCEDURE PROVIDES GENERAL GUIDANCE FOR BRC CONTRACTORS FOR TECHNICAL ISSUES ADDRESSED DURING ENVIRONMENTAL SITE INVESTIGATION AND REMEDIATION ACTIVITIES. IT IS NOTED, HOWEVER, THAT EACH SITE IS UNIQUE AND THESE GUIDELINES ARE NOT A SUBSTITUTE FOR COMMON SENSE AND GOOD MANAGEMENT PRACTICES BASED ON PROFESSIONAL TRAINING AND EXPERIENCE. IN ADDITION, INDIVIDUAL CONTRACT TERMS MAY AFFECT THE IMPLEMENTATION OF THIS STANDARD OPERATING PROCEDURE. BRC CONTRACTORS RESERVE THE UNRESTRICTED RIGHT TO CHANGE, MODIFY OR NOT APPLY THESE GUIDELINES IN THEIR SOLE, COMPLETE, AND UNRESTRICTED DISCRETION TO MEET CERTAIN CIRCUMSTANCES, CONTRACTUAL REQUIREMENTS, SITE CONDITIONS, OR JOB REQUIREMENTS.

1.0 INTRODUCTION

The purpose of this Standard Operating Procedure (SOP) is to provide the user with the basic theory and methods to perform soil gas investigations. It's is intended to serve as a guide and provide options for sample collection and analysis that can be used on a site-by-site basis serving as a standard practice. Site-specific procedures should be developed in the work plan phase, based on site conditions and project objectives, for each application.

Soil gas investigations monitor the soil atmosphere within the vadose zone to directly measure characteristics that can be indicators of processes occurring in the subsurface. Soil gas investigation is used as a method to determine the presence, composition, and origin of potential contaminants in and below the vadose zone. Soil gas investigations can provide useful information in a variety of applications such as the following:

- Horizontal and vertical delineation of surficial discharges and/or contaminant spills of volatile compounds
- Potential releases from underground storage tanks
- Landfill gas characterization and migration delineation
- Delineation of volatile organic compounds (VOCs) in groundwater at the water table
- Evaluation of the degree of microbial activity as it pertains to natural degradation of contaminants
- As an aid in soil vapor extraction (SVE) system design and effectiveness evaluation
- As a basis for locating a permanent monitoring well array

Soil gas as it exists in the subsurface is a dynamic equilibrium of the processes of partitioning, migration, emplacement and degradation. Partitioning controls movement from one physical phase to another. The five physical phases are liquid, free vapor, trapped vapor, solute, and sorbed. Migration refers to movement over distance, horizontal or vertical. Emplacement refers to establishment of residence within a particular physical phase. Degradation is the breakdown of compounds, typically, by oxidation or reduction reactions.

2.0 RESPONSIBILITIES

The **Project Manager** or **Task Leader** (a qualified Nevada Certified Environmental Manager [C.E.M.]) selects the site-specific sampling methods, with input from the Field Team Leader, Site Geologist, and Site Chemist, and oversees activities and work progress.

The **Site Geologist** (a qualified Nevada C.E.M.) selects the site-specific sampling options and helps prepare technical provisions for fieldwork.

The **Field Team Leader** (a qualified Nevada C.E.M.) implements the selected sampling program and assists in the selection of sampling methods.

The **Site Chemist** assists with the selection of sample collection techniques and analytical protocols; assures that the laboratory adheres to analytical program requirements; and reviews data for compliance with data quality objectives and contract compliance.

3.0 METHODS

Soil gas monitoring has a set of procedures that must be followed in order to provide data quality and usefulness. This section describes the primary procedures that are common to all soil gas monitoring techniques:

- Planning and preparation
- Survey design
- Soil gas probe installation
- Soil gas sample collection
- Handling and transport of samples
- Sample analysis
- Interpretation of analytical results
- Report preparation

3.1 Planning and Preparation

The planning and preparation step includes development of project objectives, including purpose of the survey data application, and data quality objectives. This step includes gathering of historical information regarding the project area and selection of appropriate sample collection methods and survey design. Budgetary constraints must be considered during the planning step.

3.2 Survey Design

A scaled facility map depicting potential sources and proposed sampling points should be prepared. The locations and coordinates of identifiable geographic landmarks (*e.g.*, street center-

line, benchmark, street intersections, wells, north arrow, and property lines) should be included on the map.

The spacing of samples is dependent on the objectives of the survey and the soil conditions present. In some cases, a 200-foot horizontal spacing may be adequate for screening a large area, of permeable soils, with a low permeability cover. In areas of low permeability soils, with high moisture content a very tight spacing (*e.g.*, 20 feet) may not be adequate to detect a hot spot.

