Journal of Remediation-In Press: July 2008

Residential Vapor Intrusion Evaluation: Long Duration Passive Sampling v. Short Duration Active Sampling

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ABSTRACT

Sampling indoor air for potential vapor intrusion impacts using current standard 24-hour sample collection methods may not adequately account for temporal variability and detect contamination best represented by long-term sampling periods. Mr. Henry Schuver of the U.S. Environmental Protection Agency (EPA) Office of Solid Waste stated at the September 2007 Air & Waste Management Association Vapor Intrusion Conference that U.S. EPA may consider recommending longer-term vapor sampling to achieve more accurate time-weighted-average detections.

In November 2007, indoor air at four residences was sampled to measure trichloroethene (TCE) concentrations over short- and long-duration intervals. A carefully designed investigation was conducted consisting of triplicate samplers for three different investigatory methods: dedicated 6-liter Summa canisters (U.S. EPA Method TO-15), pump/sorbent tubes (U.S. EPA Method TO-17), and passive diffusion samplers (MDHS 80). The first two methods collected samples simultaneously for a 24-hour period, and the third method collected samples for two weeks.

Data collected using Methods TO-15 (canisters) and TO-17 (tubes) provided reliable short-duration TCE concentrations that agree with prior 24-hour sampling events in each of the residences; however, the passive diffusion samplers may provide a more representative time-weighted measurement. The ratio of measured TCE concentrations between the canisters and tubes are consistent with previous results and as much as 28.0 ug/m^3 was measured

INTRODUCTION

For the past several years, Summa canisters have been used routinely in the United States for air quality studies, including indoor air vapor intrusion studies. They have become the reference standard used for quantifying volatile organic compounds (VOCs) in investigations and risk assessment. To date, sorbent tubes and passive diffusion samplers are less commonly used as a tool for indoor air and vapor intrusion assessment in the United States, however, they are used routinely throughout Europe. The subject study was designed to compare these three methods at

four residential locations suspected of being impacted by groundwater-to-indoor air vapor intrusion. Sorbent tubes with constant air flow and passive diffusion tubes are likely to become mainstays of air sampling in the United States because of several issues associated with the use of Summa canisters that will be presented later in this paper. Vapor intrusion guidance documents for the U.S. Environmental Protection Agency (EPA), as well as leading state environmental agencies, recommend collection of gas samples by either Method TO-15 (canisters) or Method TO-17 (sorbent tubes).

There is a growing concern that the current standard 24-hour collection period used to sample indoor air for potential vapor intrusion impacts may not adequately account for temporal variability and detect contamination best represented by longer-term sampling periods. Mr. Henry Schuver of the U.S. EPA Office of Solid Waste stated at the September 2007 Air & Waste Management Association vapor intrusion conference in Providence, Rhode Island that EPA may consider recommending longer-term sampling to achieve more accurate time-weighted-average detections. The purpose of the research described in this paper is to examine the longer sampling time using passive diffusion tubes and to compare these results to shorter-term testing periods using canisters and sorbent tubes. In order to set the stage for where the research was conducted and how the necessity of the testing came to be, the following paragraphs provide some background on the setting and scope.

Areas of groundwater contamination at Hill Air Force Base (AFB), Utah have been organized into 12 Operable Units (Hill AFB, 2004) (OUs). Nine of the 12 Hill AFB OUs contaminated with volatile organic compounds (VOCs) have portions of shallow groundwater plumes that underlie Hill AFB buildings and seven residential communities. Previous indoor air quality sampling in areas of shallow groundwater indicates vapor phase contaminants are more likely to be present in the indoor air of overlying buildings. Up to 2,900 homes may be impacted by vapors emanating from the soil gas above these groundwater plumes, and some residences even have indoor sumps containing the contaminated groundwater from these plumes.

Residential indoor air sampling has been conducted at off-base residential locations since 1997 in the seven communities surrounding Hill AFB. The sampling has been conducted to test for the presence of indoor air vapors potentially originating from dissolved VOCs in groundwater plumes. The VOCs dissolved in the groundwater originating from nine OUs on Base are capable of moving upward through the soil and posing a potential long-term human health risk in residential indoor air if those vapors enter homes above the plume. Over 1,500 individual residential locations have been tested using over 5,000 individual 6-liter stainless steel Summa sample canisters.

Hill AFB communicates indoor air results with homeowner/residents, discussing the level of risk present and options for installing a mitigation system if contaminants are above mitigation action levels. Indoor air monitoring programs are implemented, with a focus of collecting at least one sample during the winter at residences overlying or in proximity to contaminated groundwater. The frequency and schedule of the monitoring program is dependent on the concentrations measured and whether a mitigation system is installed in the residence.

