Proceedings of the Annual International Conference on Soils, Sediments, Water and Energy

Volume 16 Article 10

1-1-2011

Vapor Intrusion Assessment – A Comparative Analysis of Subsurface Vapor Sampling Methods

Laurent C. Levy
Sanborn, Head & Associates, Inc., llevy@sanbornhead.com

David Shea
Sanborn, Head & Associates, Inc., dshea@sanbornhead.com

Daniel B. Carr
Sanborn, Head & Associates, Inc., dcarr@sanbornhead.com

Follow this and additional works at: http://scholarworks.umass.edu/soilsproceedings

Recommended Citation

Levy, Laurent C.; Shea, David; and Carr, Daniel B. (2011) "Vapor Intrusion Assessment – A Comparative Analysis of Subsurface Vapor Sampling Methods," *Proceedings of the Annual International Conference on Soils, Sediments, Water and Energy*: Vol. 16, Article 10.
Available at: http://scholarworks.umass.edu/soilsproceedings/vol16/iss1/10

This Conference Proceeding is brought to you for free and open access by ScholarWorks@UMass Amherst. It has been accepted for inclusion in Proceedings of the Annual International Conference on Soils, Sediments, Water and Energy by an authorized administrator of ScholarWorks@UMass Amherst. For more information, please contact scholarworks@library.umass.edu.

Part VI: Vapor Intrusion

Chapter 9

VAPOR INTRUSION ASSESSMENT – A COMPARATIVE ANALYSIS OF SUBSURFACE VAPOR SAMPLING METHODS

Laurent C. Levy, Ph.D., P.E.[1§], David Shea, P.E.[2], Daniel B. Carr, P.E., P.G.[3]
[1]*Sanborn, Head & Associates, Inc., 1 Technology Park Drive, Westford, MA 01886,* [2]*Sanborn, Head & Associates, Inc., 20 Foundry Street, Concord, NH 03301,* [3]*Sanborn, Head & Associates, Inc., 95 High Street, Portland, ME, 04101*

ABSTRACT

The paper and presentation focus on subsurface vapor data collected as part of a vapor intrusion assessment where tetrachlorothene (PCE) is the principal volatile organic compound of interest. In support of this assessment, we have conducted soil gas sampling and analysis to aid in identifying and delineating the presence of PCE in soil fill and residual silt-clay saprolite soils derived from in-place weathering of siltstone bedrock.

During the assessment, we collected soil gas samples from temporary points, which were advanced using hand-operated Geoprobe® direct push rods to depths ranging from 2 to 7 feet below ground surface. Grab samples were collected using the Geoprobe® post-run tubing (PRT) system into evacuated glass vials, which were later analyzed off-site.

Following vial collection and retrieval of the Geoprobe® rods, several sampling locations were completed with permanent soil gas monitoring implants constructed using stainless steel screen and tubing, and backfilled using a glass bead pack overlaid by bentonite chips. Several weeks later, we collected soil gas samples from the monitoring implants using Summa canisters.

[§] Corresponding Author: Laurent C. Levy, Ph.D., P.E., Sanborn, Head & Associates, Inc., 1 Technology Park Drive, Westford, MA 01886, Tel: 978-392-0900, Email: llevy@sanbornhead.com

Despite the differences between sampling techniques, time and duration of sampling, and volume of the samples, PCE concentrations measured in vial and canister samples are remarkably comparable, generally exhibiting order of magnitude agreement. With some limitations, the results suggest that vial sampling can be used as a complementary method to conduct subsurface vapor surveys.

Canister samples collected from the vapor implants on a bimonthly basis illustrate the effects of seasonal variability and underline the importance of monitoring over a period of time under different seasonal conditions to support a rigorous assessment of vapor intrusion potential.

