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Identification of Chlorinated Solvent Sources in the Indoor Air of Private Residences around Hill Air Force Base, Utah

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IDENTIFICATION OF CHLORINATED SOLVENT SOURCES IN THE INDOOR AIR OF PRIVATE RESIDENCES AROUND HILL AIR FORCE BASE, UTAH

by

Andrew J. Hall

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Civil and Environmental Engineering

Approved:

Dr. William Doucette Major Professor	Dr. R. Ryan Dupont Committee Member
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UTAH STATE UNIVERSITY
Logan, Utah

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ABSTRACT

Identification of Chlorinated Solvent Sources in the Indoor Air of Private Residences Around Hill Air Force Base, Utah

by

Andrew J. Hall, Master of Science

Utah State University, 2008

Major Professor: Dr. William J. Doucette
Department: Civil and Environmental Engineering

Volatile chlorinated solvents such as trichloroethylene (TCE), 1,2 dichloroethane (1,2 DCA), and perchloroethylene (PCE) have been identified in the indoor air of residences located near Hill Air Force Base (AFB), Utah. These vapors can originate from either volatilization of contaminates from shallow contaminated groundwater and transport into residences or from sources within the residence. The focus of the thesis was the development of a testing strategy for determining sources of TCE, 1,2 DCA, and PCE in the indoor air of residences near Hill AFB.

Eight residences were selected for this study by Hill AFB based on prior detections of TCE, 1,2 DCA, and PCE in indoor air. Residents were asked to turn off the heating, ventilation, and air conditioning (HVAC) system and keep windows and doors closed for at least 3 hours prior to the sampling visit to reduce mixing of residence air. Indoor air samples were collected on Tenax© sorbent tubes from various locations within the residences to determine the location of the potential source(s). Sampling tubes were analyzed by thermal desorption gas chromatography/mass spectrometry (GC/MS).

Results from a tracer experiment using sulfur hexafluoride gas confirmed the effectiveness of sampling approach.

In cases where elevated levels of chlorinated solvents were found, the suspected source materials(s) were removed and the room air was re-sampled. If removal of the materials reduced or eliminated indoor air contamination, an emission chamber was used to determine contaminant emission from the materials. Sources were identified in three of the sampled residences. Sampling in two of the residences was discontinued due to scheduling problems. Sources were not located in the remaining residences.

The emission of contaminants from items identified as sources in two of the residences was measured using an emission chamber developed for this project. An ornament from residence U8-8452 emitted 36.4 ng/min/cm^2 of 1,2 DCA. The emission of 1,2 DCA from a wedding dress located at residence U8-8211 was below the method detection limit of 1.99 pg/min/cm^2 but the emission of PCE was 18.9 ng/min/cm^2 and decreased by a factor of 7 during repeated measurements.

(153 pages)

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Andrew J. Hall

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INTRODUCTION

Background Summary

Prior to 1980, organic solvents used in operations at Hill Air Force Base (AFB), Utah, were disposed of in chemical disposal pits and landfills located on the base, near base boundaries. Many of these solvents, including trichloroethylene (TCE) and 1,2 dichloroethane (1,2 DCA), with lesser amounts of perchloroethylene (PCE), have leaked from these disposal areas contaminating the shallow groundwater aquifers in and around the base. Chlorinated solvent vapors originating from the groundwater plumes can travel through soil void spaces and enter overlying residences through cracks or voids in the foundation slab. This route of indoor contamination is known as vapor intrusion (VI).

In 1993, Hill AFB began testing the indoor air of residences found above shallow contaminated groundwater for chlorinated solvents. In 2003, testing began in earnest to determine locations where VI is a possible concern. Over 1,500 residences have been tested and some of the sampled residences contained levels of chlorinated solvents that were above Hill AFB mitigation action levels (MALs). The MALs were determined through either background levels derived from a literature search (e.g., TCE) or risk based concentrations (e.g., 1,2 DCA and PCE) (MWH, 2004).

Vapor Removal Systems (VRSs) are recommended in residences where concentrations were above the MAL (MWH, 2004). A VRS is installed in the sub-slab of a building, where a fan is used to transport air from below the building to outdoor air above the building. This transport of contaminants minimizes the potential for intrusion of these vapors into the building (Folkes 2002).

Despite the installation of VRSs, Hill AFB has measured chlorinated solvent concentrations in some residences that are above the prescribed action level. The VRSs are designed to eliminate the potential for VI, suggesting that the source of indoor contaminants is somewhere within the residence itself, although it is possible that short-circuiting of the VRS is occurring. Additionally, there is doubt whether VI is the source of all indoor contaminants. Household items, for example: solvents, cleaners, and dry-cleaned fabrics, can potentially contain these same chlorinated solvents, which makes indoor air contaminant sources difficult to determine.

Project Background

Residences selected for this study were selected by Hill Air Force Base based on prior detections of TCE, 1,2 DCA and PCE in indoor air. Residents were asked to turn off the heating, ventilation, and air conditioning (HVAC) system and keep windows and doors closed for as long as possible (3 hour minimum) prior to the sampling visit. Samples were collected on Tenax© sorbent tubes from the majority of rooms within the residences in order to determine potential source locations of contaminants.

After determining potential source locations, repeat sampling visits were performed in order to obtain more area samples and liquid and/or solid samples of products which could be emitting the contaminant of interest in the residence. When sampling efforts indicated that the potential source(s) had been found, the source(s) was (were) removed and area sampling was performed in order to determine if the objects removed were the sources of the indoor air contamination.

Where possible, objects were tested using an emission chamber to determine the mass release rate from the object that was contributing to the indoor air contamination.

Additionally, various household items which contain TCE, 1,2 DCA, and PCE were also tested in the emission chamber. The household item results were used to better understand the relationship between product use and the associated mass release rates.

A residence was used as a model in simulating a building which contained an indoor source. An inert tracer gas (sulfur hexafluoride) was used to simulate an indoor source of air contamination. Measurements were performed throughout the residence with and without the HVAC system in operation to ensure that the testing strategy for locating a source of indoor air contamination was not flawed. Results of this model residence were used to ensure that the testing strategy used for determining source locations in residences sampled near Hill AFB was effective.

Objectives

The overall objectives of this thesis research were threefold: to identify the source(s) of chlorinated solvents in the indoor air of selected residences located near Hill AFB; to develop, test, and model a sampling strategy for identifying indoor sources; and to determine emission rates of chlorinated compounds from household objects. The contaminants of concern (COC) were limited to the following chlorinated solvents known to be released into the environment from operations at Hill AFB: TCE; 1,2 DCA, and PCE. Sampling was conducted to determine possible sources of these contaminants, VI or indoor, so that they could be eliminated or minimized. Liquid and solid samples from potential source materials were sampled and analyzed by headspace GC/MS. If the materials contained the COC, an emission chamber was used to quantify COC emissions from these materials that could be used to predict indoor air contaminant levels. The results were used to determine the feasibility and practicality of room-by-room sampling to determine the source of indoor air contaminants and to establish a set of standard procedures that can be used in future source identification projects. Results from this study have helped to develop an improved understanding of the contribution of indoor sources to vapor intrusion investigations and mitigations. Specific tasks to be accomplished included:

1. Develop and test a sampling and analysis strategy to locate and identify indoor sources of COC.
2. Design and perform laboratory experiments to determine the mass release rate of COC from selected sources identified during Task 1.
3. Use a controlled release of a tracer gas within a test residence to corroborate the room-by-room testing strategy used in actual residences.

LITERATURE REVIEW

Physical/Chemical Properties of TCE, 1,2 DCA, and PCE

TCE (CAS # 79-01-6); 1,2 DCA (CAS # 107-06-2); and PCE (CAS # 127-18-4) are suspected carcinogens (HSDB, 2005a, b, c). Selected properties and the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs) for each chemical are shown in Table 1, Table 2, and Table 3, respectively. The COC are readily degraded in the atmosphere by reaction with hydroxyl radicals. The half reactions for 1,2 DCA and PCE are 63 and 96 days, respectively, and the half reaction for TCE is only 7 days (HSDB, 2005a, b, c). The COC may undergo photolysis in indoor air; however, the rate is expected to be much slower inside compared to rates outside (Carslaw 2007). The vapor pressures and Henry's Law constants listed indicate that TCE, 1,2 DCA, and PCE are all volatile chemicals.

Table 1. Selected properties of TCE

Property	Value	Reference
Molecular Weight (g/mol)	131.39	(Lide 1999)
Boiling Point (˚C)	87.2	(Lide 1999)
Melting Point (˚C)	-84.7	(Lide 1999)
Vapor Pressure (mm Hg at 25˚C)	73.49	(Daubert and Danner 1989)
Aqueous Solubility (mg/L at 25˚C)	1,280	(Horvath et al. 1999)
Henry's Law Constant (atm-m^3/mol)	0.0103	(Munz and Roberts 1987)
Log Octanol Water Partition Coefficient (Log Kow)	2.61	(Hansch, Leo, and Hoekman 1995)
Organic Carbon Normalized Sorption Coefficient (Koc)	100	(Wilson et al. 1981)
OSHA Permissible Exposure Limit (ppm$_v$)	100	(OSHA, 2005)

Table 2. Selected properties of 1,2 DCA

Property	Value	Reference
Molecular Weight (g/mol)	98.96	(Lide 2000)
Boiling Point (˚C)	83.48	(Riddick et al. 1986)
Melting Point (˚C)	-35.66	(Riddick et al. 1986)
Vapor Pressure (mm Hg at 25˚C)	78.9	(Daubert and Danner 1989)
Aqueous Solubility (mg/L at 25˚C)	8,600	(Horvath et al. 1999)
Henry's Law Constant (atm-m^3/mol)	9.79×10^{-4}	(Dilling 1977)
Log Octanol Water Partition Coefficient (Log Kow)	1.48	(Hansch, Leo, and Hoekman 1995)
Organic Carbon Normalized Sorption Coefficient (Koc)	32	(Chiou et al. 1979)
OSHA Permissible Exposure Limit (ppm$_v$)	50	(OSHA, 2005)

Table 3. Selected properties of PCE

Property	Value	Reference
Molecular Weight (g/mol)	165.83	(Lide 1999)
Boiling Point (˚C)	121.3	(Lide 1999)
Melting Point (˚C)	-22.3	(Lide 1999)
Vapor Pressure (mm Hg at 25˚C)	18.5	(Riddick et al. 1986)
Aqueous Solubility (mg/L at 25˚C)	206	(Horvath et al. 1999)
Henry's Law Constant (atm-m^3/mol)	0.0184	(Munz and Roberts 1987)
Log Octanol Water Partition Coefficient (Log Kow)	3.40	(Hansch, Leo, and Hoekman 1995)
Organic Carbon Normalized Sorption Coefficient (Koc)	363	(Karickhoff 1981)
OSHA Permissible Exposure Limit (ppm$_v$)	100	(OSHA, 2005)

Hill Air Force Base

Hill AFB, Utah is located approximately 30 miles north of Salt Lake City and 8 miles south of Ogden (Figure 1). The base stretches across two counties (Davis and Weber) and is bordered by six communities (Sunset, Clearfield, Roy, Layton, South Weber, and Riverdale) (Figure 2).

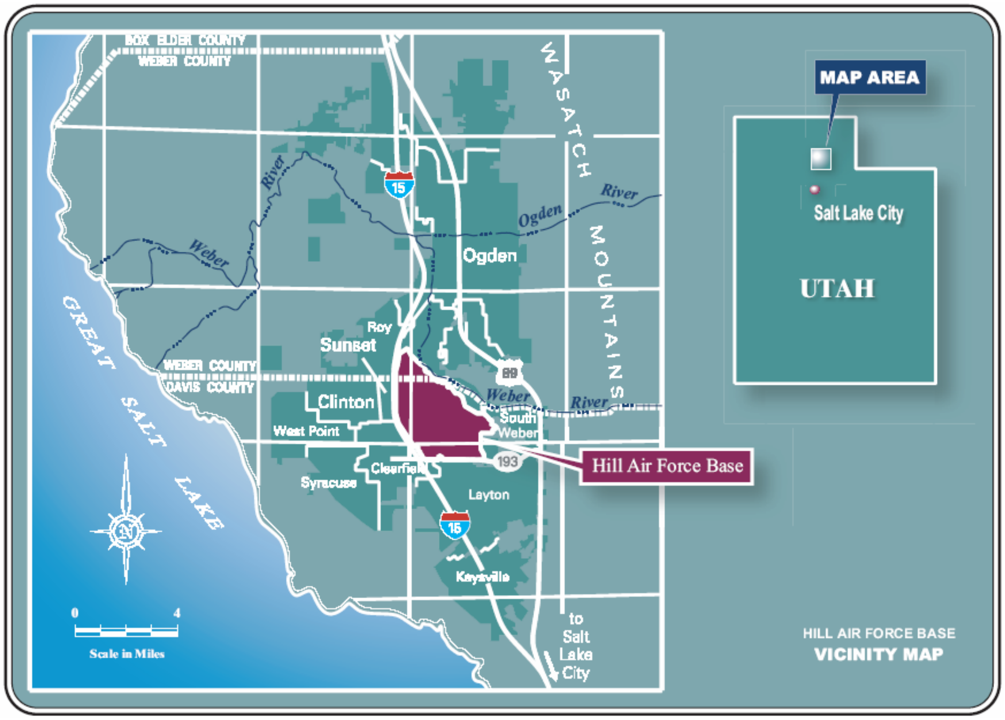

Figure 1. Hill AFB vicinity map (Gorder 2008).

