

## Groundwater Plume, Source and Risk Identification Using Passive Soil Gas

**Joseph E. Odencrantz** (joe.odencrantz@beacon-usa.com) and Harry O'Neill  
(Beacon Environmental Services, Bel Air, Maryland, USA)

**ABSTRACT:** The results from sixty passive soil gas (PSG) samplers placed at a grain silo and mixed-use industrial facility with a known chlorinated solvent release aided with the rapid investigation time-schedule. The samplers were used to determine potential sources, plume extent and vapor risks in areas beyond the previous discrete soil sampling and permanent groundwater monitoring well network. Passive soil gas testing involves the installation of sorbents in a one-inch diameter hole, three-foot deep and the samplers are then placed at a depth of approximately six inches. The samplers were installed in grid pattern at a spacing of 25 to 50 feet at the site and across the street. The depth to groundwater was approximately ten to twelve feet below grade.

The installation of numerous monitoring wells in areas where Trichloroethene (TCE) and Tetrachloroethene (PCE) were discovered using the PSG samplers revealed that there were indeed two separate sources and groundwater plumes at the site, which became co-mingled downgradient. In this previously uninvestigated portion of the site, TCE was found at 600 ng in a PSG sampler and a permanent groundwater monitoring well was subsequently installed in that vicinity. The groundwater concentration of TCE in that well was 400 ug/L. The PSG sampling network was wide enough to identify the approximate size of this new plume. In a region approximately 75 feet downgradient from the previously discussed location, 294 ng of TCE was discovered in a PSG sampler. The groundwater monitoring well installed at this location revealed 110 ug/L of TCE. Further yet, a cross-gradient PSG sampler revealed 107 ng of TCE and the groundwater monitoring well placed at the location revealed 74 ug/L of TCE. The PSG investigation was completed from start to finish in a two-week period of time. The paper will focus on the importance of PSG sampling for source identification, groundwater investigation and complying with regulatory directives for the assessment of the vapor intrusion pathway for risk assessment purposes.

### INTRODUCTION

The use of passive soil gas (PSG) sampling for soil and groundwater source identification and assessment of spatial variability is an effective tool for site investigation and remediation. PSG sampling and analytical methods are used to target a broad range of volatile and semi-volatile organic compounds (VOCs and SVOCs), even when present at low concentrations. It is necessary to use state-of-the-art sampling and analytical procedures to provide the foundations for this highly sensitive technology to identify trace levels of compounds present in the vapor phase. The purpose of the work described in this paper was to determine potential sources, plume extent and vapor risks in areas beyond the previous discrete soil sampling and permanent groundwater monitoring well network at a site in the Western United States of America.

Small, easy-to-carry field kits containing detailed instructions and the requested number of field samples are provided so a project manager can have the samplers installed by local personnel at a convenient schedule. To install a PSG Sampler, a 3/4" diameter hole is made to a depth of four inches using a hammer and a metal stake provided in the kit. When applicable, a

hammer drill, slide hammer, or other comparable equipment can be used to create a 1/2" or larger diameter hole to a three-foot depth. In either case, the PSG sampler (which contains two sets of hydrophobic adsorbent cartridges) need only be installed in the upper portion of the hole. For locations covered by asphalt or concrete surfacing, a 1 1/4" to 1 1/2" diameter hole is drilled through the surfacing to the underlying soils, and the hole is sleeved with a sanitized pipe provided in the kit. After the Sampler is installed inside the pipe, the hole is patched with an aluminum foil plug and a thin concrete patch to protect the sampler. The samplers are exposed to subsurface gas for approximately three to 14 days, depending on the objectives of the investigation and the compound concentrations that are expected to be present at the site. Following the exposure period, the Samplers are retrieved and shipped to BEACON's laboratory for analysis. A trip blank, which remains with the other PSG samples during preparation, shipment, and storage, is included with each batch of up to 40 field samples.

The adsorbent cartridges used by Beacon Environmental are hydrophobic, which allows the samplers to be effective even in water-saturated conditions. Extensive empirical evidence, which is supported by a government study, has proven that hydrophobic adsorbents work perfectly well in high moisture conditions and should not be encased by a hydrophobic membrane (The Marines Project, 2002). The use of surrogates and internal standards by the laboratory during the analysis of samples verifies that moisture is not a problem during the analysis of the samples. Therefore, water does not adversely impact adsorption of compounds in the field or the analysis of the samplers at the laboratory.

Soil gas samples are analyzed by the laboratory using gas chromatography/mass spectrometry (GC/MS) instrumentation, following modified EPA Method 8260B procedures. Samples for this project were analyzed for a broad range of organic compounds from vinyl chloride to naphthalene. Analytical results were based on a five-point initial calibration, and internal standards and surrogates were included with each sample analysis. In addition, a BFB tune was performed daily and a method blank was run following the daily calibration. The laboratory's reported quantitation level (RQL) for each of the targeted compounds is 25 nanograms (ng), however, the actual detection limits are even lower. The sampler design includes two sets of adsorbent cartridges, which allows for confirmatory or duplicate analysis from any selected location.