Keywords: vapor intrusion, soil gas, tetrachloroethene, sampling, canister, vial, implant

1. INTRODUCTION

In this paper, we compare results from soil gas samples collected as part of a vapor intrusion assessment where tetrachlorothene (PCE) is the principal volatile organic compound (VOC) of interest. In support of this assessment, we collected soil gas samples from temporary probes using pre-evacuated glass vials; and from permanent implants, which were constructed following retrieval of the temporary probes and sampled using 1-liter Summa canisters. For perspective, we also review vapor concentration changes over time at the permanent implants, as well as the precision of data associated with each sampling method through the collection of field replicate samples. We show that despite their limited sensitivity relative to canister samples, vial samples can be a cost effective and reliable method to obtain subsurface survey data.

2. MATERIALS AND METHODS

2.1 Sampling from Temporary Probes Using Glass Vials

Temporary probes were driven into the saprolite at multiple locations to depths ranging from 2 to 7 feet (ft) below ground surface and sampled using a Geoprobe® post run tubing (PRT) system (Geoprobe® Systems, 2010). The probe installation procedure, which is shown on Figure 1, consisted of breaking the asphalt (where present) using a hammer drill; and manually driving a series of 1-inch (in) diameter Geoprobe® direct-push stainless steel hollow rods fitted with an expendable stainless steel drive point. Upon reaching sampling depth, field personnel inserted Teflon® tubing and a PRT adapter into the rods and threaded

the adapter to the PRT point holder (see Figure 1). The rods were then retracted by approximately 6 inches to expose a sampling window between the drive point and the PRT point holder. To limit potential for ground surface leakage during vapor sampling, the annular space around the rods was sealed at ground surface with hydrated bentonite. Between sampling locations, the probe's stainless steel parts were cleaned using Liquinox® detergent and potable water. Teflon® tubing was discarded after one use.

Soil gas samples were collected from the temporary probes into 22-milliliter (ml) pre-evacuated glass vials provided by Microseeps, Inc. of Pittsburgh, Pennsylvania. The soil gas sampling procedure consisted of first purging the equivalent of one volume of Teflon® sampling line using a disposable syringe fitted with two stopcock valves. Following purge, about 40 ml of sample was withdrawn from the probe and injected into a vial by piercing its septum with a needle and pressurizing the vial with the sample. The procedure was repeated on a second vial. Between sampling locations, syringes, needles, and stopcock valves were discarded.

The vials were shipped to Microseeps for analysis of PCE and its common breakdown compounds by gas chromatography/electron capture detector (GC/ECD). For quality control purposes, we also prepared blind duplicate samples, which were obtained by collecting a second pair of vials at selected sampling locations; and equipment blanks, which were prepared by collecting and injecting ambient air into a pair of vials using a single-use syringe, stopcock valve, and needle.

2.2 Sampling from Permanent Probes Using Canisters

Following vial collection and retrieval of the stainless steel rods, twelve of the temporary probes (with depths ranging from 3.4 to 5 ft) were finished with permanent probes (referred to as soil gas monitoring implants) by lowering a 6-in long, ¼-in diameter stainless steel screen connected to ¼-in diameter stainless steel tubing in each exploration and threading the screen to the remaining drive point at the bottom of the exploration (see Figure 2). Glass beads were poured around the screen as filter pack to approximately 6 in above the top of the screen. The remainder of each borehole was filled with hydrated bentonite chips to within approximately 6 inches of the ground surface where a road box was installed and set in concrete. Leak testing was later conducted with helium tracer gas to confirm the integrity of the installation.