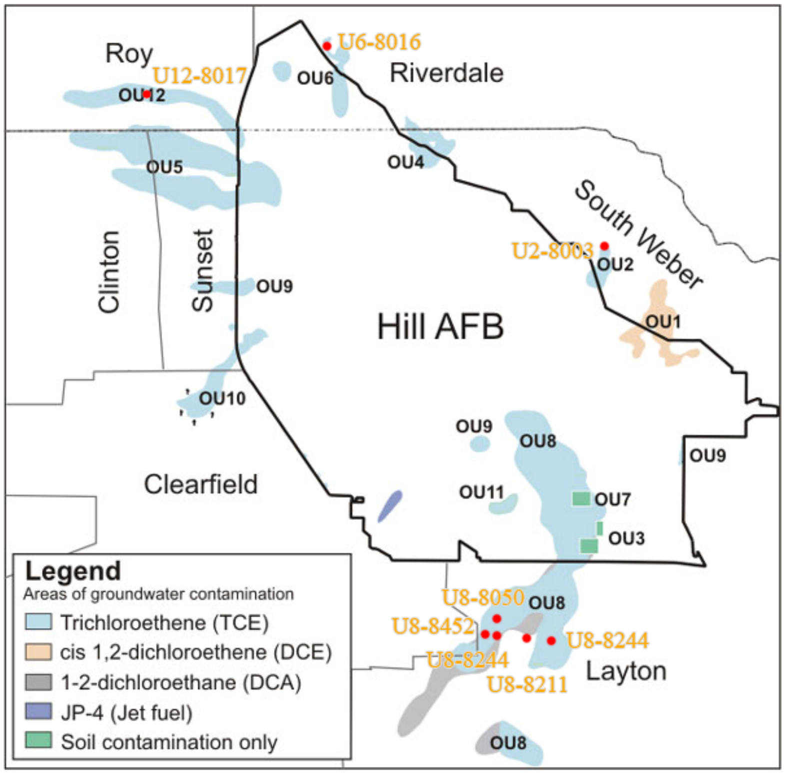

Figure 2. Groundwater contamination at Hill AFB and surrounding areas with sampled residence location adapted from Hill AFB Restoration Advisory Board (2005).

Historically, Hill AFB's operations have focused on supply and repair of aircraft and missile parts, some of which involved the use of chlorinated organic solvents that were disposed of in several chemical pits and landfills located on the base. These solvents have since leaked from their containers into shallow aquifers surrounding the base. Hill AFB has worked since 1980 to mitigate potential problems associated with contaminant plumes and remediate contaminated areas (ATSDR, 2003).

Since 1993, Hill AFB has sampled over 1,500 residences suspected to be impacted by VI due to migration of the groundwater plumes. Testing performed by Hill AFB since 2001 has determined that COC levels have been above Hill AFB's MAL in some residences. The MALs were determined for each chemical based on either a risk based concentration as defined by the USEPA (2002) or by a literature based background threshold value for indoor air (MWH, 2004). These MAL concentrations are shown in Table 4. VRSs were installed where concentrations were above the MAL or when resident's concern merited the installation. Eight residences were sampled for this thesis research and their locations are shown in Figure 2.

Vapor Intrusion

The United States Environmental Protection Agency (USEPA) has defined VI as "the migration of volatile chemicals from the subsurface into overlying buildings" (Eklund 2005) (Figure 3). Since the "Vapor Intrusion Pathway" is of concern with regards to human health at a large number of contaminated Superfund, Resource Conservation and Recovery Act (RCRA) and other sites, the USEPA developed draft guidance for evaluating VI into indoor air (USEPA, 2002). Although not recognized as a regulation dealing with VI, the guidance does provide recommendations for assessing the potential risk of VI.

The draft guidance recommends utilizing a model developed by Johnson and Ettinger (1991). The Johnson and Ettinger Model (JEM) uses inputs from groundwater concentrations of volatile chemicals and predicts indoor air concentrations based on various parameters. It requires the following information:

1. depth to contaminated groundwater,
2. diffusivity of the chemical,
3. diffusion coefficient through cracks in the foundation,
4. foundation opening (cracks) and total foundation (basement) area,
5. soil type and characteristics,
6. air flow rates through the soil, and in the building.

Additionally, the model assumes the foundation and soil are at steady state and that there are no concentration gradients within the building. Although functional, other studies have determined that the JEM has a few inherent limitations. The model assumes that a building has a basement, but neglects differences associated with crawl spaces or combinations of basements and crawl spaces (Mills et al. 2007).

In addition, studies (Tillman and Weaver 2006, 2007a, b) have indicated that often there are insufficient data to use this model, and McHugh, de Blanc, and Pokluda (2006) noted that with newer buildings, the indoor air is positively pressurized, causing a net flow of indoor air into the surrounding soil, rather than a flow of soil air into the indoor environment.

Table 4. Mitigation action levels for selected chlorinated solvents for Hill AFB

Contaminant	Hill AFB Mitigation Action Level (ppbv)
TCE	0.43
1,2 DCA	0.23
PCE	1.2

While other models have been developed that apply assumptions or corrections for these inadequacies (Abreu and Johnson 2005, Mills et al. 2007), none of these models attempt to incorporate indoor sources into their assumptions or calculations. Furthermore, Eklund (2005) postulates that VI is an important issue at a relatively small number of sites since there are numerous confounding errors which can be caused by indoor sources.

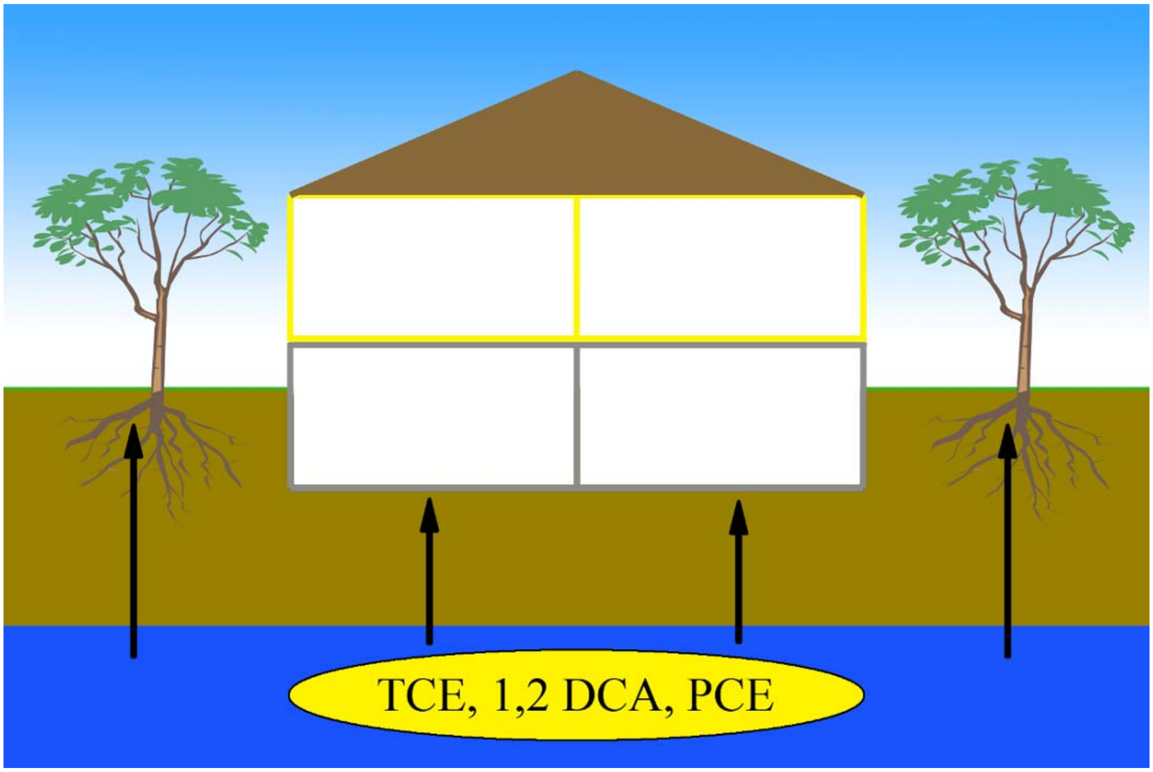

Figure 3. Vapor intrusion diagram.

The Agency for Toxic Substances & Disease Registry (ATSDR) (2003) studied the effects of potential VI for residences near Hill AFB. This study found that although the JEM predicts a potential for VI (based on historic high concentrations in the groundwater plumes), sampling efforts rarely found levels comparable to those derived from the model indicating that the JEM over-predicts indoor air concentrations. However, sampling efforts did find some locations with values higher than Hill AFB's MAL.

Although sampling efforts by both Hill AFB and the ATSDR have shown that VI is not occurring in a majority of buildings nor at levels predicted by the JEM, it is still believed that VI is occurring in some residences around the base. This belief is based on the observation that concentrations of COC normally decrease after VRS installation (Case and Gorder 2006).

Eklund and Simon (2007) studied PCE intrusion from contaminated soil under a building that had previously been used as a dry-cleaning facility. They found that despite having 2.6 parts per thousand by volume in the sub-slab soil gas, indoor air concentrations were normally six orders of magnitude less. These differences vary significantly (two to three orders of magnitude) from other measured attenuation factors. Ekland and Simon suggest that values used by the EPA are conservative, and in some situations may be extremely conservative, producing inflated indoor air concentration predictions. Results from this study indicate that there are potential issues with current attenuation factors given by the EPA.

Additionally, McHugh et al. (2008) have worked to evaluate the movement of soil gases through building foundations by utilizing radon as a tracer to determine VI potential. McHugh et al.'s methods introduce a potentially effective way to determine the impact of VI on indoor air concentrations of volatile organic compounds (VOCs). Utilizing radon as a surrogate for VI measurements minimizes problems from potential indoor sources. Initial results do appear promising; however, further testing must be performed before this method can be recognized as an appropriate method for determining VI potential.

Vapor Removal Systems

Vapor removal systems represent an effective way of eliminating vapor intrusion into buildings (Folkes 2002). VRSs draw gases from the sub slab region of a building and then transport these gases to the outside air above the building (Figure 4). In order for a VRS to function properly, cracks and/or broken seals between the building and the surrounding soil should be sealed so that air transfers from inside the building are minimized. The systems that have been installed by Hill AFB in the surrounding communities have one or more suction points (Figure 5) and either an interior (Figure 6) or exterior fan (Figure 7) to convey gases from below the residence to the outside of the residence.

As mentioned previously, Hill AFB has installed numerous VRSs in residences that have been presumed to be effected by VI. After installation of these VRSs, COC levels in most residences decreased to below MAL levels; however some residences continued to have levels of COC that were above the MAL (Figure 8). It is predicted that these measurements are due to indoor sources of COC (Figure 9); however, it has been extremely difficult to determine the exact source for most of these residences.

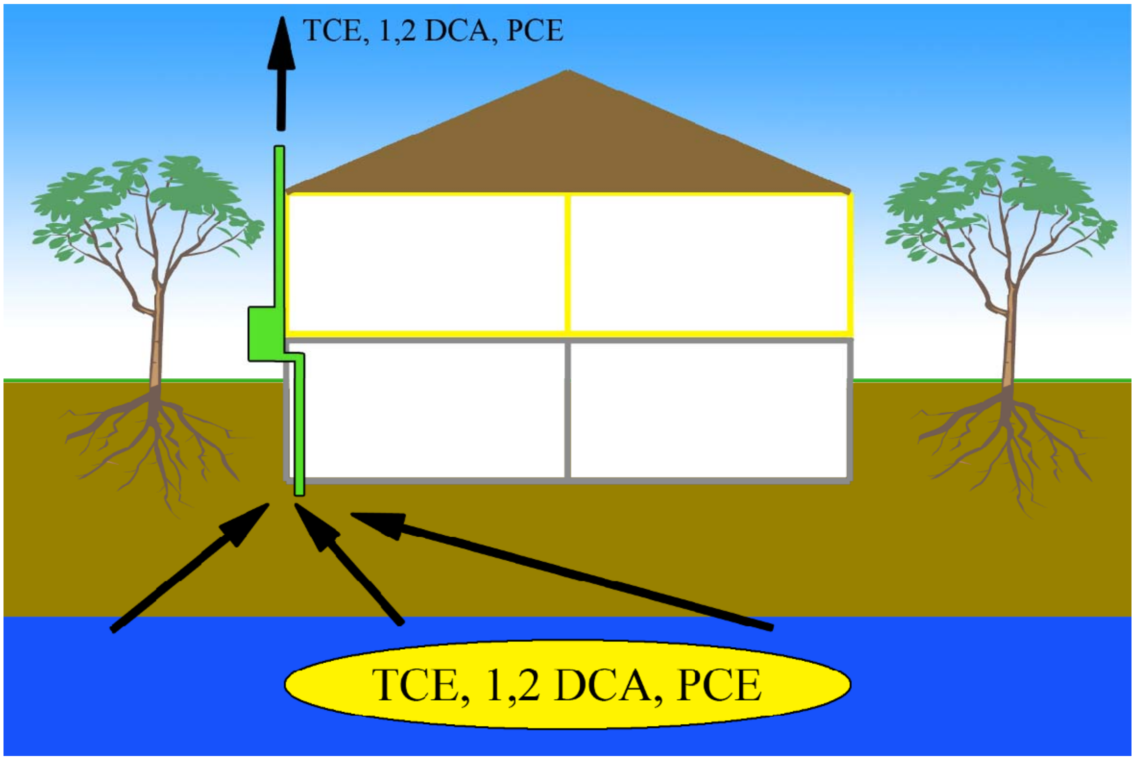

Figure 4. Schematic of a basic vapor removal system.