Non-specific portable organic vapor analyzer (OVA), photoionization detector (PID) and/or gas chromatograph (GC) hand-held detectors typically are not sufficiently sensitive for most survey purposes. Use of an on-site mobile laboratory with laboratory-grade certifiable instrumentation and procedures for real-time analysis of individual VOCs provides the detection limits and reliability needed for most surveys.

Maintain flexibility in the sampling plan such that field modifications (grid pattern density, location, and depth) can be made as real-time evaluation of analytical test results occurs. Include in the work plan decision-making criteria for these adjustments and explain decisions in the report.

Re-sample at any sampling point if anomalous data (*i.e.*, 2 to 3 orders of magnitude difference from surrounding samples) are obtained.

3.3 Probe Installation and Leak Check

Probe installation includes assembling the 1-inch outside diameter (OD) sample rods with a Post Run Tubing (PRT) adaptor and o-rings into the bottom of the first length of rod. The expendable sample tip is installed in the end of the first length of rod and the drive tip is put into place while setting the rod and tip on the sample location and inside of the ground seal ring. The use of a ground seal ring is recommended, which consists of a 4-inch length of 3 to 6-inch diameter PVC which is placed on the ground and filled with a bentonite slurry thus sealing the probe/ground interface (Note: most leakage occurs along the probe and soil). Install the hammer cap and advance the probe tip into the ground a few inches, fill the ground ring with the bentonite slurry, and advance the probe to the desired depth. With the hammer cap installed, withdraw the probe from the tip about 3 inches. Remove the hammer cap, install a length of clean, virgin polyethylene tubing and PRT adaptor, fitting the adaptor in the bottom of the rod. Turn the tubing and adaptor in a counter clockwise direction (reverse threads) until a tight seal is obtained.

Sealing is facilitated by the o-rings on the adaptor tip. The probe tubing is then purged for the desired purge volumes and the soil gas sample collected.

As part of the sample collection procedure, probe and sampling train leak checks can be performed in order to demonstrate the integrity of the soil gas sample. Leak check involves preparing the probe as described above, connecting the sampling media of choice as described in the subsequent sections, enclosing the probed and sample collection train, introducing a tracer compound to the enclosure, and collecting the sample with an environment around the probe and sample collection train so that a 'leak in' the sample will result in the presence of tracer compound in the sample. If the sample, when analyzed, does not contain the tracer species to the level identified in the specific work plan, then the sample integrity is intact and the sample has been shown to represent the soil gas sampled from the subsurface. But, if the tracer species is found in the sample above the criteria for the leak-check, then the sample has been shown to be compromised and can be identified as not representative of the subsurface soil gas (*e.g.*, the presence of the tracer species indicates a likely dilution of soil gas or a low bias in the sample concentration).

The most common method of implementing a leak-check for the soil gas sample collection is bag method where a flexible-wall bag is sealed around the probe on the ground surface, encapsulating the sample train, and is outfit with inlet and outlet gas ports for tracer addition and bag flushing. A common and effective tracer species is helium gas at source concentration (10% to 100%). The tracer gas is interfaced to the inlet port on the bag or containment, the exhaust port is opened and the tracer gas is flushed into the enclosure achieving addition concentration (*e.g.*, helium concentration in the bag equals the bottle gas concentration), and the bag is sealed for sampling. A screening level measurement may be made with a real time instrument sensitive to helium at the trace gas addition for confirmation; however, this is not required. The helium gas tracer is the trace gas of choice for canister sample collection since the sample in the canister can be analyzed in the laboratory by gas chromatograph/thermal conductivity detector (GC/TCD) for helium at relatively low cost. If canisters are not used for sample collection, other tracer species such as alcohol or isobutene may be used and detected in the GC analysis.

3.4 Sample Collection

Obtain samples at an adequate depth (nominally 5 feet) below ground surface (bgs) to minimize potential dilution by ambient air. Conduct a site-specific purge volume versus contaminant concentration test at a location with known VOCs in soil gas. In an area with unknown conditions, conduct this test at the first location where VOCs are detected or in the area of

suspected VOC contamination. Adjust the purge rate and time to achieve the optimal purge rates and volume. Describe specific method and equipment to determine optimal purge rates and volumes in the Work Plan. Avoid application of high vacuum and flow rates to sampling trains to decrease the chances of leakage. Calibrate flow rate to less than or equal to 100 milliliters per minute. In general, minimize purging to ensure samples are representative of VOCs concentrations at the probe tip. Optimum purge volume may be compound specific. “Lighter” (higher volatility) early eluting VOCs, such as vinyl chloride, may reach their highest concentration with less purging than “heavier” (less volatile) late eluting VOCs, such as tetrachloroethylene (PCE). Therefore, optimize the purge volume for the compound(s) of greatest interest.