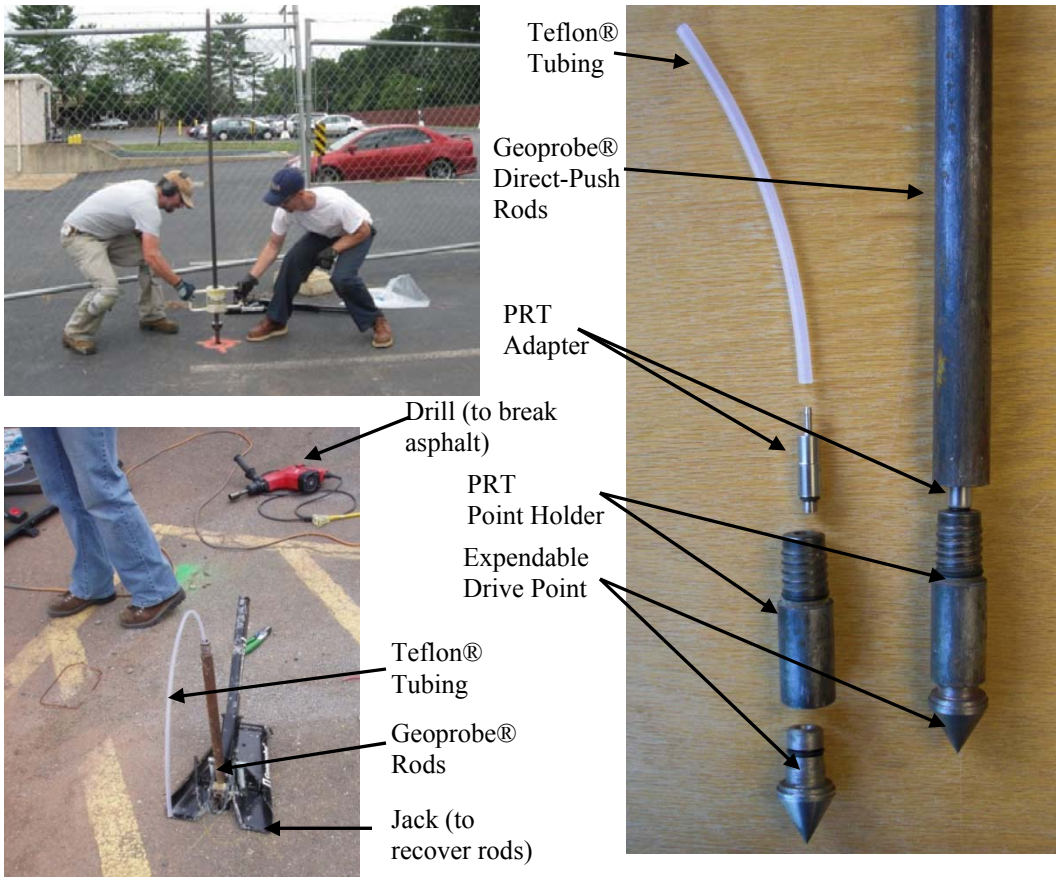

Figure 1. Installation of temporary soil gas sampling probe.

About a month following implant installation, we collected soil gas samples using 1-liter, stainless-steel, pre-evacuated Summa canisters and 1-hour capillary column flow controllers (Air Toxics Ltd., 2010) provided by Air Toxics Ltd. of Folsom, California ATL. The canisters were individually certified clean for the list of target compounds. The typical sampling procedure consisted of connecting a short section of Teflon® tubing to the implant using Swagelok® stainless steel compression fittings (see Figure 2); purging the implant of the equivalent of one volume (corresponding to the length of the implant and attached tubing) using a disposable syringe; connecting the canister and collecting the sample over an hour during which the canister vacuum dropped from about 30 inches of mercury (in Hg) to about 5 in Hg. The canisters were submitted for analysis of PCE and its common breakdown products by gas chromatography/mass spectrometry (GC/MS) (USEPA, 1999).

Between sampling locations, reusable sampling equipment, such as Swagelok® fittings and valves were cleaned using Liquinox® detergent and potable water. Teflon® tubing and Swagelok® ferrules were discarded after use. Flow controllers were used only once before being returned to the laboratory.