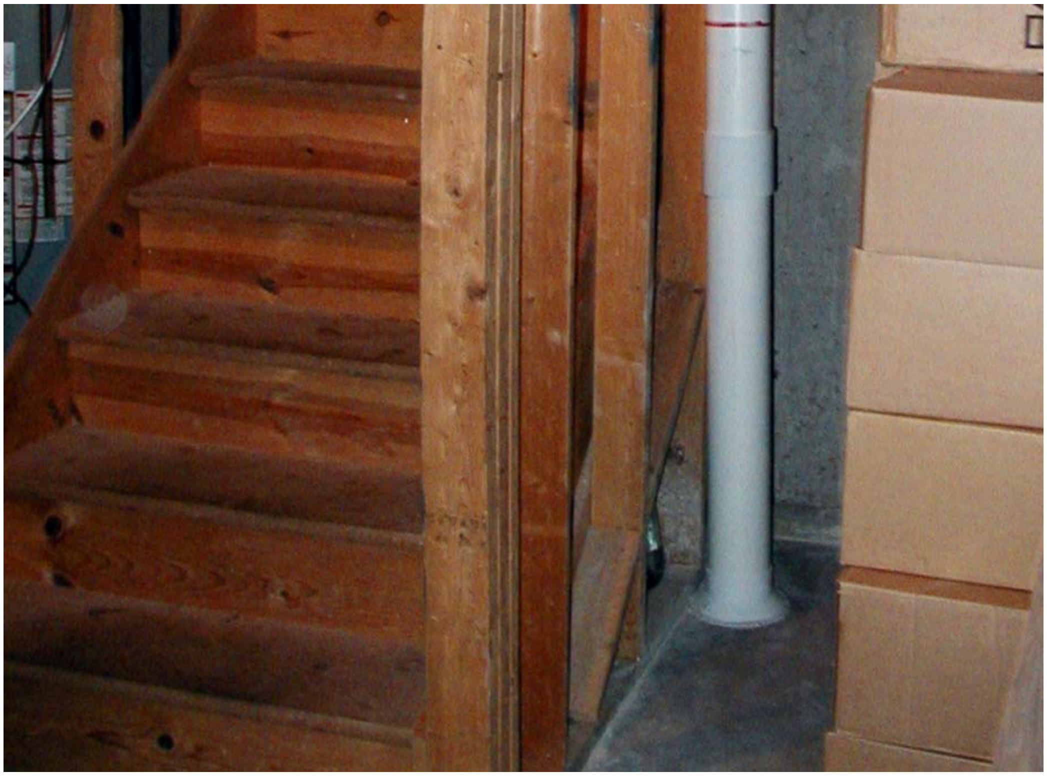

Figure 5. Suction point for a VRS installed in a residence near Hill AFB.

Figure 6. Interior VRS fan installed in a residence near Hill AFB.

Figure 7. Exterior VRS fan installed in a residence near Hill AFB.

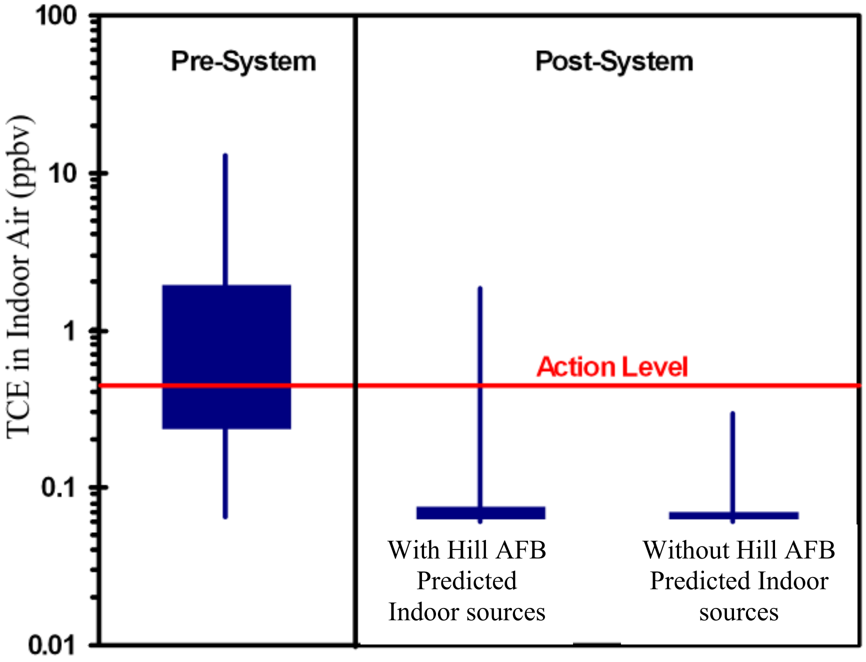

Figure 8. TCE concentrations in indoor air (ppbv) before and after VRS installation.

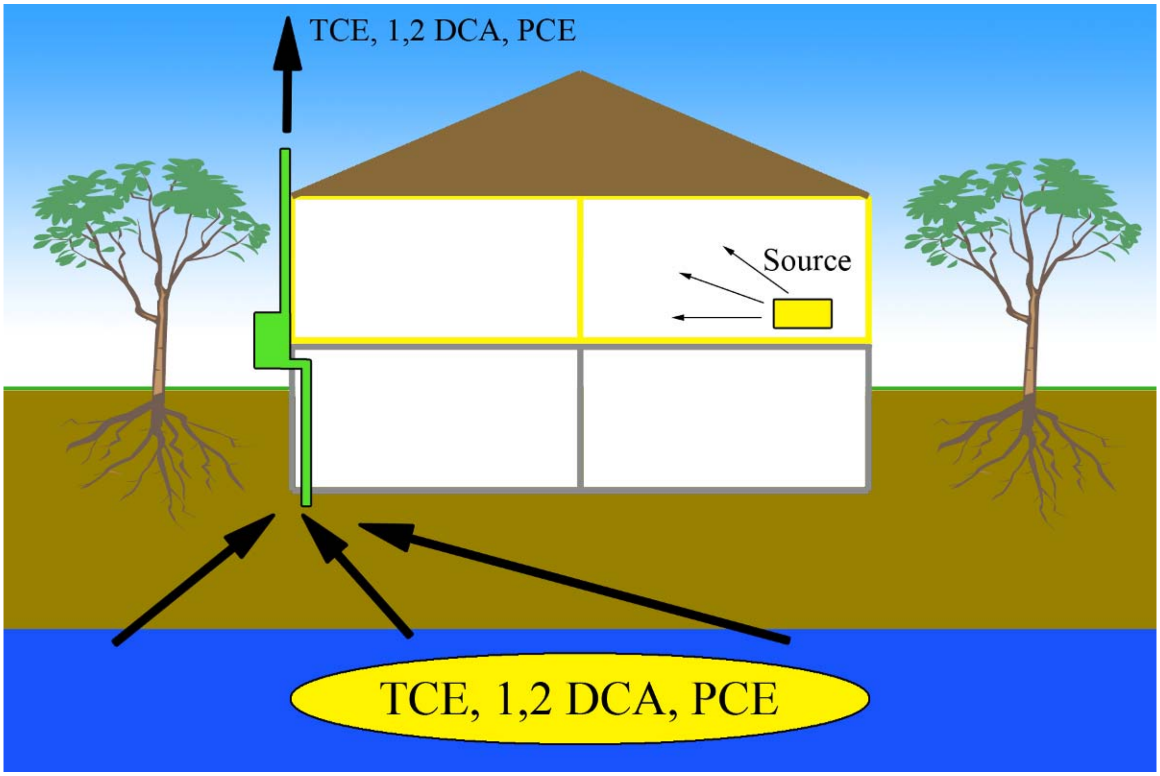

Figure 9. Schematic of indoor source influence on residences with a VRS.

Potential Indoor Sources of TCE, 1,2 DCA, and PCE

Indoor sources of chlorinated solvents are often difficult to define and locate (Eklund 2005, Tillman and Weaver 2006, 2007a, b). Multiple surveys of common household products have been performed in order to define some of these sources (Kawauchi and Nishiyama 1989, Tichenor et al. 1990, Sack et al. 1992). Although these studies did not perform analysis for every product that could contain the contaminants of interest for this study, they can help to illustrate products or product classifications that could be important in locating sources of indoor air chlorinated solvent contamination. The following summarizes the results of these surveys by author.

Sack et al. (1992)

Sack et al. (1992) analyzed 1,159 household products for chlorinated solvents. The study focused on multiple products from the following classifications: automotive products; household cleaners and polishes; paint related products; fabric and leather treatments; cleaners for electronics; oils, greases, and lubricants; adhesive products; and miscellaneous household items. Components of these categories are shown in Appendix A.

Measurable amounts of PCE and TCE were found in each of the product classifications, while measurable amounts of 1,2 DCA were only found in three classifications (automotive products, oils greases and lubricants, and miscellaneous products). However, on a percent weight concentration basis, there were only six product types with significant amounts of TCE and only two with significant amounts of 1,2 DCA (Table 5).

Table 5. Percent by weight concentrations of TCE, 1,2 DCA, and PCE as determined by Sack et al. (1992)

	TCE	1,2 DCA	PCE
Automotive Products	0.1	0.1	21.5
Household Cleaners/Polishes	0.0	0.0	21.6
Paint-related Products	3.0	0.0	4.4
Fabric and Leather Treatments	0.0	0.0	30.6
Cleaners for Electronic Equipment	0.3	0.0	22.7
Oils, Greases and Lubricants	0.3	0.1	12.3
Adhesive Related Products	34.7	0.0	16.1
Miscellaneous Products	33.9	0.0	17.5

The results of the Sack et al. (1992) study are useful for specifying potential classifications of products which contain the COC. These classifications can be helpful in narrowing down potential indoor air COC sources. However, no data were provided which identified specific products that contained each chemical. Since all the product classifications contained some levels of PCE and TCE, these product classification differences may only be useful for determining 1,2 DCA sources. Additionally, since specific products are not known, it is not possible to determine which products contained all the contaminants and separate them from products which only contained one or two of the COC.

Tichenor et al. (1990) and Kawauchi and Nishiyama (1989)

Tichenor et al. (1990) and Kawauchi and Nishiyama (1989) studied PCE accumulation on dry cleaned clothing fabrics and the resulting PCE emissions that occurred. Kawauchi and Nishiyama (1989) performed tests on clothes which were in common use and on a “Test Texture” which consisted of 12 different kinds of fibers sewn together. Samples were taken from each of the fabrics 1 to 2 days after dry-cleaning. PCE was extracted using hexane and was analyzed by a gas chromatograph equipped with an Electron Capture ^{65}Ni detector.

They found up to 68.5 μg/g of residual PCE on clothing and 13.6 mg/g on the “Test Texture”. The surface of a winter skirt and winter jacket had the highest concentrations of PCE for the clothing, and acetate fibers contained the highest concentrations in the “Test Texture.” In addition, they found that PCE was still detected at between 6 and 20 ng/g on a dry-cleaned shirt that was left on a hanger after 5 months of dry cleaning (approximately 1 to 2 percent of the original levels).

Tichenor et al. (1990) found that PCE residuals were highest in Arnel fabrics and the half-life of PCE on that type of fabric was approximately 24 hours. Furthermore, they studied PCE emissions and found that dry cleaned clothes emit PCE into the surrounding areas for at least 7 days (tests were performed for a maximum of 7 days). Acetate fabrics emitted the most PCE (6.7 mg/m^2/hour), and rayon fabrics emitted the least (0.055 mg/m^2/hour).

It was also determined that air exchanges influenced the emission rate. Additionally, indoor air concentrations of PCE were measured in a test residence with recently dry-cleaned clothes (the fabric of the clothes was not reported). Indoor air concentrations decreased from 3 mg/m^3 (44.2 ppbv) to 0.02 mg/m^3 (0.003 ppbv) over a period of 7 days; however, this study did not produce data for PCE emission beyond 7 days.