Explain the expected zone of influence for sample points, taking into consideration soil types, land cover, drive point construction, and sample purge rate/time/volume in the Work Plan. The vertical zone of influence for purging and sampling must not intersect the ground surface. Soil gas sample collection and handling procedures should be specified in the Work Plan. Provide the procedures to prevent collection of samples under partial vacuum and the methods to minimize equipment cross-contamination between sampling points.

Avoid making a pilot hole (*e.g.*, using a slam bar) prior to inserting the probe rod, except to drill through concrete or asphalt. The process of making a pilot hole may promote vapor contaminant aeration and result in biased low sample concentrations.

The Work Plan should specify the sampling equipment (*e.g.*, gas tight syringe, sorbent trap) that will not compromise the integrity of the samples. Assure that the probe tip, probe, and probe connections have the same diameter to provide a good seal between the formation and the sampling assembly. If space develops between the probe and the formation, seal (*e.g.*, with bentonite) the area around the probe at the surface to minimize the potential for ambient air intrusion.

Some sampling systems (*e.g.*, Geoprobe) use the probe rod as a conduit for the tubing that connects to the probe tip. Assure a tight fit between the tubing and the probe tip to minimize potential leakage and dilution of the sample. Follow the sampling method specified in the Work Plan.

3.4.1 Sample Collection Methods

Soil gas sample collection methods should be selected based on site-specific factors and project objectives. The following basic sampling systems are based on the collection of soil gas by a whole-air or sorbent method in an active or passive approach:

- Whole-air methods sample the atmosphere as a mixture of gases including contaminant (target) and non-contaminant (non-target) vapors.
- Sorbent methods sample contaminants adsorbed onto a collection medium exposed to a whole-air sample stream.
- Active methods obtain a soil gas sample by positioning a device in the subsurface and withdrawal of the soil atmosphere.
- Passive methods obtain a soil gas sample by placing the collection device in the soil or on the soil surface and allowing the device to come into equilibrium with the soil atmosphere.

The active whole-air method is the most common method used during site investigation. The process begins by penetrating the soil surface to the desired sample collection depth. For depths of less than 5 feet, a simple “slam-bar” may be used to create a small diameter hole (generally less than 1 inch). Deeper collection points are realized by direct push hydraulic installation equipment. The slam-bar rod is withdrawn and a hollow cylindrical probe fitted with a retractable point is inserted. The point prevents soil from plugging the probe during insertion. The probe is withdrawn slightly to allow the point to drop and expose the inlet. Care should be exercised to ensure that the probe is sealed at the ground surface to prevent ambient air from being drawn into the sample interval. A vacuum pump is then attached to the sample port and the probe is purged of one volume. Determining the volume of the probe and the flow rate of the pump allows calculation of the purge duration. Example:

$$\begin{aligned}\text{Probe volume} &= 193 \text{ cc} \\ \text{Pump flow rate} &= 100 \text{ cc/min} \\ \text{Time} &= \frac{193 \text{ cc}}{100 \text{ cc/min}} = 1.93 \text{ min or } 1 \text{ min } 56 \text{ sec}\end{aligned}$$

At the completion of the purge duration, sample collection should begin immediately. Sample collection duration is dependent on the sample container or collection media. Sample container requirements are included in the *BRC Quality Assurance Project Plan* (QAPP; BRC and ERM 2008).

Deeper soil gas sample collection can be accomplished using hydraulic push or conventional drill rigs. As an example, use a Geoprobe[®] to drive a rod to the desired depth. The Geoprobe[®] rod is fitted with an expendable tip. Retracting the rod back slightly opens the tip. The rods are purged and a sample collected in a similar manner as discussed for shallow soil gas sample collection.

The sample collection device or container is dependent on the target compound(s) and the method of analysis. For VOC screening, the device could be a PID for total VOCs or compound specific detector tubes. For quantitative VOC results using GC analysis sample containers such as Summa canisters, Tedlar bags, glass syringes, glass bulbs, or charcoal tubes can be used. Other soil gases such as methane, carbon dioxide, oxygen, sulfur dioxide, cyanide, etc. can also be qualitatively or quantitatively monitored depending on analytical method selected in the planning stage.