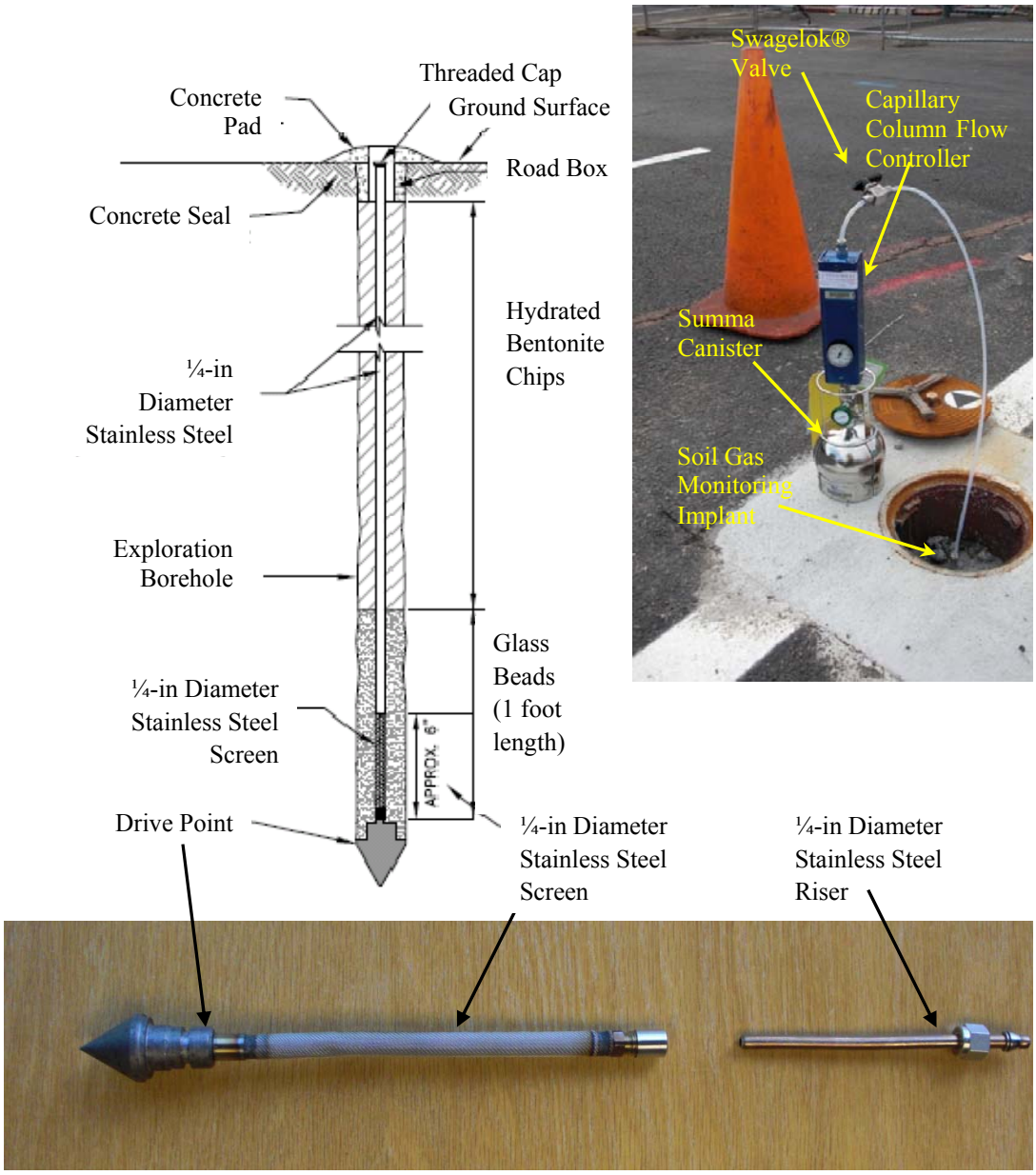

Figure 2. Installation and sampling of soil gas monitoring implant.

Blind duplicate samples were collected using pairs of canisters and flow controllers connected in parallel with a Swagelok® "T" fitting. Two-hour flow controllers were used to maintain a sample collection rate similar to that of a single canister equipped with a 1-hour flow controller. We also collected equipment blanks, which were prepared in the field by connecting a laboratory-provided canister filled with nitrogen to a regular sample canister and flow controller. The equipment blank was submitted for analysis along with the other canisters.