Indoor Air Concentration Studies for TCE, 1,2DCA, and PCE

Several studies have been performed to determine TCE; 1,2 DCA; and PCE concentrations in typical indoor air samples. These background indoor air concentrations can be used for comparison between residences impacted and not impacted by VI. It is important to note that while studies of residences that are not above known groundwater plumes may provide appropriate background concentrations of organic solvents, the results do not focus on eliminating indoor sources. Additionally, background indoor air concentrations can be skewed towards values above the "true" background concentration since potential indoor sources may be present in the buildings studied. Table 6 summarizes the results of three studies (Gordon et al. 1999, Van Winkle and Scheff 2001, Kurtz and Folkes 2002) that measured indoor air concentrations of TCE; 1,2 DCA; and PCE when VI is not believed to be present. Van Winkle and Scheff (2001) determined a correlation between PCE detections and sampling locations on carpet. This correlation could be explained by the sorption and de-sorption of PCE onto carpet pad (Olson and Corsi 2002). Correlations for TCE, and 1,2 DCA were not observed.

Table 6. Background indoor air concentrations of COC from selected studies

	TCE		1,2 DCA		PCE	
	Mean Conc. (ppbv)	Sample Detections	Mean Conc. (ppbv)	Sample Detections	Mean Conc. (ppbv)	Sample Detections
Van Winkle and Scheff (2001)	0.072	90 % (10)*	0.0146	19 % (10)	0.384	100 % (10)
Gordon et al. (1999)	< 0.336	100 % (185)	NA**	NA	NA	NA
Kurtz and Folkes (2002)	0.0316	13.8 % (282)	0.0133	24.8 % (282)	0.165	69.9 % (282)

* Values in parenthesis represent number of samples

** NA – Study did not include 1,2 DCA and PCE

Indoor Air Modeling

Various modeling techniques have been developed for indoor air contaminants. For example, nodal, multi-nodal, zonal, and computational fluid dynamics (CFD) modeling methods have been used for indoor air quality modeling (Megri and Haghighat 2007). Additionally, variations have been made based on chemical decay characteristics, constant and non-constant sources, building materials, and other potential variations which can occur within a building (Guo 2002).

CFD models typically provide the most accurate predictions, but often require information that is not available at all site locations. Nodal and multi-nodal models often over simplify situations by assuming that air within a room is essentially homogenous. Also, these modeling techniques require source information including the duration of source emission and source location (Guo 2002). Many air quality models additionally assume that a building is one well mixed chamber (Elkilani et al. 2001, Abreu and Johnson 2005) or a composite of two to three well mixed chamber (Mills et al. 2007, Dodson et al. 2008).

Various indoor air models (Sparks et al. 1996, 1999a, b) have been developed for volatile organic compounds (VOCs); however, the sources for these models are assumed to decrease significantly over time (a few hours to a month) rather than act as a constant source of indoor air contamination. Since the residences selected for this study have had significant COC concentrations for more than 3 months, it is assumed that any source in the residence is at least semi-constant.

Sparks also developed a mass balance model for the USEPA called RISK (Sparks 1997) with the ability to simulate a constant source of VOCs and room to room air transfers. This model assumes that each room is well mixed when simulating time steps that are more than a few tens of minutes. The model also allows for sources and sinks of contaminants in multiple rooms. Based on data obtained by Sparks, it appears that rooms are well mixed at larger time steps. Large rooms must be divided into smaller rooms in order to satisfy the well mixed assumption. As mentioned previously, there is not much data on indoor sources, and less data on indoor sinks of contaminants. Further, determining individual room air exchange rates is extremely difficult and in most residential cases unpractical especially when trying to determine individual room air exchange rates with outdoor air as compared to transfer within the building.

An effort has been made by Liu and Zhai (2008) to develop an inverse model to determine source location. Although potentially useful, this modeling approach requires knowledge regarding source release time and assumes that air only flow into and out of the room through HVAC vents. When working within a residence without running the HVAC system, where, although potentially minimal, there is air transfer into and out of rooms through doors and windows. Additionally, when dealing with VI or indoor sources, the source release time is often unknown, especially since the source is often unknown as well.

Although indoor air quality modeling may be useful in determining potential locations of contaminant sources, it is often difficult or impossible to determine or measure all the required inputs for the model. Due to this difficulty, oversimplifying assumptions or default data can often be used causing unrealistic results. Additionally, insufficient data are often collected for determining the actual fit of a model to realistic situations.

MATERIALS AND METHODS

Sampling Overview

Sampling was conducted at residences that had been identified in coordination with Hill AFB as having potential indoor sources. Individual sampling visits were coordinated with homeowners' schedules. Homeowners were requested to limit the amount of air mixing in each room of the residence prior to sampling to facilitate identification of individual sources on a room-by-room basis. Suggested steps to minimize air mixing were presented to homeowners while scheduling the sampling event and included the following:

1. Switch off existing vapor removal systems 24 hours prior to the sampling effort.
2. Discontinue HVAC system use as early as possible on the morning of the scheduled sampling.
3. Close windows in the residence for 24 hours before the sampling effort. At a minimum, all windows must be closed on the morning of the scheduled sampling.
4. Close all internal doors in the residence on the morning of the scheduled sampling.
5. Minimize activity in the residence, where practical, on the day of sampling, including opening and closing of internal doors. (This is not essential, but minimizing air mixing increases the chances of identifying a room of interest.)
6. Movement during the sampling should be minimized. The sampling team and residents must make every effort to minimize their movements, especially opening and closing of doors to minimize movement of air.

Sampling locations were chosen inside each residence in order to gain a better understanding of the potential locations of contaminant sources. Potential locations included main or common areas (living rooms, kitchens, etc.) and as many individual rooms (bathrooms, bedrooms, etc.) as possible. These samples included one central sample for each level of the residence (e.g., basement, main floor, etc.) excluding the attic. When sampling large open rooms, sampling occurred in areas nearest to potential source locations (e.g., shelves with cleaners, polishes, cracks in the foundation, etc.). In addition, one sample was obtained from outside the residence in order to obtain a baseline (background) measurement.

Samples were collected using two Tenax© sorbent tubes (Alltech Associates; Deerfield, IL) attached in series to a SKC Air Chek Sampler Model 224-43XR (Eighty Four, PA) (Figure 10). Pumps were typically set from 100 to 150 mL per minute for approximately 30 minutes unless concentrations were such that a different flow rate and/or run time would be needed. Air flow measurements were taken at the beginning and end of each sampling event using an Alltech Digital Flow Check™ model DFC™ Flowmeter (Nicholasville, KY). Standard operating procedures can be found in Appendix B.

If a potential source location was found (high concentrations relative to other rooms), the materials in the vicinity were cataloged, sampled, and/or removed. If physically possible, samples of potential contaminant sources were collected in volatile organic analysis (VOA) and/or headspace vials. If items were removed, the residence was once again sampled to indicate whether the removed items were sources. Results from each of the samples (Sorbent Tubes, VOA, and headspace vials) were used to determine possible sources of the indoor air contaminants.

Quality assurance/quality control

Field blanks and laboratory blanks for Tenax© tubes were prepared following recommendations listed in EPA Method TO-17. Both closed and opened field blank tubes were transported to each residence. Tubes were aligned in series to determine whether breakthrough occurred. If there were significant amounts of COC on the back tubes it was assumed that breakthrough had occurred. However, when breakthrough occurred, the concentrations were always above the highest standard in the calibration curve and could not be accurately determined and results were discarded.

Figure 10. Area air sample apparatus setup.

Where possible, tubes were spiked and transported with sampling events as field spike samples. In addition, a spike recovery study was performed at the Utah Water Research Laboratory in Logan, Utah. Laboratory blanks and continuous calibration verification (CCV) samples were included approximately every 10 samples during analysis.

Emission Chamber

A forced air emission chamber was used to measure COC emission rates (Figures 11 and 12) for materials where chlorinated solvent vapor emission could potentially be an issue. The emission chamber used in this study was constructed from a 21 quart, aluminum All American Pressure Cooker/Canner (Wisconsin Aluminum Foundry Co., Inc., Manitowoc, WI) modified to create a flow through sampling system similar to the systems described by Tichenor (1989), Sparks et al. (1999b), and Afshari, Lundgren, and Ekberg (2003).

An inlet was added to the bottom of the chamber with a stainless steel manifold that circles the bottom and top of the chamber. An outlet was added to the side of the system with a tube which was positioned in the center of the chamber. A Dwyer stainless steel low pressure gauge (Michigan City, IN) was added to the top of the system to ensure that there was no pressure build-up in the system. Two small 4-inch metal fans were mounted on the bottom of the chamber, and an additional 4-inch metal fan was mounted to the top of the chamber to ensure that the system was well mixed.

Finally the chamber was placed in a room that was held at a constant temperature and the chamber air temperature was monitored using a Thermo Fisher Scientific Pocket Size Type K Thermometer with an attached thermocouple that was inserted into the system. A room temperature of approximately 18 to 19 °C corresponded to a 25 °C chamber air temperature. Two, 4-inch hobby fans were used to blow room air around the chamber to keep it cool.

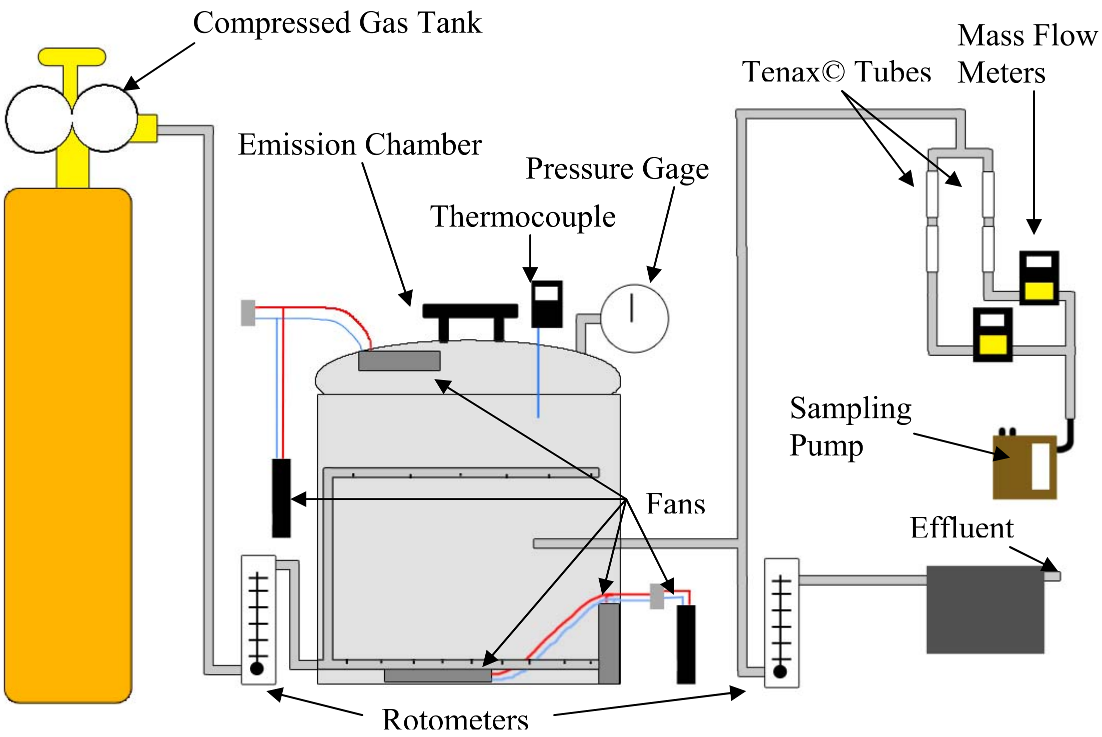

Figure 11. Schematic of the emission chamber system.

Figure 12. Photograph of the emission chamber sampling apparatus.

During the course of research activities multiple lessons were learned about the system which necessitated changes in order to create a well mixed, inert chamber. The initial system was developed using a Presto 23 Quart Pressure Cooker/Canner (National Presto Industries, Inc, Eau Claire, WI) which used a rubber gasket to seal the chamber and had an outlet at the top of the chamber. Measurements indicated that the rubber gasket was sorbing the COC and desorption caused high contaminant concentrations when no products were being sampled. The All American Pressure Cooker/Canner was used to replace the gasket system mentioned above since it utilized a metal on metal seal.

Further modifications included the addition of three plastic bladed hobby fans to mix the chamber and moving the outlet point to the side of the system to sample air from the middle of the mixed chamber. Although the fans increased mixing, it was determined that desorption of the COC from the fan blades was relatively slow and therefore the system could not be easily purged of the COC. The hobby fans were replaced with three metal bladed fans (one mounted on top and two mounted on the bottom of the chamber) and testing indicated that system purges decreased COC concentrations to below detection limits. Finally, the initial pressure gauge contained a rubber diaphragm, which was replaced by a stainless steel pressure gauge with brass wetted parts.