The handling and transport of soil gas samples is highly dependent on the type of sample container and analytical method. The period of sample handling and transport represents the greatest opportunity for loss or gain of contaminants to or from sample containers. In general, the time between sample collection and analysis should be minimized. Samples should be protected from light and heat and caution should be exercised to prevent sample container leakage. In situations where a portable analyzer is used, the whole-air active sampling system can be coupled directly to the analyzer, effectively eliminating the handling and transport phase.

When shipping samples for off-site analysis, factors such as container type and sample life must be considered. It is not recommended to use overnight air freight when using syringes, glass bulbs, or Tedlar bags due to the compression/decompression changes during flight.

Soil gas analysis procedures are based on protocols established for the analysis of contaminants in ambient air. Analytical procedures are dependent on the project specific compounds of concern. Decisions on analytical procedures and methods are made during the planning phase based on the purpose of the soil gas survey, budgetary restraints, and data quality objectives.

Soil gas data interpretation involves the examination of raw data and the selection of appropriate and useful displays. Interpretation of soil gas data cannot be correlated to underlying soil, rock, and groundwater contaminant concentrations at a high confidence level. However, the detection of contaminants in soil gas does suggest the existence of a contaminant source and increases in contaminant concentrations can indicate close proximity to a potential source. The interpreter

should use sound judgement when examining soil gas data as they relate in context with other site characteristics.

Reporting of soil gas investigation results should be presented in a format that meets the requirements of the end user. The results must meet the project objectives developed during the planning phase. The report should include a description of the purpose of the investigation and rationale for the selection of the particular monitoring technique employed. The selected technique should be based on the physical properties of the vadose zone and the physical and chemical properties of the compounds of interest. A discussion on the vadose zone properties as they relate to survey design should be included. Regional and local hydrogeologic conditions within the survey area should be described. Local conditions with regard to soil type(s), moisture content, groundwater flow directions, aquifer characteristics, groundwater quality, etc. should be included. A detailed site drawing showing physical structures, sample point locations, paved areas, buried utilities, suspected source areas, etc. should be presented. Isoconcentration maps and cross-sections with concentration profiles showing changes with depth are highly useful displays. Lastly, conclusions drawn from the results of the study and any appropriate recommendations should be presented.

The Work Plan should include, but is not limited to, the following topics: survey design, sample collection procedures, laboratory analysis of the soil gas samples, analytical data reporting and quality assurance/quality control (QA/QC) data requirements.

3.4.2 Whole Air Sample Collection with Evacuated Canisters

One common if not preferred method for sample collection and analysis of soil gas samples is evacuated canisters. The advantage of this approach is that samples can be collection on site, preserved in the stainless steel canisters, shipped, and analyzed off site at a higher level of QA standards and for an extended list of analytes in a qualified off site laboratory.

For sample gas collection by canister, the probe is installed as for any other soil gas sample collection media or technique, and, as for other media, the probe ground seal is recommended. The probe ground seal consists of a 4-inch long piece of PVC pipe, 3 to 6-inch diameter dropped over the probe after installation and filled with a slurry of bentonite sealant. The best way to install the ground seal is to place the seal on the ground, advance the probe assembly through the PVC ring, push the probe below the surface at least a few inched, add the bentonite, and continue

with the soil gas probe advance to the depth of interest. This procedure prevents the probe tip from contact with the bentonite slurry and thus avoiding any plugging issues.

Purge the sample line by using a vacuum pump and extract one purge volume from the sample line (25 cc per 5-foot length of ¼-inch tubing). Monitor pressure in the system and do not exceed 50 inches of water pressure. The target pressure is 20-inch water, and if 50 inch water pressure is reached, the location will probably not be suitable for sampling, which requires a relocation of the probe to a nearby location (*e.g.*, 10 feet).

Purge the line for one purge volume monitoring and maintaining pressure and flowrate: target pressure is 20-inch water or less, and target sample rate is 100 cc/minute or less. Record sampling conditions. Collect the sample in either 1-liter or 3-liter canisters. The 1-liter canister will require about 10 minutes for sample collection and the 3-liter about 30 minutes. Fill the sample containers to 80%-to-90% of volume, or to within a residual canister pressure of about 5 to 10 inch mercury. The flow rate and pressure is controlled by using either a clean rotometer (needle valve controlling flowrate) or a fixed orifice sealed by compression fitting to the canister inlet limiting the flowrate to 100 cc/minute. After sample collection, seal the canister by closing the valve and sealing the port with a compression plug fitting. The canisters are to be labeled and shipped back to the laboratory in protected cardboard boxes.