3. RESULTS AND DISCUSSION

3.1 Comparison of Vial and Canister Data

To compare sampling methods, we evaluated the relative percent difference (RPD) between results for a given sample analyte using the following equation:

$$RPD = \frac{|c_1 - c_2|}{(c_1 - c_2)/2} \times 100\% , \qquad (1)$$

where *RPD* is the relative percent difference and c_1 and c_2 indicate the analyte concentration in the vial sample and canister sample, respectively.

Figure 3 presents a graphic comparison of PCE analytical results associated with canister samples (along the y-axis) and vial samples (along the x-axis). As illustrated by the figure, PCE concentrations in canister samples are comparable to those obtained using vial samples. Where PCE was detected in both the vial and canister samples, agreement is typically within the same order of magnitude, as delimitated by the band representing the 100% *RPD* between sample pairs. In most instances where PCE is below the detection limit in a sample obtained using vials (about half of the 12 samples), PCE is either below detection limit in the companion canister sample or detected at a concentration comprised between the canister detection limit and the vial detection limit.

While most concentrations fall within the same order of magnitude, differences in concentration are to be expected. The samples were collected at different times and using different means. They were analyzed by two different labs using different analytical methods. The samples are also different in volume. For perspective, the vial sample contains approximately 40 ml of gas and is collected in a few seconds as a grab sample. In contrast, the canister sample is equivalent to about 800 ml of gas and is collected over an hour (flow rate of 13.3 ml per minute). Assuming that the gas comes from air-filled porosity associated

with fracturing, and considering site subsurface conditions, a canister sample may draw gas from a subsurface volume equivalent to a sphere with a radius on the order of 1 foot, while the sphere of influence of the vial sample will only extend to about a third of that radius. In practice, the gross volume of subsurface is unlikely to be spherical or regularly shaped.

3.2 Observed Seasonal Variations

In Figures 4 and 5, we present PCE concentrations recorded in bimonthly sampling of soil gas monitoring implants. Each of the selected implants was sampled 4 to 6 times over the course of about one year using the canister sampling method summarized in Section 2.2.

Figure 4 shows the range of PCE concentrations obtained for six selected implants. Each vertical bar represents the minimum, maximum and median PCE concentrations measured in canister samples during the one-year period. For perspective, the figure also shows the vial-canister data pairs presented in Figure 3. Figure 5 shows changes in PCE concentration as a function of time for three implants selected from Figure 4.

The analytical results show changes in PCE concentration by about one half to two orders of magnitude over the course of one year. Of particular interest, PCE concentrations at implant A reach several hundreds of micrograms per cubic meter ($\mu g/m^3$), even though PCE was initially below detection limits in both the vial sample and the first canister sample.

Collectively, the data presented herein suggest that one sampling event may be insufficient to properly assess VOC vapor conditions. The results also show that the difference in PCE concentrations measured in the vial sample and the initial canister sample is small relative to the change in PCE concentration observed over time at a given location.

Seasonal variations in soil gas concentrations, especially at depths close to the surface, have been reported previously (ITRC, 2007) and are attributed to changes in temperature, precipitation, and soil moisture cycling in the vadose zone. For the subject site, we believe that soil gas concentration variations in excess of one order of magnitude can be further attributed to the heterogeneous nature and low effective porosity of the fractured sedimentary rock and saprolite soil.