OVERVIEW OF EXPERIMENTAL METHODS

Investigations at Hill AFB, Utah have evaluated vapor-intrusion-to-indoor-air impacts originating from groundwater plumes contaminated with VOCs (predominantly trichloroethene [TCE]) emanating from the Base and migrating beneath adjacent residential communities. To date, over 5,000 24-hour indoor air samples have been collected in residences.

In November 2007, indoor air at four residences was sampled to measure TCE concentrations over short- and long-duration intervals. A carefully designed investigation was conducted consisting of triplicate samplers for three different investigatory methods: dedicated 6-liter Summa canisters (U.S. EPA Method TO-15), pump/sorbent tubes (U.S. EPA Method TO-17), and passive diffusion samplers (British Method for the Determination of Hazardous Substances [MDHS] 80).

It has been established in numerous studies since 1992 that Summa canisters are the reference standard for air sampling in the United States. Sorbent tubes with pumps, however, are also approved and/or suggested for use in vapor intrusion testing by the U.S. EPA (U.S. EPA, 2002), the ITRC (ITRC, 2007) and the State of New Jersey (New Jersey Department of Environmental Protection, 2005). It should also be noted that Dr. DiGiulio of the U.S. EPA states (U.S. EPA, 2002) Method TO-17 "has several advantages including, rigorous QA/QC requirements, commercially available thermal desorption units and a large selection of sorbents, small size and weight of the sorbent and equipment, and the possibility of moisture management by dry purging and sample splitting prior to injection into the gas chromatograph.." The ITRC Guidance Document states that passive diffusion sampling is a viable alternative for vapor intrusion assessment.

FIELD SAMPLING PROGRAM

MWH contracted Beacon Environmental Services, Inc. (Beacon) to collect air samples using three different sample collection media/equipment at four different residences. Three units (triplicate) of each sample collection device were set up simultaneously in each of four homes and run for either 24 hours or two weeks. The first two methods (U.S. EPA Methods TO-15 and -17) collected samples simultaneously for a 24-hour period, and the third method (MDHS 80) collected samples for two weeks. The testing began November 12, 2007.

The first sample method incorporated 6-liter stainless steel Summa canisters and flow controllers already dedicated to the Hill AFB residential sampling program at each site. All flow controllers were set to collect whole air for 24 hours at elevations of approximately 4,200 feet above sea level. The canisters were dedicated to the Hill AFB residential sampling program after they were individually certified clean. Following dedication to the program, canisters have been batch-certified clean. All Summa canisters and flow controllers have been tracked since the dedication of these canisters over four years ago. A historical review of the sample data from the 12 canisters used in this study show no TCE detections over 242 ug/m^3; and no evidence of carryover was seen in any of the canisters used for this air sampling method study. The Summa canister analyses for this study were performed at an analytical laboratory located in Simi Valley, California using Method TO-15. Sample canisters are pressurized with humidified nitrogen to drive the sample from the

canister and into the gas chromatograph/mass spectrometer for analysis in scan mode. Reporting limit in an undiluted sample for TCE analyzed by Method TO-15 is 0.7 ug/m^3.

The second sample method utilized PAS 500 low-flow mini-pumps that drew indoor air at a flow rate of 20 mL/min for 24 hours through special sorbent-packed ¼-inch diameter stainless steel tubes. The flow rates of the pumps were measured using a National Institute of Standards & Technology traceable flow meter at the beginning of the sampling event and then again at the end of the sampling event. The sorbent tubes were analyzed by U.S. EPA Method TO-17 by Beacon at its laboratory in Bel Air, Maryland using a Thermal Desorption System connected to a gas chromatograph/mass spectrometer (TD-GC/MS). The TD system allows for the recollection during analysis of the sample split onto a secondary, clean sorbent tube. This advanced feature eliminates the prior "one-shot" limitation of Method TO-17 where duplicate or confirmatory analyses were not possible. The reporting limit for TCE analyzed by Method TO-17 is 0.3 ug/m^3.

The third sample method utilized passive diffusion samplers (PDS), consisting of ¼-inch diameter stainless steel tubes packed with a custom adsorbent. During sample collection, one end of the tube remained sealed and the other end was fitted with a sampling cap to allow for the free diffusion of compounds onto the adsorbent without the need for a porous membrane. These tubes were exposed to indoor air for two weeks and then analyzed following U.S. EPA Method TO-17 by Beacon using the above mentioned TD-GC/MS instrumentation. The reporting limit for TCE using the PDS method is 0.5 ug/m^3.