3.5 Laboratory Analysis

The project Work Plan should specify the target analyte list. The target analyte list should be determined based on site history and conditions. A method detection limit (MDL) study should be performed for each target analyte at least annually. The MDLs should be confirmed prior to analysis. Practical quantitation limits (PQLs) should be provided for each analyte based on the laboratory instrument's ability to achieve reasonable limits. Action goals or limits should be determined in the Work Plan based on site history and contaminants of concern. Contract required quantitation limits (CRQLs) are then established based on all of the information provided above.

The following detectors are used for soil gas analysis:

- Electrolytic conductivity detector (ELCD) (*e.g.*, Hall)
- PID (Note: see SOP-39 for additional information on PID principles and procedures.)
- Flame ionization detector (FID)
- Mass spectrometer (MS), either full scan analysis and/or selective ion mode (SIM) analysis

- Electron capture detector (ECD)

The detectors chosen will depend on the target analytes and goals of the project.

3.5.1 Quality Control Requirements for On-Site Analysis

The following section describes the minimum requirements for QC for the analysis of soil gas samples that are analyzed by GC. All standards and QC samples must be clearly identified and documentation maintained to trace them to their original source.

3.5.1.1 Calibration Requirements for On-Site Analysis

The GC must be equipped with a type of column that can separate all of the target compounds. Coelution of the target analytes is not acceptable unless the compounds are distinguished and quantified by two different types of detectors in use at that time. Analyze the initial calibration and daily mid-point calibration check standards, laboratory control samples (LCS), method blank, and samples using the same GC conditions (*i.e.*, detector and temperature program). Use a GC analytical run time sufficient to identify and quantify all of the target analytes. The analytical run sequence requirements are provided below.

Perform an initial calibration for all target analytes. An initial calibration should be performed when: when the GC column is changed, when the GC operating conditions have changed, or when the daily midpoint calibration check standard does not meet the specified criteria.

The calibration should include at least three different concentrations of the target analytes, with the lowest standard not exceeding five times the CRQL for each compound. Calculate the response factor (RF) for each compound and calibration concentration prior to analyzing any field samples. Calculate the average RF for each compound. The percent relative standard deviation (%RSD) for each target analyte must not exceed 20% except for the following compounds which must not exceed 30%:

- Trichlorofluoromethane (Freon 11)
- Dichlorodifluoromethane (Freon 12)
- Trichlorotrifluoromethane (Freon 113)
- Chloroethane
- Vinyl chloride

Verify the true concentration of the standard solutions used with the LCS after each initial calibration. Conduct the verification using a LCS mid-point concentration within the initial calibration range. The LCS must include all the target compounds and the RF must be within 15% difference from the initial calibration.

The calibration must be verified using the calibration standard solution with a mid-point concentration within the linear range of the initial calibration before any samples are analyzed. The daily mid-point must contain all the target analytes. Assure that the RF of each compound (except for trichlorofluoromethane (Freon 11), dichlorodifluoromethane (Freon 12), trichlorotrifluoromethane (Freon 113), chloroethane, vinyl chloride) is within 85% to 115% of the average RF from the initial calibration. The RFs for trichlorofluoromethane (Freon 11), dichlorodifluoromethane (Freon 12), trichlorotrifluoromethane (Freon 113), chloroethane, vinyl chloride must be within 75% to 125%.

3.5.1.2 Quality Control Samples

LCSs are prepared using a second source standard that is totally independent from the standards used for the initial calibration. Second source means a different supplier (whenever possible) or a different lot from the supplier.

Field blank samples are used to detect possible interferences from ambient air. Investigate and determine the source(s) and resolve laboratory contamination problem prior to analyzing samples, if the blank indicates measurable concentrations above the CRQL of the target analyte(s).

Add surrogate compounds (if used) to all calibration and daily mid-point check standards, blanks, site samples, and samples for second column confirmation to monitor the relative retention time (RRT) shift between GC runs. This is recommended for better compound identification when ELCD, PID, ECD, and FID are used for analysis. Two to three different surrogate compounds should be used to cover the different temperature programming range for each GC run.

Assure that the surrogate compound concentration is within the initial calibration range. Use a surrogate for both primary analysis and second column confirmation. Second column confirmation can be done with a different GC. The representative sample can be collected in Tedlar bag and confirmation can be done off site. Second column confirmation may not be necessary if the compounds present have been confirmed from previous soil gas investigations.

3.5.1.3 Quantitation

Assure that the requirements for initial calibration, daily mid-point, blank, and LCS are met before any field samples are analyzed. Analyze samples within 30 minutes after collection to minimize VOCs loss. Longer holding times may be allowed if the laboratory uses special sampling equipment (*e.g.*, sorbent trap, glass bulb) and demonstrates that the holding time can exceed 30 minutes with no decrease in results.