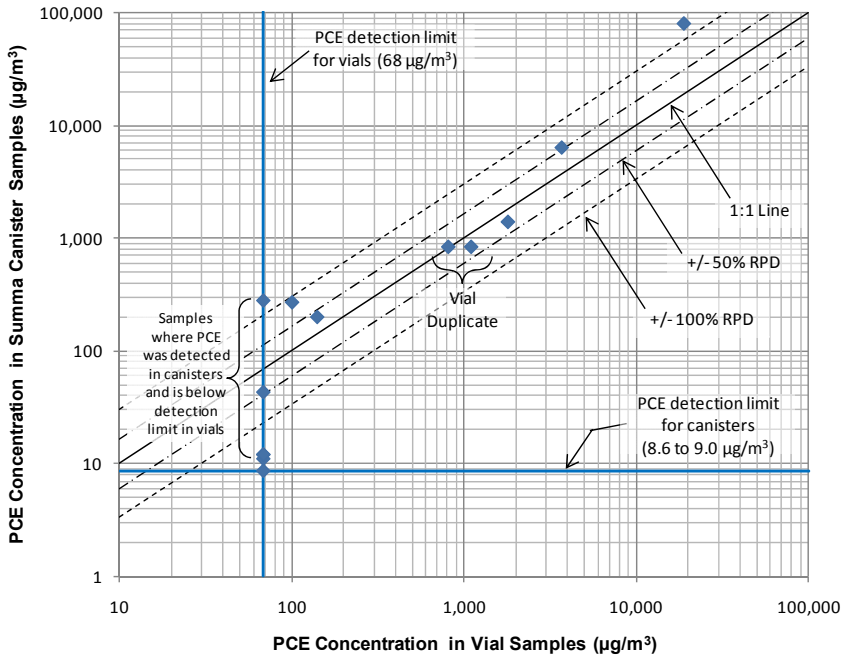

Figure 3. Comparison of PCE concentrations from vial and canister samples.

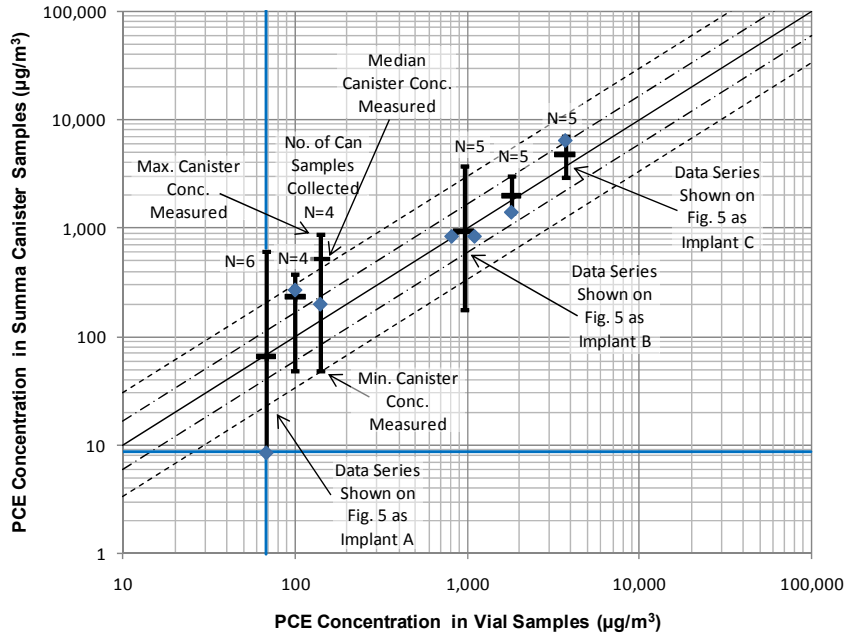

Figure 4. Range of PCE concentrations in samples collected bimonthly at selected soil gas monitoring implants.