The inlet gas originated from either a compressed Nitrogen or an ultra-high-purity compressed air cylinder. The ultra-high-purity air was used when porous materials were tested that needed to be returned to a resident. The outlet gas was removed using a high volume air pump. The inlet and outlet gases were directed through rotameters to determine the flow through the system. The outlet gas was split and sampled using a SKC Air Chek Sampler Model 224-43XR (Eighty Four, PA) which drew gas through two sets of Tenax© tubes in series followed by Alborg GFMS-010024 (Orangeburg, NY) mass flow meters (to determine sample volume collected).

Prior to and after sampling an item, a control sample was performed in order to ensure that there was no residual contamination in the system. The sampling tubes were analyzed using the same procedures as the indoor air sample tubes. When sub-sampling of objects was performed, their surface areas were either determined by direct measurement or by calculation using Adobe Photoshop Extended CS3 (San Jose, CA). The standard operating procedure for emission chamber measurements can be found in Appendix B.

Emission chamber testing

A VICI Metronics Dynacal® extended life tubular (XLT) permeation device (Houston, TX) was used to ensure that chamber procedures would develop non-flow dependant emission measurements. Dynacal® XLT permeation devices are small inert apparatuses which contain a compound in equilibrium between its gas and liquid or solid phase. A permeation tube, rated at 650 ng per minute of TCE at 30 °C, was placed in the emission chamber after it had equilibrated to a constant temperature (normally between 24 and 26 °C). Since the emission chamber's temperature was less the rating for the emission tube, a direct correlation between the actual and measured concentrations could not be determined. A study was performed to determine the amount of air exchanges or time required before constant emission rates were observed in the chamber. Additionally, triplicate emission rates were measured to determine the variability of the system.

Afshari, Lundgren, and Ekberg (2003) recommends allowing at least 10 air exchanges prior to sampling so that a steady state condition is reached within the chamber; however, at about eight air exchanges, results from the study show that the emission rate remained constant. Multiple air exchange rates were tested to determine the requirements for air exchanges for the emission chamber developed for this thesis research.

The permeation tube was placed in the system and 5 minute samples were collected with 5 minute steps between each sample. The data show that after approximately 15 minutes (Figure 13) or 3 to 4 air exchanges (Figure 14) the emission from the tubes was constant for both of the tested flows. A mass recovery experiment was not conducted to determine the efficiency of the system, and in hindsight, it would have been advantageous to test the mass recovery of the system at both flows.

Since the rotameters in the system were more easily calibrated at lower flows, a flow rate of four liters per minute (LPM) was chosen for use in further experiments. After determining the time required to reach steady state in the chamber, the system was run three times with system purges between samples to determine the variability within sampling results. Results show (Table 7) that the data are consistent with an average emitter release of 449.9 ng per minute and a 95 percent confidence interval of 32.1.

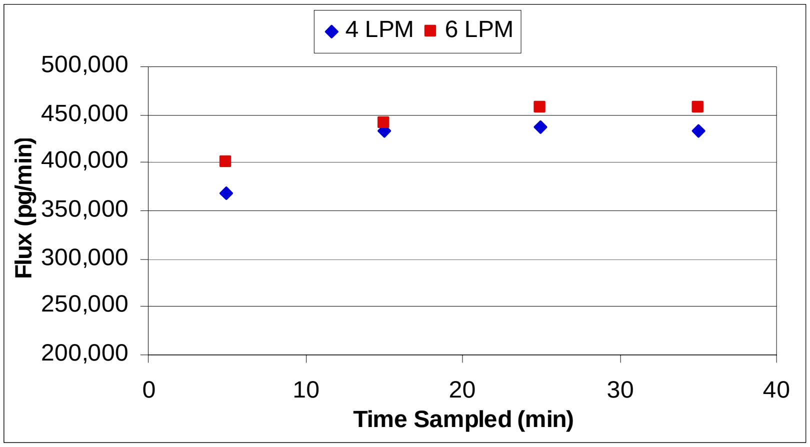

Figure 13. Emission rate versus time sampled for varying flow rates.

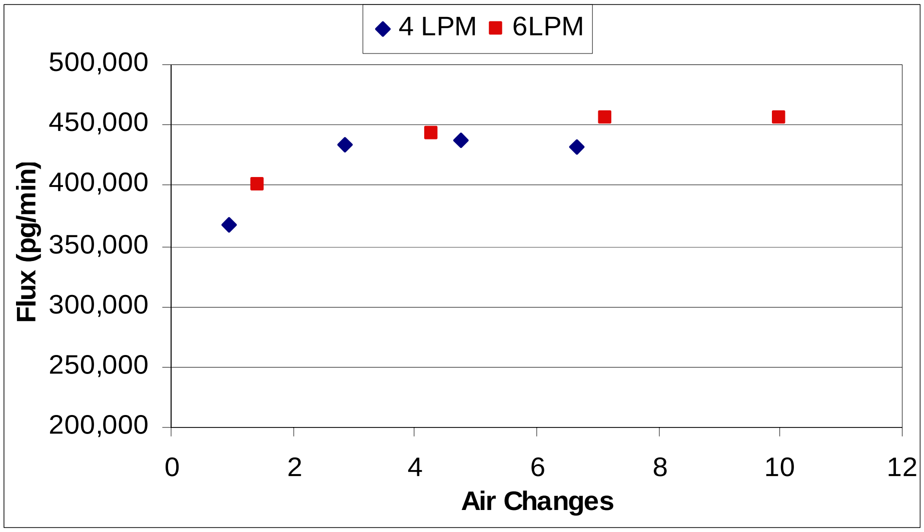

Figure 14. Emission rate versus air exchanges for varying flow rates.

Table 7. TCE emitted from triplicate samples at four LPM flow

Sample Name	TCE Emitted (ng/min)
4 LPM # 1	481.3
4 LPM # 2	426.0
4 LPM # 3	442.5
Average	449.9
Std Deviation	28.3
95% Confidence Interval	32.1

Quality assurance/quality control

Before each sampling event, a “pre-control” was performed by running the system without placing anything inside. After each sampling run, a 25 minute post purge was performed in order to eliminate any remaining COC from the system. During the purge, 6 LPM of compressed nitrogen or air were flushed through the system, and the SKC Air Chek Sampler pump was run in order to flush gas through the entire system. Additionally, a “post-control” was run after the final clean-out phase was performed to ensure that there was no residual COC.

Sub-Slab Soil Gas Sampling

Sub slab air sampling was performed following the USEPA's Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (USEPA, 2002). This was accomplished by drilling a series of small holes (e.g., diameter of 9/16") in the foundation, usually the basement, of a building. A stainless steel tube with a 3/8 inch Swagelok fitting was placed in the hole and the hole was then sealed using bentonite clay and adding water to expand the clay. The holes were located away from the edges of the foundation in order to limit dilution from air which is not below the slab. The COC sample was taken by pulling a volume (typically 1 to 2 liters) of soil gas from the sub-slab region through Tenax© sorbent tubes following the general approach described in EPA Method TO-17.

Quality assurance/quality control

A watch glass filled with a 200 mg/L solution of bromodichloromethane (CAS: 75-27-4) in methanol was placed next to the sampling hole to ensure that an adequate bentonite seal between the stainless steel tube and the foundation was made,. Bromodichloromethane has a vapor pressure of 50 mm Hg at 20 degrees Celsius (Callahan et al. 1979). Sorbent tubes were analyzed by thermal desorption GC/MS as described in the following section. If analysis revealed any bromodichloromethane, it was known that the bentonite seal had failed and the data were not used.

Sample Analysis

Tenax© sampling tubes

Tenax© tubes were analyzed using a thermal desorption gas chromatography/ mass spectrometry (GC/MS) procedure. Trap samples were introduced into a Hewlett-Packard® 6890/5793 GC/MS equipped with a DB-624 capillary column (30 m x 0.25 mm ID x 1.4 µm film thickness) using a Perkin Elmer TurboMatrix ATD Automated Thermal Desorber. Desorber operating conditions were as follows: 5 minute trap purge; cryo-trap temperature = -30°C; Tenax© tube desorb = 300°C for 10 minutes; cryo-trap temperature program -30°C initial temperature to 320°C at 40°C/s, transfer to GC/MS at 225°C. The moisture control system, traps, and tubes were thermally cleaned between each sample. The desorber operated at a pressure of 9.4 psi causing a nominal flow rate of 1 mL/min.

Chromatographic conditions were as follows: DB-624, 30 m x 0.25 mm, 1.4 µm film thickness column (J&W Scientific, Folsom, CA); temperature program 35ºC for 2 min to 170 ºC at 30ºC/min, then 170 to 230ºC at 70 ºC/min. with a 1 min. hold at the final temperature. The MS was operated in selected ion monitoring (SIM) mode (TCE: m/z 60, 95, and 130; 1,2 DCA: 62, 64, 49 m/z; PCE: 166, 131, 94 m/z). An external standard approach was used to quantify the mass of TCE; 1,2 DCA; and PCE collected in each trap. Standards were prepared by loading 1 µL of known amounts of TCE; 1,2 DCA; and PCE dissolved in methanol onto clean Tenax© traps with a micro-syringe. Standard amounts range from 200 to 100,000 pg. New standard curves were prepared approximately every month, or when CCV samples showed instrument drift from previous standard curves.

Method detection limits (MDLs) were calculated according to the standard USEPA approach (Berthouex and Brown 2002). Seven tubes were spiked with 995 pg of TCE, 1,2 DCA, and PCE. The standard deviation of the resulting instrument determined masses was multiplied by the one-sided 99 percent t-statistic for seven samples (3.14) to determine the MDL. The results of the study are presented in Table 8.

Additionally, a spike recovery study was performed to ensure that the tubes would retain the COC during the sampling event. Three tubes were spiked with approximately 2000 pg of TCE; 1,2 DCA; and PCE, and air was drawn through the system for approximately 30 minutes. A blank tube was also placed following the spiked tubes. At the same time, three blank tubes were subjected to a similar sampling event in order to determine background concentrations of the COC.

The sampled tubes were analyzed for COC concentrations and the results are shown in Table 9. Spike recoveries were 103%, 93.7%, and 106% for TCE, 1,2 DCA, and PCE, respectively, indicating there were not significant problems with sampling protocols. It was interesting to note that the background outdoor air concentrations of PCE were 68 percent of the spike amount. Additional testing of outdoor air in the same location used for this study confirmed that PCE was present in the outdoor air at the levels measured previously. Additional spike recovery data can be found in Appendix C. The equation for spike recovery calculation is found in Equation 1 where:

R is the spike recovery in percent;

$C_{spiked/sampled}$ is the average concentration of COC in the spiked tubes that had air drawn through them;

$C_{non\text{-}spiked/sampled}$ is the average concentration of COC in the non-spiked tubes that had air drawn through them; and

C_{ccv} is the average concentration of CCVs spiked concurrently with spiked tubes but that did not have air drawn through them.

$$R = \frac{C_{spiked\ /\ sampled} - C_{not-spiked\ /\ sampled}}{C_{spiked\ /\ not\ sampled}} \tag{1}$$

Table 8. MDL calculation for TCE, 1,2 DCA, and PCE

Sample	TCE (pg)	1,2 DCA (pg)	PCE (pg)
1	1060.73	1059.58	1039.64
2	960.58	1025.00	1048.37
3	981.08	1023.37	1053.83
4	978.21	1015.97	1050.68
5	982.10	1006.92	1035.78
6	964.42	970.81	1031.12
7	1049.76	985.48	1022.66
Standard Deviation	40.95	28.87	11.34
MDL	128.58	90.66	35.62

Table 9. Spike recovery sample results

	Average Mass Collected (pg)		
Sample	TCE	1,2 DCA	PCE
Non-Spiked Tubes with Air Drawn Through	<MDL	<MDL	1519.78
Spiked Tubes with Air Drawn Through	2197.42	2087.48	3741.08
Difference Between Non-Spiked and Spiked Tubes	2197.42	2087.48	2221.3
Spiked Tubes (no Air Draw Through)	2134.19	2228.3	2106.44
Percent Recovery	103.0%	93.7%	105.5%

Headspace and VOA vials

Liquid samples (e.g., paints, carpet cleaners, etc.) were analyzed using a headspace GC/MS method. Aliquots (1 to 100 µL) of samples collected in VOA vials were transferred to headspace vials containing 10 mL of distilled water (DW) for analysis. In hindsight, diluting the samples with 10 mL of matrix modifying solution (a solution of DW saturated with sodium chloride) would have been more appropriate to help drive the COC from the liquid into the headspace of the vials.

Headspace samples (gas volume of 2 mL) were then introduced into a Hewlett-Packard® 6890 GC/5973 MS (running EnviroQuant, Chemstation G1701AA version D.03.00 data acquisition and analysis software) using a Tekmar 7000HT Headspace Analyzer/Autosampler. The autosampler platen/sample temperature was set to 50 ºC, the sample equilibrium time was 10 min. and the transfer line and sample loop temperatures were 180 ºC. Chromatographic conditions were as follows: DB-624, 30 m x 0.25 mm, 1.4 µm film thickness column (J&W Scientific, Folsom, CA); helium carrier gas at 0.7 mL/min (2.9 psi); temperature program 30 ºC for 3 min to 170 ºC at 30 ºC/min, then 170 to 230ºC at 50 ºC/min. with a 1 min. hold at the final temperature (total run time = 9.7 min.); split/splitless inlet vent flow 13.2 mL/min.; and split ratio is 15:1. The MS was operated in full scan mode in order to identify if the COC were in the liquid. In the event that the COC were found in the liquid, samples were diluted and spiked onto a Tenax© tube and analyzed using the methods mentioned earlier.