## **FIELD SAMPLING PROGRAM**

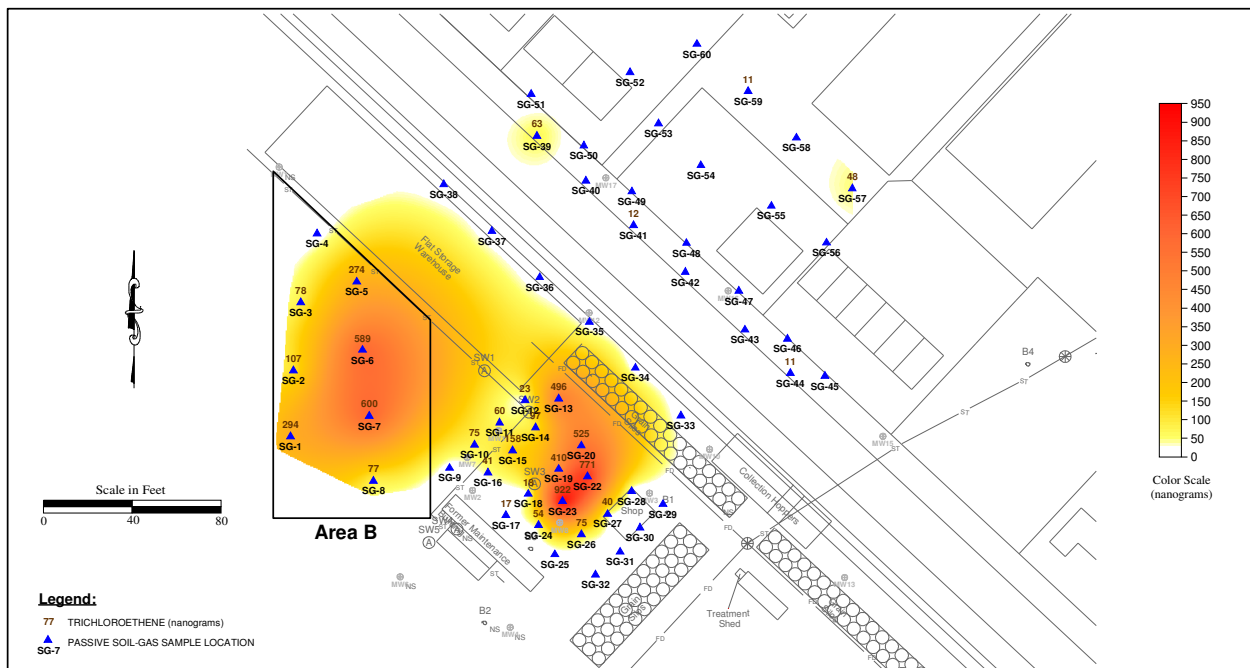
It has been established in numerous guidance documents that passive soil gas sampling is a valuable tool for site assessment (New Jersey Vapor Intrusion Guidance (2005) and Interstate Technology and Regulatory Council. (2007)). An environmental consulting company (confidential) contracted Beacon Environmental Services, Inc. to install sixty PSG samplers across a site in the western United States in June 2005 placed at a depth of six inches and the holes were all drilled to a depth of three feet (one-inch diameter from surface to one-foot depth and one-half inch diameter from one to three feet in depth). The samplers were installed in a grid pattern at a spacing of 25 to 50 feet at the site. The samplers were left in the subsurface for eleven days and were retrieved in late June 2005. Twenty-six of the locations were drilled through native materials (sand/gravel) and thirty-six were through asphalt.

After the samplers were retrieved, the results were reported to the client three days after the samplers arrived at the laboratory. The final report on the project was prepared and returned to the client two weeks after the data was reported. The primary compound of interest at the site is

trichloroethylene (TCE) and this paper will be limited to examining the spatial distribution of TCE.