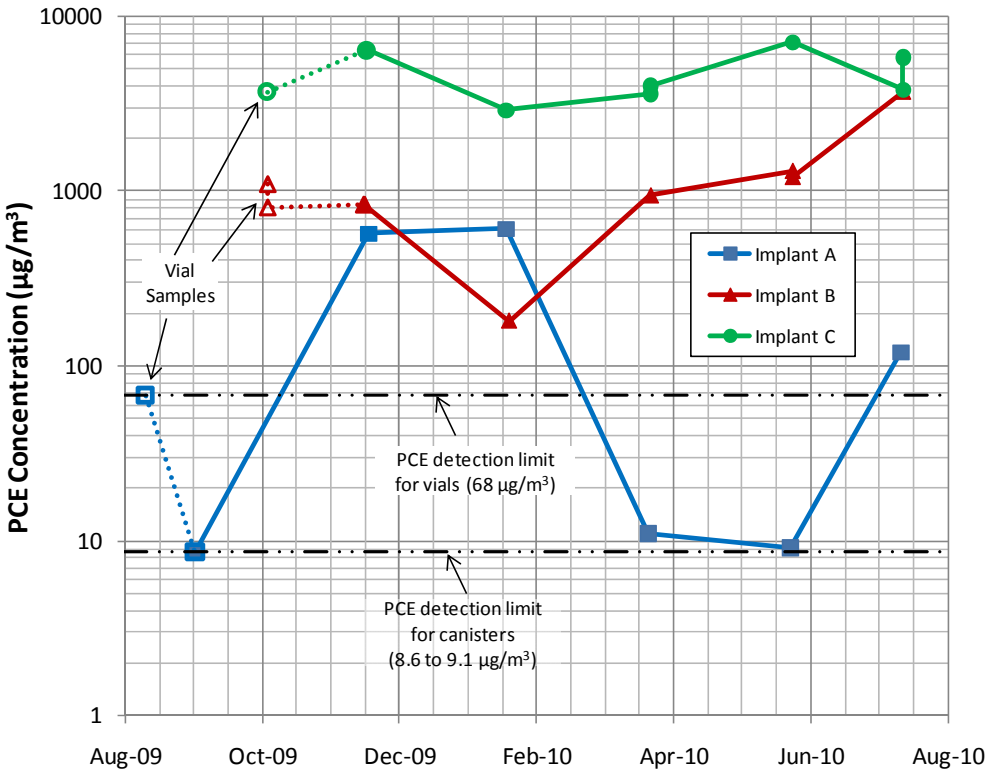

Figure 5. PCE concentration recorded in bimonthly sampling of selected soil gas monitoring implants.

3.3 Comparison of Method Precision

Precision is the degree of agreement among repeated measurements of the same characteristic (e.g. analyte concentration) under the same or similar conditions. Precision data provide an indication of the consistency and reproducibility of field sampling and analytical procedures. For canister sampling, precision is assessed by analyzing blind duplicates samples collected in the field using two canisters connected in parallel (see Section 2.2) For vial sampling, the duplicate soil gas sample is collected into a second pair of vials.

To evaluate sampling method precision, we calculated the *RPD* for the duplicate sampling results using equation (1) where c_1 and c_2 now refer to the original and duplicate sample concentrations, respectively.

Figure 6 provides a graphical comparison of blind duplicate samples collected into vials and canisters. The canister dataset includes 21 soil gas sample pairs for which one to three analytes were detected, including PCE, trichloroethene (TCE)

and cis-1,2-dichloroethene (35 data points). The vial dataset includes 4 soil gas sample pairs for which one to three analytes were detected (9 data points).