Exhibit 1 shows the experimental arrangement for each of the four homes in the study. The overall layout is shown and a box indicates the passive diffusion samplers that were hung.

Exhibit 1. Experimental layout with the passive diffusion tubes denoted by the box.

A comparison of the tubes versus cans dimensions and weight is worthwhile due to both size limitations and potential visibility issues at sites. The tubes are ¼-inch diameter, four-inches long and weigh 1.8 ounces. The cans are slightly over one-foot in height, nine-inches in diameter and weigh six pounds. There are clear advantages with the tubes in terms of transportability, visibility and cost on a per unit basis. A tube is typically fifteen times less expensive than a can on a per unit basis. The analytical costs of both tubes and cans vary considerably due to laboratory QA/QC, location, volume of samples to be analyzed and state/local regulatory requirements.

RESULTS/DISCUSSION

Data collected using Methods TO-15 (canisters) and TO-17 (sorbent tubes with pumps) provided reliable short-duration TCE concentrations that agree with prior 24-hour sampling events in each of the residences and the PDS time-weighted measurements tracked very closely to the TO-17 results. The results of the testing program are presented below in Exhibit 2. The measured TCE concentrations are consistent with previous results with as much as 28 ug/m^3 measured. The PDS results are consistently lower (on average) than concentrations measured using both the TO-15 and -17 methods and the effects of time-weighting of the samplers are more evident at increasing concentrations. The effects of time-weighting the sampling process over a two-week period reproduced the relative change from residence to residence. The TO-17 results more closely track the PDS concentrations with a range of 3.5 to 30 percent lower concentrations for the two-week versus 24-hour sampling periods, respectively.

Exhibit 2. Results of Indoor Air Testing Near Hill AFB, Utah Nov. 12-26, 2007

Compound	TCE		
Units	ug/m3		
Lab	Beacon	Air Lab	Beacon
Method	TO-17	TO-15	MDHS 80
Exposure	24 hr Tube	24 hr Can	2 wk PDS
Location			
8158	**20.4**	**28**	**12.1**
8158	**18.1**	**27**	**11.7**
8158	**10.9**	**19**	**10.8**
8016	**1.9**	**3.3**	**1.8**
8016	**2.0**	**3.6**	**1.7**
8016	**2.2**	**3.6**	**1.8**
8116	<0.3	<0.7	<0.5
8116	<0.3	<0.7	<0.5
8116	<0.3	<0.7	<0.5
8078	**1.2**	**1.8**	**1.0**
8078	**1.1**	**1.8**	**1.0**
8078	**0.9**	**1.7**	**1.1**

The data collected using Methods TO-15 (canisters) and TO-17 (tubes) provided reliable short-duration TCE concentrations that agree with prior 24-hour sampling events in each of the residences, and the passive diffusion samplers provide time-weighted measurements over a two-week period. The ratio of measured TCE concentrations between the canisters and tubes are consistent with on-going research (Odencrantz and O`Neill, 2008). Exhibit 3 is the time history of all homes tested in this study and illustrates the large variability of TCE concentrations over the period of records. The results from the research presented in here are delineated on each of the four plots and the only data set presented are those from EPA Method TO-15 (since all previous testing was performed using this method). As clearly evidenced by the work presented here, all three methods are viable options for the determination of TCE impacts in the indoor air environment. .