Assure that concentrations of constituent(s) in the sample do not exceed 50% of the highest concentration in the calibration range. Reanalyze the sample using a smaller volume or dilution if the detected concentration exceeds 50 percent of the highest concentration in the calibration range.

Attain detection limit of not more than 1 microgram per liter ($\mu\text{g/L}$) for all target compounds. If lesser sample volumes or dilutions are used to off-set possible high concentration of constituents in the initial run, use the initial run to calculate the results for constituents that are not affected by the high concentration so that detection limit of 1 $\mu\text{g/L}$ for these compounds can be achieved. Quantify sample results using the average RF from the most recent initial calibration. Add surrogate compounds to all samples if GC/MS is not used for analysis or compound confirmation. Conduct compound confirmation by GC/MS or surrogate compounds and second column. Identify VOCs through MS and retention time comparison if MS is used for analysis.

Detection limits may be raised above 1 $\mu\text{g/L}$ for compounds with high results (*i.e.*, the limit as specified in the Work Plan) and those closely eluting compounds for which quantitation may be interfered by the high concentrations. Quantify sample results according to this SOP for analytes that are not affected by the high concentration compounds.

When dilution with ambient air is used for samples with high results, dilute and analyze in duplicate at least one sample each day to verify the dilution procedure. Ambient air should be checked periodically during each day of analysis.

Shorten the GC run time under the following conditions only:

- The number and identification of compounds are known from previous soil and soil gas investigations.
- The consultant has been given permission by the regulatory agency to analyze only for specific compounds.

Meet the following requirements when shortening GC run-time:

- Client and chemistry staff must approve the shortened run time.
- The compounds must not coelute.
- Perform initial calibration and daily mid-point calibration check and analyze LCS and samples under the same conditions as the shorter GC run-time.
- Quantitate using the average RF from the initial calibration utilizing the shorter run-time.
- Perform a normal run-time analysis whenever peaks are detected within retention time windows where coelution, as indicated by the calibration chromatograms, is likely.

Analyze an LCS as the last GC run of the day. Include the same compounds used in the daily mid-point calibration check analysis. Attain RF for each compound within 80% to 120% of the average RF from the initial calibration. If the RF is not within these limits, all test results generated from the same day will be considered questionable and may be rejected by the project chemist.

Analyze an LCS at the detection limit concentration instead of the mid-point concentration if all samples from same day of analysis show non-detect (ND) results. The recovery for each compound must be at least 50%. If it is less than 50%, all the ND results of the samples become questionable.

Analyze on-site the evaluation check sample as part of the QA/QC procedures when presented with such a check sample by chemistry staff. Provide preliminary results on-site.

If the results show that the soil gas analyzer has problems with analysis, all the results generated during the same day may be rejected. Correct all problems before any more samples are analyzed.

Unannounced, on-site inspection by project chemist is routine. Provide upon request hard copies of the complete laboratory data, including raw data for initial calibration, daily mid-point check, LCS and blank results. Failure to allow such inspection or to present these records or field data may result in rejection of all sample results. The soil gas analyzer must understand the instruments, analytical and QA/QC procedures and must be capable of responding to reasonable inquiries.

Maintain the following records in the mobile laboratory:

- A hard copy record of calibration standards and LCS with the following information:
 - Date of receipt
 - Name of supplier

- Lot number
 - Date of preparation for intermediate standards (dilution from the stock or concentrated solution from supplier)
 - ID number or other identification data
 - Name of person who performed the dilution
 - Volume of concentrated solution taken for dilution
 - Final volume after dilution
 - Calculated concentration after dilution
- A hard copy of each initial calibration for each instrument used for the past few months
 - The laboratory SOPs

Report all sample test results and QA/QC data using the reporting formats in the project work plan. Compounds may be listed by retention time or in alphabetical order. Include in the table of sample results all compounds in the analyte list. Report unidentified or tentatively identified peaks. Submit upon request all data in electronic format and raw data, including the chromatograms. Identify the source(s) of the contaminants detected in the investigation, as indicated by the data.