Solid samples were analyzed using a headspace GC/MS method. Headspace vials were weighed before and after sampling in order to determine sample weights. Sample analysis was similar to liquid samples with the autosampler platen/sample temperature set to 80 ºC rather than 50 ºC in order to improve sensitivity. Additionally, the MS was operated in selected ion monitoring (SIM) mode (TCE: m/z 60, 95, and 130; 1,2 DCA: 62, 64, 49 m/z; PCE: 166, 131, 94 m/z). The only solid samples tested were the cardboard from a wedding dress storage box. A calibration curve was created using approximately 8 grams of uncontaminated cardboard and standard amounts of COC spiked onto the cardboard ranged from 9.95 to 333.33 ng.

ROOM-BY-ROOM SOURCE DETERMINATION MODEL RESIDENCE

Background

The development of the residence testing strategy for this thesis research included an assumption that by closing the doors and windows of a residence and turning off the HVAC system, a room with a source can be separated from those without a source. A residence located in Logan, UT (UWRL-1) was selected for use as a physical model for simulating source effects on indoor air concentrations. Floor plans for the residence can be found in Appendix D. A tracer gas was used to simulate a continuous point source contaminant at the residence. HVAC system use was varied in order to better understand the impact of the HVAC system on indoor air concentrations of potential contaminants.

Materials and Methods

Sulfur hexafluoride (SF_6) gas (CAS: 2551-62-4) was chosen as the tracer for this study because of its relatively low toxicity and the ability to be detected at low concentrations using a Thermo Scientific MIRAN 205B Series SapphlRe Infrared Analyzer (Waltham, MA). The gas was released using a needle valve and was set at a flow rate of 3 mL per minute (14 mg/min). The SF_6 was placed in rooms above the basement to simulate indoor sources of COC. Although the release of SF_6 created a higher emission rate than was predicted for COC sources in actual residences, it was assumed that source release rate changes would be scaled throughout the residence. Further, the release rate had to be sufficient for the Infrared Analyzer to detect the gas. Due to this limitation of the instrument, no study was performed to ensure that the emission rate effects could be scaled throughout the residence. It is suggested that an additional study using a TCE emitter at levels similar to those found in household products be performed to test the scaling assumption.

After allowing the gas to release for over 3 hours, concentrations were measured for 3 minutes in each major room. Measurements within the room were performed at 15 to 30 second intervals for a total of 6 to 12 measurements that were averaged to determine the room's concentration. This was done to minimize SF_6 concentration variations that were observed. After measuring concentrations in each of the rooms of the residence, the HVAC system fans were turned on and allowed to mix the room air for at least 1 hour. Each room was then sampled again to determine differences between a mixed and a non-mixed residence. Prior to sampling, the MIRAN was zeroed outside the residence using a VOC filter. After sampling, the outdoor air was tested to ensure that the instrument did not drift. After each sampling event, the SF_6 gas was stopped and the windows of the residence were opened to allow the SF_6 gas to leave the residence. In hindsight, it would have been additionally effective to measure room concentrations of SF_6 in each room for 2 to 3 hours after HVAC fans had been operated to determine when and if steady state conditions were reached. Additionally, it would have been helpful to have begun the release of SF_6 when the HVAC system was operating and after 1 to 2 hours, turn the system off. Concentrations could then have been measured 3 hours after the fans had been shut off to better simulate a room-by-room sampling conditions that would be observed in the field.

Two source locations were selected to best represent situations which were similar to those that were expected in the field. First, SF_6 was released in a small bedroom (source location one) to mimic sources that are located in bedrooms, small storage rooms, or other small rooms. Then, SF_6 was released from a large living room (source location two) to imitate a source which is located in a large open room (e.g., kitchen, living room, large storage room, etc.). Finally, a repeat of the living room event was performed to determine reproducibility of the results. No mass balance was performed on the SF_6 concentrations since not every room/space in the residence was sampled (e.g., small bathrooms, closets, etc.). Concentration results are shown in Appendix E.

Additionally, the upstairs South bedroom was used to determine a room air exchange rate when the HVAC system was not in use. SF_6 gas was released in the room at 100 mL per minute for three seconds. Concentrations were measured for a period of 107 minutes and the air exchange rate was calculated using the concentration decay method described in Appendix F.

Finally, the SF_6 emission rate from source location two with the HVAC fans in operation was used to determine if measured values corresponded with those determined by the RISK indoor air quality model. The air exchange rate for the home was estimated using the mean regional data gathered by Murray and Burmaster (1995) of 0.59 air exchanges per hour. The volume of the residence and each room was computed based on information available from the floor plans found in Appendix D.

Results/Discussion

As predicted, concentrations of SF_6 were highest in the source rooms when the HVAC system was not in use and room concentrations throughout the residence were nearly identical when the HVAC system was on (Figures E 19, E 20, and E 21). The concentrations in the upstairs bathroom (Figure E 19) were relatively high when the source was downstairs due to a laundry shoot that connected to the laundry room that was near the kitchen. Additionally, concentrations in the upstairs hallway (Figure E 19) were high when the source was in the main floor living room since the hallway overlooks the main living room (there is no wall between the rooms). Measurements from side areas of the main living room (north and west) indicated that without the HVAC system running, the rooms are not well mixed.

When the SF_6 source was located in the upstairs bedroom, room concentrations varied significantly based on sampling location. These results indicated that without running the HVAC system, the system was diffusion limited (mixing was likely caused by air currents created from temperature differentials), and room entrances and exits (e.g., windows and doors) often acted as boundaries for mass transfer of the source gas. Since the well mixed assumption used in most current models does not apply in a residence without the HVAC system in use, additional studies must be performed to determine the necessary parameters for developing an effective computational model.

When the HVAC system was used, air was mixed throughout the residence causing rooms to be well mixed and concentration measurements to be more uniform over time. This was indicated by the decrease in the 95 percent confidence interval levels when the HVAC fan was turned on as compared to when it was off. Since the well mixed assumption is satisfied when the HVAC system is in operation, the RISK model can be used for modeling in that situation.

While measuring room concentrations the first time with the source in location two and the HVAC fans in use, it was observed that the downstairs office window was open. Since air was flowing more easily into and out of this room, the concentrations in the downstairs office were lower than those performed the second time that the source was in location two. Further, SF_6 gas escaped through the open window in the downstairs office which depressed air concentrations by nearly 300 ppbv the other rooms when the fan was turned on. Since mixing is minimized when the HVAC system is off, this difference between the two sampling events with the source in location 2 was not as pronounced when the fans were off.

Measurements were performed in the upstairs south bedroom to determine the air exchange rate for the room with and without HVAC system use. After 45 minutes, concentrations reached their peak of 3,342 ppbv. The next 55 minutes were used in determining the natural air exchange rate of 0.720 per hour from the room (Figure 15). Based on the floor plans shown in Appendix D, the room was calculated to have a volume of 36.2 m^3 and the volumetric air exchange rate was 26.05 m^3 per hour. After this stage of sampling, the HVAC system was activated and additional measurements were recorded, and the resulting air exchange rate (Figure 16) was 5.035 per hour (182.3 m^3 per hour).

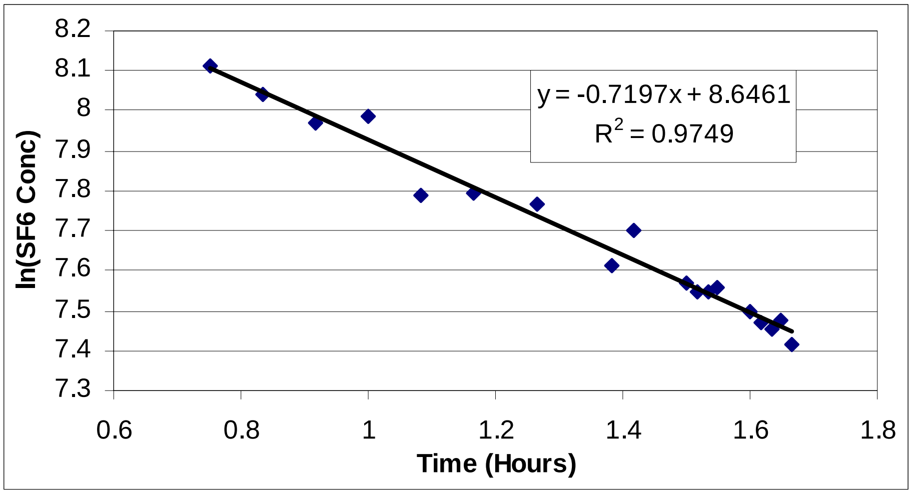

Figure 15. Log of the SF_6 concentration versus time for the upstairs south bedroom of UWRL-1 without operating HVAC fans.

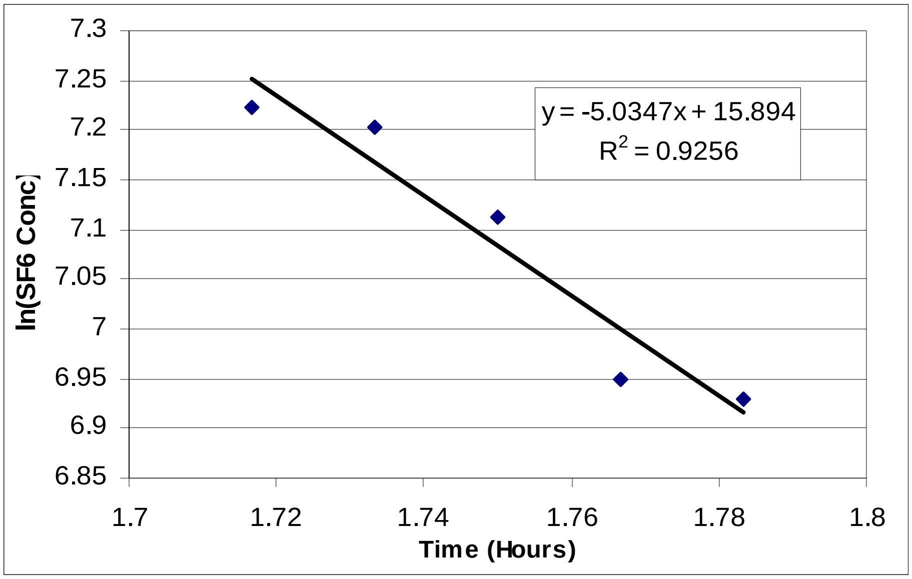

Figure 16. Log of the SF_6 concentration versus time for the upstairs south bedroom of UWRL-1 with operating HVAC fans.

Results show that by not operating the HVAC system, air exchanges in a room can be decreased significantly, by a factor of seven in this test residence, indicating that not operating the HVAC system will significantly reduce mixing. These results further validate the testing strategy to reduce mixing used for this thesis research.

The RISK model was used to determine if model would predictions of indoor air concentrations would be similar to those measured at UWRL-1. The model operating parameters included a source emission rate of 14 mg/min of SF_6 and an air exchange rate of 0.59 exchanges/hour. Room volumes (Table 10) were calculated from the floor plans shown in Appendix D. HVAC system flows for individual rooms were assumed to be similar to the calculated value for the upstairs South bedroom and were normalized to each room’s volume. Air flow into each room bordered by only one room was assumed to entirely from the HVAC system, and air flow out was assumed to travel to the adjoining room. HVAC system return flows were established in the main and downstairs living room. A complete list of HVAC system flows can be found in Table 11.

Two scenarios were used, one for each source location. The time step for each scenario was 24 hours to compensate for problems associated with small time steps. Initial indoor air concentrations were set equal to those measured prior to running the HVAC fans for each source location. Results (Figures 17 and 18) were significantly different from measured concentrations.

Measured values were almost 10 times higher than predicted when the source was in location two and three times higher that predicted with the source in location one. The air exchange rates were varied to determine if modifying the rate would change the predicted values; however, results indicated that changing the air exchange rate did not significantly change results.

Additionally, HVAC air flow rates were modified to try and fit the model to measured values. After modifying values multiple times, it was determined that despite large changes in HVAC flows, predicted data still did not fit measured values. It is interesting to note that although the model was set to the measured initial room concentrations, initial model predictions (0.1 hours) were significantly lower than the measured conditions. It is possible that this is caused by the difficultly of the model to handle short time steps, and it would be recommended to perform residence measurements of SF_6 concentrations at time steps beyond one hour to determine if model predictions and actual measurements would converge. Further it is also recommended that HVAC flow measurement studies be performed for three or more rooms in the residence to determine if the assumptions made were representative of the residence.

