



Soil-Gas Measurement

Introduction

The term “soil-gas” refers to the atmosphere present in soil pore spaces. Volatile compounds introduced into the subsurface can be present in the gas phase or more commonly, can undergo a transition from a liquid or sorbed phase (pure product, dissolved, or adsorbed to soil) to become part of the soil atmosphere. Techniques for measuring soil gases were developed early in this century for agricultural studies and for petroleum exploration. Within the last 5 years, soil-gas measurement has become an accepted environmental site screening tool. The technique is rapid, low cost, and provides a high yield of information when carefully applied. Because it is an indirect measure of underlying contamination and because of the potential for false negative results, the technique should be used only for site screening and not for confirmation.

The fate and transport of contaminants and their occurrence and detectability in the soil gases are very compound- and site-specific. Soil-gas technology is most effective in detecting compounds having low molecular weights, high vapor pressures, and low aqueous solubilities. These compounds volatilize readily as a result of their favorable gas/liquid partition coefficients. Once in the gas phase, volatile compounds diffuse vertically and horizontally through the soil toward zones of lower concentration.

Degradation processes (e.g., oxidation or reduction) can eliminate or transform contaminants in the soil atmosphere. The susceptibility of a contaminant to degradation is influenced by such factors as soil moisture content, pH, redox potential, and the presence of microorganisms that can degrade the compound. Biological degradation by microorganisms has been shown to be an important and relatively rapid means of contaminant loss for the non-chlorinated hydrocarbons and mixtures. Other site-specific characteristics affecting results are: soil type, air-filled porosity, depth to the source, barriers to vapor transport, and hydrogeology. Because site-specific factors influence contaminant concentrations detected in the soil gases, a quantitative correlation between soil-gas concentrations and underlying contamination is difficult to generalize.

Applications

Soil-gas surveys can be used to:

- identify contaminants and relative concentrations
- identify sources; indicate extent of contamination
- monitor the progress of cleanups
- guide placement of subsequent confirmatory samples (soil borings, monitoring wells)
- monitor at fixed vapor wells (long-term monitoring)
- detect leaks through use of tracer compounds

Typical primary sources include surface spills, leaking underground storage tanks, pipes, trenches, dry wells, or landfills. Contaminants from such sources frequently reach the water table, causing the groundwater to become a source of contamination to downgradient sites. The nature of the source will influence the vertical and horizontal dispersion of gas-phase contaminant vapors.

Contaminants detectable in soil gases include many common chlorinated solvents and the lighter fractions of petroleum products, substances that are widespread environmental contaminants. Of the 25 most commonly encountered contaminants at Superfund sites, 15 are amenable to detection by soil-gas sampling. Inorganic contaminants that can be detected by soil-gas sampling include radon, mercury, and hydrogen sulfide.

Selected Compounds Detectable in Soil Gases

Aromatic hydrocarbons: Benzenes, toluene, xylenes, naphthalene

Aliphatic hydrocarbons: C₁-C₁₀ (e.g., methane, butane, pentane, iso-octane cyclohexane)

Mixtures: Gasoline, JP-4

Chlorinated hydrocarbons: Chloromethanes (e.g., chloroform, carbon tetrachloride); chloroethanes; chloroethenes (e.g., vinyl chloride, di-, tri-, and perchloroethene)

Other: CO₂, CS₂, H₂S, NO_x, radon, mercury compounds

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The Technique

Soil-gas samples can be collected by active or passive methods. For active sampling, a probe is driven into the ground, withdrawn several inches, and soil gases are pumped from the subsurface into a sample container (e.g., evacuated canister, tube, vial glass bulb, gas sample bag, syringe) or through a sorbent medium.

Typically, active soil gas systems require the removal of several hundreds of mLs of soil gas during line purging and sample collection which may lead to the lack of correlation between these measurements and collected soil samples. A new “micro-purge” system in which very small quantities of gas are collected (several mLs) is currently being developed and tested with promising results.

For passive sampling, a sampler containing a sorbent with an affinity for the target analytes is placed in the ground for a period of time, and contaminants are collected by virtue of diffusion and adsorption processes. Passive sorbers have been shown to collect and identify a greater number of volatile organic compounds in soils than the active soil gas collection methods collected at the same site. Passive vapor sorbers are also capable of collecting some of the low molecular weight polycyclic aromatic hydrocarbons (PAHs) present at the site. After exposure, the passive sampler is transported to a laboratory for analysis.

The most commonly used technique for analyzing soil-gas samples is gas chromatography (GC) in combination with a detector appropriate to the target analytes. Analyses can be done on- or off-site. Soil-gas samples can also be screened in the field using organic vapor detectors, which provide results expressed as total hydrocarbon concentration relative to a calibration standard.

The design of a soil-gas survey depends on the data required (e.g., identifying and quantifying specific compounds vs. measuring total hydrocarbon concentration) and the nature of the contamination. A feasibility study is recommended whenever possible, particularly for sites where little information is available. Such a study can be valuable in verifying the effectiveness of the method at the site, selecting the appropriate sampling and analytical methods, choosing the best sampling depth, and optimizing other operational details. Because soil-gas surveying is an intrusive technique, precautions must be taken to avoid buried utility lines, tanks, or other objects.

Data Quality Objectives and QA/QC

Because soil-gas results provide an indirect measure of primary contamination, data quality objectives (DQOs) for soil-gas surveys and the QA required need not be as strict as those for confirmatory sampling and analysis of soil or ground water. However, because most soil-gas survey objectives require comparison of data among points to determine patterns of relative concentration, the investigator must be able to determine whether differences in value are real or merely due to poor method precision. Consistency in procedures is essential, as are collection and analysis of replicate and blank samples and regular checks of instrument calibration. Materials that come into contact with samples should be inert and easy to decontaminate.

Summary

Soil-gas measurement can be an effective method for determining the source and extent of volatile contaminants in the subsurface. Because of the many site- and compound-specific factors that can influence results, soil-gas measurement should be done only by experienced field investigators. With proper QA and judicious data interpretation, this technique is a useful, low-cost site screening tool.

Summary of Advantages and Limitations of Soil-Gas Measurement

Advantages

- Rapid
- Easy to do
- Low cost
- Real-time results
- Minimal disturbance to site

Limitations

- Indirect measurement
- The concentrations are only relative and cannot be related to a weight or volume of soil
- The technique cannot collect surface or near-surface samples
- Interferences (false negatives are a problem)
- Application limited to high volatility/low solubility compounds

Soil-Gas Measurement

Reference

Guidance Document for Soil-Gas Surveying, Prepared under EPA EMSL-LV Contract No. 68-03-3245 by C.L. Mayer, Lockheed Engineering and Sciences Company, Las Vegas, NV, in press.

For Further Information

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