3.5.1.4 Analytical Data Reporting

Report the following for all calibration standards, LCS and environmental samples:

- Site name
- Laboratory name
- Date of analysis
- Name of analyst
- Instrument identification
- Normal injection volume
- Injection time
- Any special analytical conditions/remark

Provide additional information, as specified, for different types of analyses. Tabulate and present in a clear legible format all information according to the following groupings:

- Initial calibration
 - Source of standard
 - Detector for quantitation

- Retention time
 - Standard mass of concentration
 - Peak area
 - Response factor (RF)
 - Average response factor (RF_{ave})
 - Standard deviation (Sd_{n-1}) of RF
 - Percent relative standard deviation (% RSD), *i.e.*, $(SD_{n-1})/RF_{ave} \times 100$ (%)
 - Acceptable range of %RSD
- Daily calibration check sample
 - Source of standard
 - Detector
 - Retention time
 - Standard mass or concentration
 - Peak area
 - Response factor (RF)
 - percent difference between RF and Rf_{ave} from initial calibration (%DIFF)
 - Acceptable range of %DIFF
- LCS. Same format as daily calibration
- Environmental sample
 - Sample identification
 - Sampling depth
 - Purge volume
 - Vacuum pressure
 - Sampling time
 - Injection time
 - Injection volume
 - Dilution factor (or concentration factor if trap is used)
 - Detector for quantitation
 - Retention time
 - Peak area
 - Concentration in $\mu\text{g/L}$
 - Sample temperature and pressure (if gas sample is collected)
 - Total number of peaks found by each detector
 - Unidentified peaks and/or other analytical remarks
- Surrogate and second column confirmation

- Mark retention time and compound name on:
 - o second column chromatogram of standard
 - o second column chromatogram of confirmation sample

Discuss the method(s) to be used for data interpolation (contouring). Provide isoconcentration maps for each VOC detected, total chlorinated VOCs, total aromatic hydrocarbons, and petroleum-based hydrocarbons for each sampling depth, as applicable. Provide cross-section(s) depicting the geology and changes in contaminant concentration with depth, as justified by the data.

3.5.2 Quality Control Requirements for Off-Site Analysis

EPA Method TO-15 GC/MS full scan and SIM operation is commonly used for the offsite analysis of soil gas samples. Use of the method will include following the operation and calibration procedures described in the EPA Method. The method uses a sorbent/thermal desorption and or cryotrapping system with a high-resolution capillary column to analyze for VOCs using full scan GC/MS. This method can be used for many VOCs including polar organics, since no dryer is used. The method can measure most compounds down to 0.2 ppbV or less.

Samples are analyzed on an HP 5890 Series II GC and HP 5971 MSD quadrapole MS detector. A 1.0 ml to 200 mL gas sample is loaded from the air sampling canister or bag onto the freezeout loop. A gas phase internal standard mixture is injected with each sample prior to sample loading. The freezeout loop is constructed of 1/8-inch by 8-inch nickel tubing packed with glass beads and is immersed in liquid oxygen while the sample is drawn through the loop using a vacuum pump connected to a mass flow controller adjusted to a flow of 50 ml/min. After the sample is trapped, it is thermally desorbed at 150° C using an electric heater and is cryofocussed onto the beginning of a 0.32 mm ID deactivated fused silica capillary column. The cryofocussed loop is then warmed and the compounds are injected onto a 60 meter, DB-5, 0.25 mm ID fused silica capillary column in the GC. The GC is temperature programmed from -10° C to 220° C at a ramp rate of 13° C/min. As the column is heated, the compounds elute off the column and enter the MS. The MS is scanned from 45 to 300 AMU with a scan rate of 1 to 2 seconds for the Full Scan mode of operation. The GC/MS is tuned and operated according to the specifications outlined in the EPA method for VOC compounds in ambient air, and EPA Method 8260 in the SW 846 Test Methods. Compounds are calibrated by the external standard procedure using NIST traceable air standards as described below. The relative percent difference (RPD) of a duplicate

pair is less than 30% at 10 ppbV and the average MDL is approximately 0.1 ppbV for most compounds at a 500 ml load volume.

The standards used for the routine analytical tests are commercial NBS/NIST traceable gas standards normally ordered at a concentration of 2 to 10 ppmv. Commercial standards are available for the TO-14 GC/MS list and special in-house standards are prepared for those compounds where commercial standards are not readily available.

The GC/MS compounds are calibrated by using a dilution of the NBS/NIST traceable standard. The initial calibration curve consists of three to five calibration points. The continuing calibration consists of one point for the GC/MS Full Scan. The response factors for the initial calibration curve are to be within 30% RSD. If the response factor for the daily standard is more than 30% RPD from the average response factor of the initial calibration a new calibration curve is prepared. Standards are prepared by using a gas dilution system on the GC or by making static dilutions to atmospheric levels. The gas dilution system is constructed from an eight-port gas sampling valve with various size sample loops. The loops are filled with the standard and flushed with “zero air.” The gas dilution system is used for the daily instrument calibration. The concentration of the individual target compounds is determined using the initial calibration curve response factors.

3.6 Quality Assurance Split Samples

Discuss soil boring locations with project staff. Locate borings and sampling depths based upon all available information including soil gas survey test results. Conduct QA according to the local regulatory agency’s standards, if any.