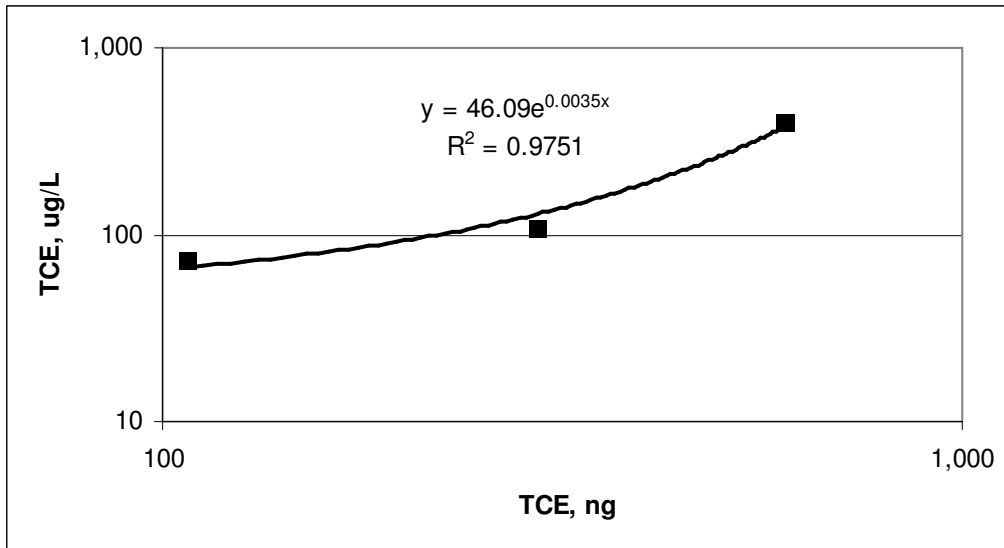
## RESULTS/DISCUSSION

An important goal in the PSG sampling program was to delineate the spatial distribution of soil gas to determine the areal extent of the groundwater in the area marked as Area B on Figure 1. The results of the PSG survey for TCE are shown in Figure 1 and there appears to be two distinct source areas: one within Area B and the other at SG-23 east of Area B. The extent of TCE impacts in the soil gas is well-defined and the groundwater flow direction is southwest. The depth to groundwater was approximately ten to twelve feet below grade. In this previously uninvestigated portion of the site (Area B), TCE was found at 600 ng in a PSG sampler and a permanent groundwater monitoring well was subsequently installed in that vicinity.



**FIGURE 1. Passive Soil Gas Results for TCE and Depiction of Area B.**

A total of three groundwater monitoring wells were installed in close proximity to three PSG locales within Area B (shown in Figure 1). As previously stated, one of the primary purposes of the PSG survey was to guide the placement of permanent groundwater monitoring wells in that previously uninvestigated area of the site. The monitoring wells were installed several months after the passive soil gas survey was performed. Beacon Environmental performed an analysis of the PSG masses to the measured groundwater concentrations from the permanent groundwater monitoring wells. The results of this analysis are shown in Figure 2 along with an exponential line of best fit, equation and correlation coefficient. The correlation coefficient means that 97.51 percent of the variability is accounted for by the equation that describes the line of best fit.



**FIGURE 2. Correlation of PSG results from SG-1, 2 and 7 with nearby groundwater monitoring wells.**

The correlation between the PSG masses and the groundwater concentrations for TCE are excellent for the three sample pairs. The equation can be used to estimate the groundwater concentration at other points in the PSG grid. An illustration of using the exponential line-of-best fit is shown in Table 1 for the maximum PSG location (SG-23)

**Table 1. Example application of correlation of TCE results for passive soil gas mass and groundwater concentrations for the maximum soil gas encountered at the site. The Delta column provides the differences between the actual and estimated groundwater concentrations by applying the site-specific correlation equation.**

<u>Locale</u>	<u>PSG, ng</u>	<u>Estimated GW, ug/L</u>	<u>Actual GW, ug/L</u>	<u>Delta</u>
SG-7	600	376	400	-23.6
SG-1	294	129	110	19.0
SG-2	107	67	74	-7.0
SG-23	922	1,162	Not Sampled	

The table illustrates the application of the correlation between PSG results with permanent groundwater monitoring wells that were installed shortly after the PSG survey was performed. The estimated concentration of TCE at a groundwater well that is installed in close proximity to SG-23 is 1,162 ug/L. If there are risk-based cleanup levels established at the site for groundwater that would trigger remedial measures, then the equation can be used to establish regions of high risk that should be verified with a permanent groundwater well. Although the inherent assumption with applying the correlation is there are similar soil and groundwater sources with respect to the soil gas mass that was measured with the PSG samplers. In other words, if all the soil gas mass in the correlations were from TCE off-gassing from the

groundwater plume, then the same assumption would apply at all the locations where the correlation was applied. If there was a recent release in soil, as an example, the soil gas and groundwater relationship should be used with caution.

## **CONCLUSIONS**

The following summarize the research completed in the study and are not in any particular order of importance.

- The results of a PSG survey resulted in the discovery of an additional groundwater source and a groundwater plume whose areal extent was determined with the results of the survey.
- Follow-up groundwater monitoring wells were installed in Area B to ascertain the results of the PSG survey. Three groundwater monitoring wells were placed near the limits of the PSG survey and the results revealed TCE in the groundwater as indicated by the PSG survey.
- An exponential correlation was established between the PSG results and the groundwater wells for TCE and had a correlation coefficient of 0.98.
- The established correlation was used to estimate the groundwater concentration in the source area and to delineate the extent of significant groundwater risk.

## **ACKNOWLEDGEMENTS**

The authors wish to express their thanks to Mr. Ryan Schneider and Mr. Steven Thornley of Beacon Environmental Services, Inc. for assisting with the implementation of the field testing.

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