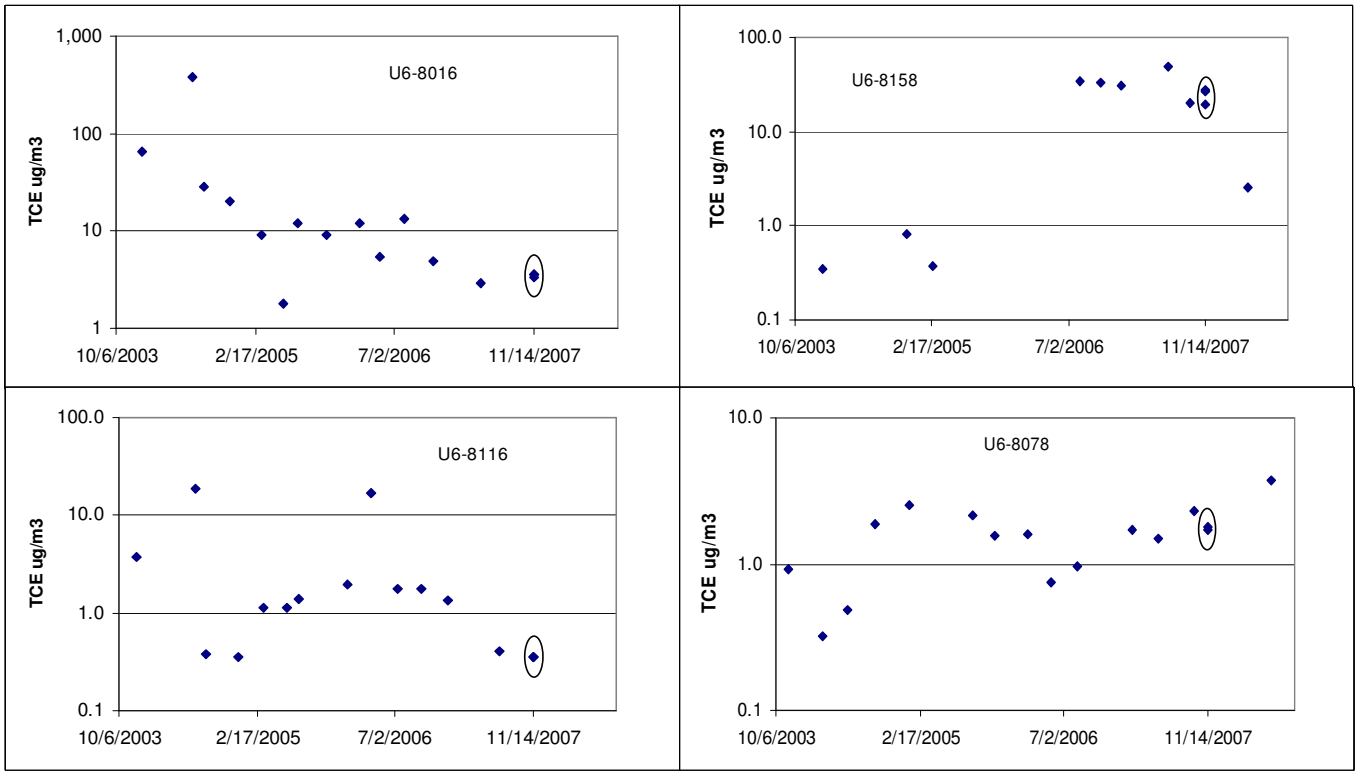

Exhibit 3. Time history of the four homes via EPA Method TO-15 with the data from this study denoted with an oval.

CONCLUSIONS

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

- The purpose of the indoor air sampling study was to compare the side-by-side testing results of 24-hour Summa canisters, 24-hour active sorbent tubes (using small low-flow pumps), and 14-day passive diffusion sample tubes. The field-based study took place in four residential locations in triplicate near Hill AFB, Utah.

- The active sorbent tubes, Summa canisters and the long-term passive diffusion tubes (PDS) were consistent for each residence for the sampling event described here and resulted in the same rankings for most to least impacted.
- The PDS results are consistently lower (on the average) than both the TO-15 and -17 concentrations and the effects of time-weighting of the samplers are more evident at increasing concentrations. The effects of time-weighting the sampling process over a two-week period reproduced the relative change from residence to residence. All methods were within a factor of two with one another at each home.
- Regardless of the method used, each had strong agreement among the three reported concentrations within each home for each method.

ACKNOWLEDGEMENTS

The authors wish to express their thanks to Mr. Jeff Dunn of MWH for assisting with the implementation of the field testing. The authors also wish to thank Mr. Steven Thornley and Mr. Ryan Schneider of Beacon Environmental Services, Inc. for their assistance in the laboratory.

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Biographical Sketches

Joseph E. Odencrantz, Ph.D., P.E. is Technical Director and Western Region Manager for Beacon Environmental Services, Inc. www.beacon-usa.com. Dr. Odencrantz is a recognized expert in site investigation and remediation, fate and transport processes and forensic evaluations. He obtained his M.S. and Ph.D. in Civil and Environmental Engineering from The University of Illinois at Urbana-Champaign and his B.S. in Civil Engineering from the

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Harry O'Neill is the President of Beacon Environmental Services and has managed soil gas investigations for 17 years for the DOD, DOE, and commercial markets. Mr. O'Neill continues to be on the forefront of passive and active sorbent technologies at the national and international level and has implemented the technologies at thousands of sites. Mr. O'Neill received his B.A. from Loyola College in Maryland.

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Paul C. Johnson, Ph.D. is an Executive Dean of the Ira A. Fulton School of Engineering at Arizona State University. He has worked in the environmental area since 1987, having numerous patents and publications. He is Editor in Chief for the NGWA's journal, Ground Water Monitoring and Remediation. Dean Johnson is the recent recipient of the Lifetime Achievement Award from the International Conference on Soils, Sediment and Water in recognition of his significant contributions to the understanding and solution of soil, sediment and groundwater pollution problems.