3.7 Soil Vapor Monitoring Well/Vertical Profiling

Depending on the objectives of the survey, soil vapor monitoring wells may be installed in areas where significant VOC concentrations were identified during a soil vapor investigation. The objectives of vertical profiling typically are to: 1) assess the vertical distribution of VOCs in the vapor phase within the unsaturated zone, 2) determine the spatial pattern of vapor phase soil contamination at different depths within the unsaturated zone, 3) identify migration pathways at depth along which VOCs may have migrated from sources, and 4) serve as discrete monitoring points to evaluate the efficiency of a cleanup action or some other long term monitoring. Soil vapor monitoring wells offer the opportunity to resample as many times as necessary to monitor soil vapor changes over time.

Install nested, cluster, and/or multi-port vapor monitoring wells to obtain discrete multi-depth soil vapor data in the unsaturated zone. Provide a schematic diagram of the well design and a cross-section of the site showing the major lithologic units and zones for vapor monitoring.

Collect undisturbed soil samples if fine-grained soils are encountered during drilling of the boring for the probes. Due to air-stripping effect, VOC analysis of soil sample is not acceptable if air drilling method is used.

Use available information (*e.g.*, geologic log, organic vapor concentration reading) to select appropriate depths for vapor monitoring. Install probes at depths with elevated vapor readings (headspace) and/or slightly above fine-grained soils which can retard the migration of VOCs. The deepest probe should be considered for installation above the capillary fringe.

Consider installing nested vapor probes in the annular space of the groundwater monitoring well to serve as a dual-purpose well if both vapor and groundwater monitoring are required. This design saves costs by installing vapor and groundwater monitoring wells in a single borehole.

Use small diameter (*e.g.*, $\leq 1/4$ -inch) continuous tubing attached from the vapor probe to the ground surface to minimize purge volume.

Design and construction of the vapor wells should consider the objectives of the wells. For example, those to serve as long-term monitoring points to evaluate the efficiency of a cleanup action and soil vapor changes over time should have the surface protection to maintain their integrity through time. Protect the tubing from being damaged or clogged by subsurface soil materials especially in deep installations (*e.g.*, placing inside a polyvinyl chloride [PVC] casing) or consider using 1/2-inch PVC pipe in place of the tubing. If tubing is used, consider attaching a weight at the probe tip and/or attaching the tubing onto a supporting pipe or rod to ensure that the probe tip remains in-place during installation.

Properly cap the top end of each tubing/pipe (*e.g.*, control valve) and label each tubing/pipe with the correct sampling depth.

Attach the bottom-end of the tubing to an appropriate vapor probe (*e.g.*, PVC screen, stainless steel wire screen, stainless steel probe, or brass elbow, etc.). Ensure that the connection between the tubing and the vapor probe is tight to prevent leakage.

Place the filter pack (*e.g.*, sand or pea gravel) around each vapor probe and isolate each monitoring zone with bentonite seals. Use an appropriate method (*e.g.*, tremie method) to avoid bridging or segregation during placement of the filter packs and bentonite seals.

Extend the filter pack to a sufficient distance above the probe to allow for settling of backfill materials. In general, the filter pack should not exceed 3 feet in thickness. In deep borings, the filter pack should extend about 4 feet above the probe to allow for settling of backfill materials and to reduce the potential for the bentonite seal settling around the probe.

Consider placing fine sand above the filter pack to prevent the bentonite seal from entering the filter pack. Place a minimum of 2 feet thick bentonite seal above and below the filter pack. Allow sufficient time (*e.g.*, 1/2 to 1 hour) for bentonite seal to properly hydrate before placing filter pack or cement-based sealing materials. Prevent infiltration of surface runoff and unauthorized access (*e.g.*, use a locking subsurface utility vault).

Specify the schedule for sampling the vapor probes. In general, soil vapor monitoring is required a minimum of 1 and 2 months after installation. If VOC stripping by air drilling methods is of concern, soil vapor monitoring should be delayed by up to two to four months following well completion to allow vapor concentrations to stabilize. The regulatory agency may require a different sampling schedule and additional sampling based upon site conditions and test results.

Specify the procedures to properly decommission vapor wells that are no longer needed. The decommissioning activity should achieve an effective and long-term seal of subsurface geologic materials and prevent cross contamination in the subsurface.

4.0 REFERENCES

Basic Remediation Company (BRC) and Environmental Resources Management (ERM). 2008. BRC Quality Assurance Project Plan. BMI Common Areas, Clark County, Nevada. April.

California DHS Direct Push Sampling SOP-3, Revision 1.1, September 29, 1998.