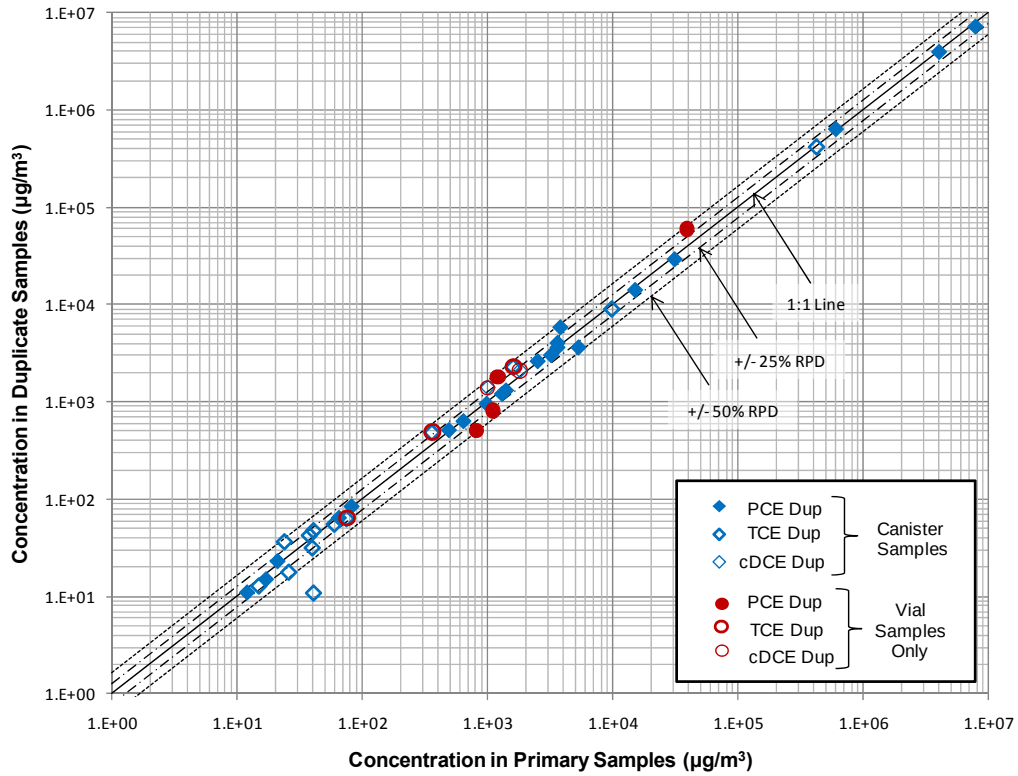

Figure 6. Comparison of blind duplicates samples collected with vials and canisters.

Overall, most duplicate pairs fall within an RPD of 50%. The RPD associated with vial duplicate pairs range from 15% to 45% (average 32% and median 34%). The range of RPDs associated with canister duplicate samples is larger with RPDs from 0 to 115% (average 16% and median 7%).

4. CONCLUSION

Comparison of soil gas data obtained as part of a vial and canister sampling program suggest that vial samples can provide a cost effective and relatively reliable way of gathering subsurface survey data:

- Despite the lesser sensitivity (i.e., higher detection limit) achieved in this case by vial sampling relative to canister sampling, concentrations of PCE from

vial samples, where detected, were found to be in generally good agreement with canister sampling results.

- Where long-term soil gas monitoring was conducted, changes in PCE concentration in canister samples collected at different times were found to be greater than differences in results that may initially exist between canisters and vials. This result suggests that one canister sampling event alone may not be sufficient to assess subsurface conditions and that multiple instances of vial sampling may prove a cost effective way of assessing subsurface conditions over different seasonal conditions.

5. ACKNOWLEDGMENTS

The authors would like to acknowledge Sanborn Head staff and other collaborators who have supported this investigation.

6. REFERENCES

Air Toxics Ltd. 2010. Guide to Air Sampling & Analysis – Canisters and Tedlar Bags. http://www.airtoxics.com/literature/AirToxicsLtdSamplingGuide.pdf (accessed September 2010).

Geoprobe® Systems. 2010. Soil Gas Sampling – PRT System Operation. http://geoprobe.com/literature/instruction/soil%20gas%20PRT%20Oper.pdf (accessed September 2010).

ITRC (Interstate Technology & Regulatory Council). 2007. Vapor Intrusion Pathway: A Practical Guideline. ITRC Vapor Intrusion Team, Washington, DC. http://www.itrcweb.org/Documents/VI-1.pdf (accessed September 2010).

USEPA (U.S. Environmental Protection Agency). 1999. Compendium Method TO-15 – Determination of Volatile Organic Compounds (VOCs) in Air Collected in Specially-Prepared Canisters and Analyzed by Gas Chromatography/Mass Spectrometry (GC/MS). In: Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air, Second Edition. Office of Research and Development, Cincinnati, OH. EPA-625/R-96/010b. http://www.epa.gov/ttnamti1/files/ambient/airtox/to-15r.pdf (accessed September 2010).