Table 10. UWRL-1 room volumes used in the RISK model

Number	Room	Room Volume (m^3)
1	Main Bedroom	53.2
2	Main Living	99.6
3	Main Kitchen	110.8
4	US* North Bedroom	34.3
5	US South Bedroom	46.7
6	US Bathroom	15.1
7	US Hallway	47.5
8	DS** Office	32.6
9	DS Living	85.4
10	DS Bedroom	33.9
11	DS Weight Room	32.6
	Total	591.7

* US = Upstairs ** DS = Downstairs

Table 11. UWRL-1 HVAC flows used in the RISK model

Number	Room	HVAC Flows, m^3/hr			
		HVAC Supply	HVAC Return	Air Transfer Out of Room	Air Transfer Into Room
1	Main Bedroom	268	0	268	0
2	Main Living	502	993	502	993
3	Main Kitchen	558	0	558	0
4	US* North Bedroom	173	0	173	0
5	US South Bedroom	235	0	235	0
6	US Bathroom	76	0	76	0
7	US Hallway	239	496	239	496
8	DS** Office	164	0	164	0
9	DS Living	430	750	430	750
10	DS Bedroom	171	0	171	0
11	DS Weight Room	164	0	164	0

* US = Upstairs
** DS = Downstairs

If additional testing mentioned previously determines that the model can accurately predict measured values, the model could then be used to determine threshold emissions which would be above Hill AFB's MAL. Since historic sampling performed by Hill AFB is done with the HVAC system in use, the model would give levels that that would be above the MAL for this residence. These values could then be scaled to yield threshold emissions of potential sources in future residences.

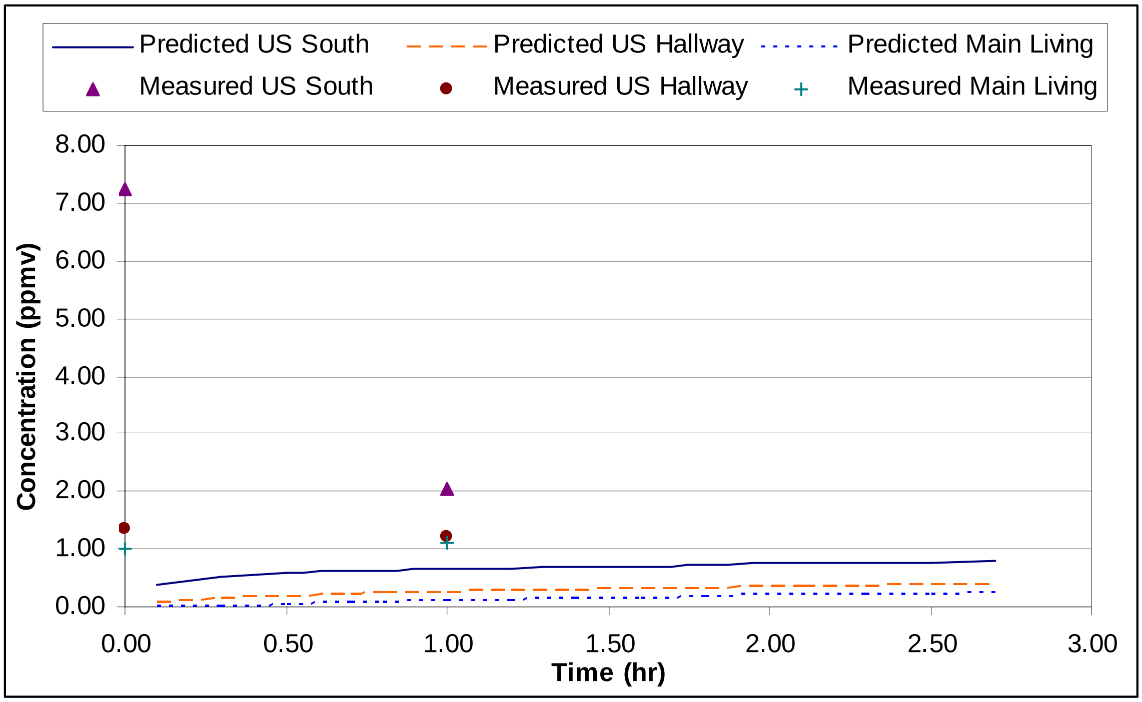

Figure 17. RISK calculated SF6 concentrations with a source in location one
US = Upstairs, DS = Downstairs.

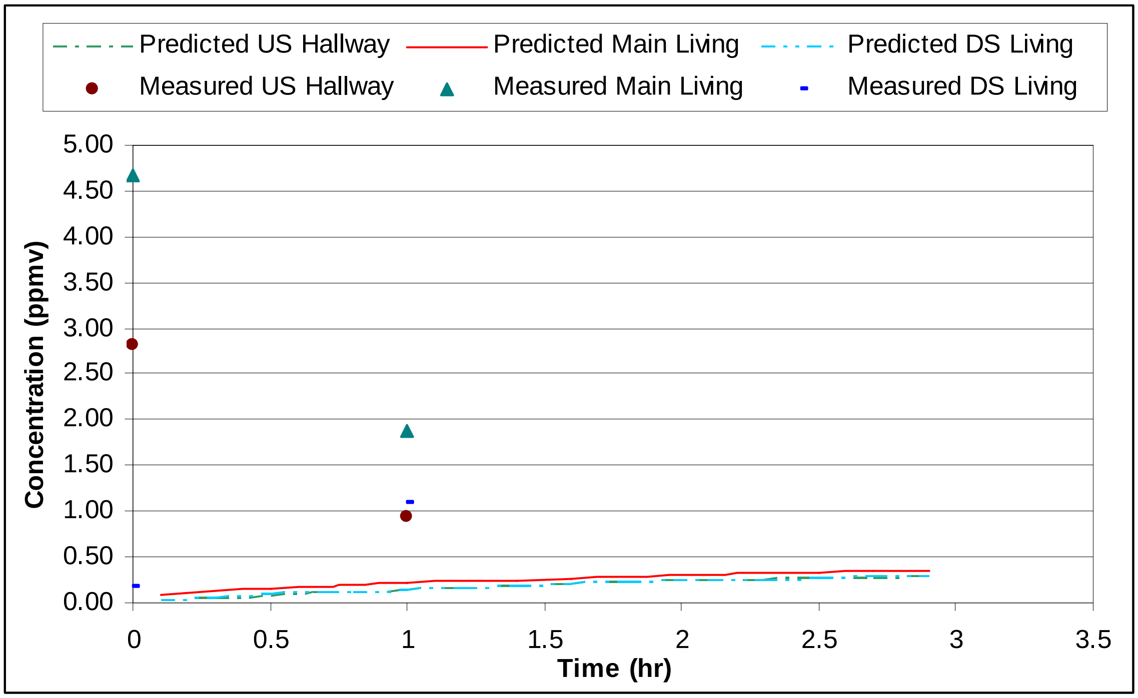

Figure 18. RISK calculated SF6 concentrations with a source in location two
US = Upstairs, DS = Downstairs.

Summary/Conclusion

A model residence was selected for determining the importance of HVAC system operation in locating a source room. Room air exchange rates were determined for a small room based on HVAC system use. Results indicated that by not operating the HVAC system in a residence, source rooms can be separated from others. Measurements show that HVAC fans will mix a room, however when the fans are not in operation, air concentrations vary based on location to the source.

Further measurements indicate that air concentrations throughout the residence are based on diffusion and air currents caused by temperature differentials when the HVAC system is in use. Air exchange measurements in the upstairs South bedroom further showed that by not operating the HVAC system mixing within a room can be significantly decreased.

The overall results from the residence indicate that despite reducing mixing, a source effects air concentrations throughout a residence. Reducing mixing does cause concentration gradients that do allow samplers to identify rooms with significant sources from others. These results confirm that the testing strategy developed for this thesis is feasible for use in determining indoor sources of COC.

The EPA RISK model was used to determine if modeled values correlated with measured values. Model results did not correspond with measured values, and discrepancies could be due to flaws in the room-to-room HVAC air flow rate assumptions, and the fact that residence measurements were only performed at one hour. It is recommended that further testing over time be performed to determine if the assumptions made were realistic and if the predicted results would match measured values for times greater than one hour. Additionally, it is recommended that the model residence be used again to test conditions that are similar to those seen in the field (start the source with the HVAC system in operation).

ROOM-BY-ROOM SAMPLING

Results/Discussion

Sampling was conducted at eight residences located near Hill AFB and identified as U12-8017, U8-8211, U2-8003, U8-8050, U8-8170, U8-8244, U6-8016, and U8-8452 (Figure 2). Each residence is addressed individually since each presented different potential sources.

A complete list of the data for indoor air sampling can be found in Appendix G. Floor plans of each residence and the concentrations measured in each room can be found in Appendix E. Emission data from source objects located though sampling efforts can be found in Appendix H. MDLs for each sample varied based on air flow rate used and time sampled, and ranged from 0.005 to 0.013 ppbv for TCE, 0.005 to 0.012 ppbv for 1,2 DCA, and 0.001 to 0.003 ppbv for PCE.

U12-8017

Residence U12-8017 is located in Roy, Utah, above the Operable Unit (OU) 12 contamination plume. Previous sampling conducted by Hill AFB indicated that TCE was the only compound of concern for this residence. The TCE concentrations in the indoor air varied during most of the sampling events. After mid August of 2007 (after sampling for this thesis was performed), concentrations were below the MDL which coincided with the removal of a predicted indoor source (Figure 19).

Sampling for this thesis research began on June 28, 2007 and concluded on August 18, 2007 after two sampling visits. Results from both sampling visits did not indicate a room of interest (Figures E 1 and E 2); however, samples of multiple cleaning supplies were collected on August 18, 2007, to determine whether the contamination was due to cleaning product use. Aliquots (1:10 dilution) of the products were run on GC/MS using a Full Scan method that was not quantified. TCE was detected in sample number seven which corresponded to Del Glitter Polish. The resident had occasionally used the product as a furniture polish. TCE was not detected in any of the remaining samples. A 1 µL dilution (1:11) of the liquid was injected onto a Tenax© tube showed that the product contained 22.11 mg/L TCE.

Emission measurements were not performed on the product because the homeowner disposed of the product after it had been determined to be a potential source of TCE in the residence. Further, the concentration of TCE in the room which contained the product was not significantly higher than the surrounding rooms indicating that emission from the product container was minimal. After removal and discontinued use of the furniture polish, further testing performed by Hill AFB confirmed that TCE levels in the residence had dropped to below the MAL (Figure 19). These results suggest that the source had been removed and that the furniture polish was the likely source.

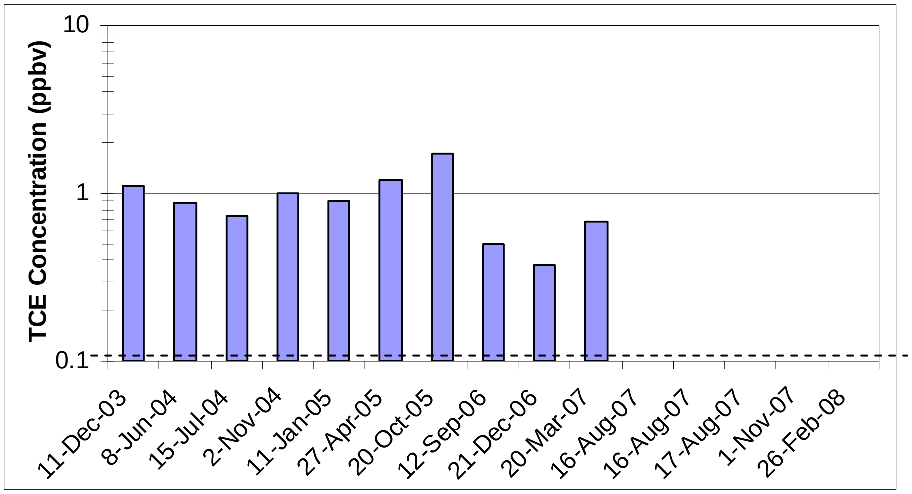

Figure 19. Historic indoor air TCE air concentrations for U12-8017 dashed line represents the MDL of 0.14 ppbv.

Sampling efforts from U12-8017 indicated that samplers need to be proactive in understanding product use in the home to determine non-point sources of COC. Room-by-room sampling did not identify the room where the furniture polish was stored (the utility room). It is predicted that emission of TCE from the container was not as significant as volatilization of the liquid after application. However, further sampling could not be conducted to confirm this assumption since the homeowner disposed of the product and it is no longer manufactured and available for consumer purchase.

U8-8211

Residence U8-8211 is located in Layton, Utah, above the OU 8 contamination plume. Hill AFB's historic sampling indicated that 1,2 DCA was the main contaminant of concern for the residence (Figure 20). After August of 2007, concentrations were below the MDL coinciding with the removal of the predicted source (August 2007) identified during the middle of sampling activities for this thesis research.

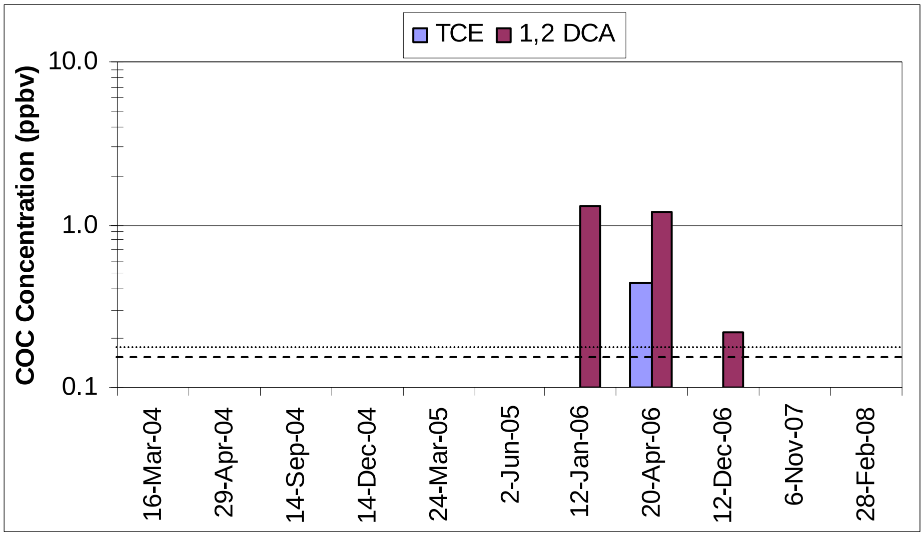

Figure 20. Historic indoor air TCE air concentrations for U8-8211 dashed line represents MDL for TCE of 0.13 ppbv dotted line represents MDL for 1,2 DCA of 0.17 ppbv.

Sampling at residence U8-8211 for this thesis research began on August 16, 2007 and concluded on May 13, 2008 after seven sampling visits. The highest levels of 1,2 DCA were found in the basement level under the stairs that was used to store luggage, paint cans, a wedding dress, costumes, and various other objects. After this visit, the resident removed the items in the storage area and placed them in a shed located outside the residence. Return sampling events indicated a decrease of 1,2 DCA in the indoor air throughout the home and beneath the stairs where the initial source was suspected to reside (Figures E 3, E 4, and E 5).

Suspect source items which had been removed (paint cans, make-up from the costume boxes, etc.) were sampled and brought back to the laboratory for analysis. GC/MS analysis indicated that none of the products sampled contained measurable amounts of any of the COC. During a repeat sampling event, the air inside a wedding dress box found beneath the stairs was sampled and GC/MS analysis determined that 1,2 DCA was present in significant amounts within the box.

It was suspected that the wedding dress which had been dry-cleaned 12 years earlier was the source and that 1,2 DCA was a contaminant in dry-cleaning solvent used. After the dress was determined to be a potential source of 1,2 DCA contamination, PCE (a common dry-cleaning agent) was added to the COC list (prior sampling had not attempted to detect PCE). Additional sampling of the dress box indicated that the box contained higher levels of PCE than 1,2 DCA; however, concentrations of PCE determined from Hill AFB's sampling and repeat sampling conducted for this thesis research did not show significant amounts of PCE in the indoor air of the residence.

An initial emission chamber was developed to determine the emission of 1,2 DCA and PCE from the dress. The emission chamber had not yet been modified to ensure that the air was well mixed and was still in the initial stages of development. Additionally, the dress could not be sub-sampled since the resident wanted the dress returned and the dress sections (top and bottom) had to be inserted into the chamber.

The top dress section had a surface area of 1.31 cubic meters and the bottom dress section had a surface area of 8.05 cubic meters. Due to the large surface areas of the dress sections relative to the size of the initial emission chamber, it is doubtful that the entire surface area was subject to air flow and mixing, but due to concern of potential damage to the dress, no further steps could be taken to obtain a more realistic emission rate. The dress was placed in the emission chamber and sampled multiple times over a 120 day period. Between sampling events, the dress was aired out in a separate room and a small fan was used to circulate air around the dress to facilitate desorption of the COC from the dress. Although 1,2 DCA was being emitted from the dress, sample masses obtained were always below the MDL. Sampling also indicated that the emission of PCE from the dress decreased over time (Figure 21); however, it did appear that the emission rate was approaching a steady state situation.

Although there were many emission rates determined from this initial chamber that may not have been entirely realistic, data obtained did indicate that the dress was acting as a source for the residence. It is likely that the cardboard box which was used to store the dress decreased the emission rate from the dress and that even the suppressed values determined with the initial emission chamber were higher than those actually occurring in the residence. Despite problems associated with determining an actual emission rate from the dress, sampling did indicate that the dress was emitting less after removal from the box. Additionally, problems with the initial emission chamber were pointed out by dress sampling and were addressed with subsequent versions of the emission chamber.

Samples of the box were taken and analyzed using the methods mentioned above with the GC/MS in Full Scan Mode. Results from initial box sample analysis indicated the presence of 1,2 DCA and PCE in the box and suggested that PCE concentrations were higher than 1,2 DCA concentrations; however, the results were not quantified because a standard curve had not yet been developed for the cardboard. The higher concentrations of PCE in the box could be due to size and weight differences of 1,2 DCA and PCE which caused the larger and heavier PCE to stay trapped within the box. Further, the vapor pressure and Henry’s Law coefficient of 1,2 DCA are higher than those of PCE and therefore 1,2 DCA is more volatile.

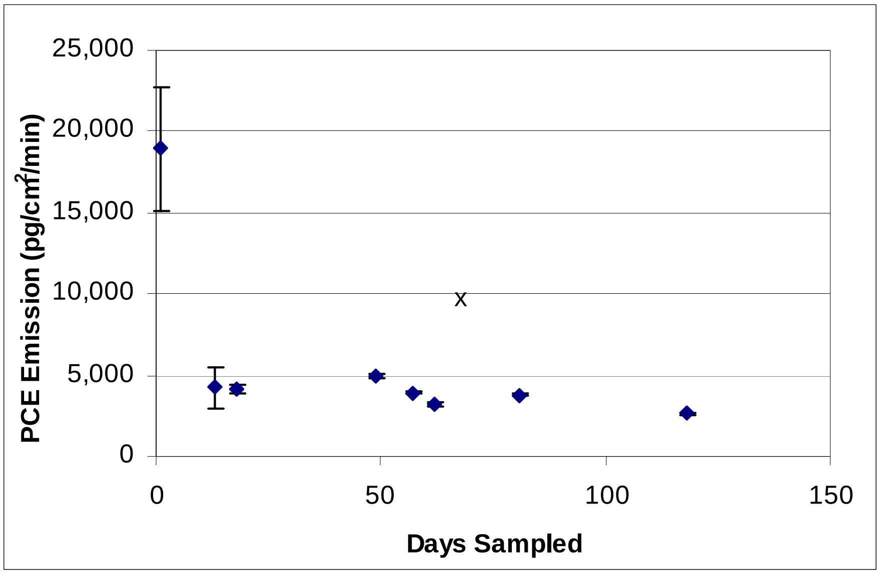

Figure 21. PCE emissions of the wedding dress found at U8-8211 error bars represent 95 percent confidence interval of samples.

It is predicted that most of the 1,2 DCA had off-gassed from the dress prior to emission chamber sampling. After removal of the dress and dress box from the residence, additional samples of the box were taken. COC were not detected on these repeat samples. It is likely that during the time between the full scan sampling of the box and the quantification scan of the box, the remaining 1,2 DCA and PCE had off-gassed since the box had been opened and exposed to fresh air and the dress had been removed.

A 100 percent polyester dress and two 100 percent silk shirts were purchased from a thrift store in order to simulate the fabrics from the wedding dress. The fabrics were dry-cleaned and one silk shirt and half of the dress were preserved in a dress preservation box similar to the one used for the wedding dress at U8-8211, while the other silk shirt and half of the dress were placed on hangers to determine differences in PCE emission based on preservation techniques. The fabrics were cut into 8.5 inch by 11 inch (21.59 cm by 27.94 cm) pieces for sampling in the emission chamber.

Fabric emissions were significantly less than those of the wedding dress found at U8-8211. The initial emission measurements of the polyester fabrics were the highest at 131.55 pg per cm^2 per minute for the fabric on a hanger and 159.93 pg per cm^2 per minute for the fabric in the box. PCE emissions from the dress did decrease over time (Figure 22) as expected. Emissions from the silk fabric were less than those of the polyester fabric both hanging up and inside the dress box.

Additionally, a section of the dress had beading which was tested 7 days after dry-cleaning. The beaded section emitted 150.88 pg per cm^2 per minute for the fabric on a hanger and 132.53 pg per cm^2 per minute for the sample in the box. These values were higher than similar sections of the dress without beading that were sampled at the same time (Figure 22). There was more beading on the U8-8211 dress than the fabrics sampled, which could have contributed to the differences in emission values observed. Sampling of the fabrics in the box did indicate that storing dry-cleaned fabrics in preservation boxes limits off-gasses and acts to maintain higher PCE levels within the dress and box. In hindsight, it would have been effective to purchase beading similar to the U8-8211 dress and subject it to dry-cleaning with PCE solvents to determine the amount of PCE emitted over time by similar beads.

Sampling efforts at U8-8211 confirmed that room-by-room sampling could be successful in determining a point source of contamination. Additionally, efforts confirmed that removal of objects in a suspected area of contamination indicate whether the source has been removed. Additional sampling of the removed materials pointed out the potential difficulty when multiple objects could be potential sources or if many objects must be removed in order to determine a source.

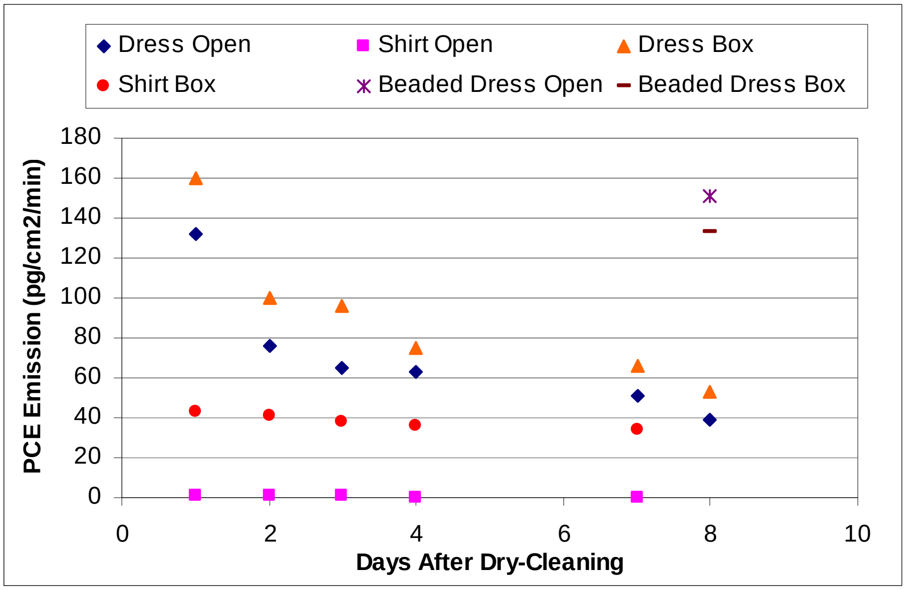

Figure 22. PCE emissions from dry-cleaned fabrics over 7 days.

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Efforts additionally indicated that room-by-room testing of future residences could be time and analytically intensive, and therefore cost prohibitive, since multiple return visits were necessary. Sampling of dry-cleaned fabrics also indicated that plastic beading and storage of the dress in a preservation box was partially the cause of high emission values from the U8-8211 wedding dress. In hindsight, it would have been helpful to compare emissions dry-cleaned materials to those that were immersed in PCE and allowed to dry to determine if elevated emissions from the wedding dress were due to spot treatments with PCE. It would also be recommended that research be done on the differences in purities of dry-cleaning solvents used in the time period when the dress was dry-cleaned and if possible, a sample of older dry-cleaning solvent be used to perform further tests.

U2-8003

Residence U2-8003 is located in South Weber, Utah, above the OU 2 contamination plume. Sampling conducted by Hill AFB at U2-8003 indicated that PCE was the contaminant of interest for this residence (Figure 23). Although sampling results were lower than the MAL of 1.2 ppbv for PCE, this residence was of interest due to resident concern about PCE detections.

Sampling for residence U2-8003 began on September 24, 2007. High concentrations of PCE were observed in the 2nd floor bathroom (Figures E 6 and E 7). During the return trip (performed on October 14, 2007), triplicate air samples were obtained from the bathroom and main areas of the residence and eight liquid samples were taken from products stored in the bathroom. Air samples confirmed the high levels in the bathroom; however Full Scan method product sampling did not indicate that any products contained PCE, suggesting that none of the products were indoor sources.

Groundwater sampling results obtained by Hill AFB near the area did not point to the presence of PCE in significant quantities rather, TCE was the main contaminant. This implies that if VI was occurring, TCE would be the expected COC in the home, which was not the case. Since no conclusive results were obtained, Hill AFB decided to install a VRS at the request of the homeowner. PCE levels did not drop after installation of the VRS (continued sampling by Hill AFB reported levels of 0.58 and 0.14 ppbv). Since PCE has continued to be detected in the indoor air of the residence after VRS installation, it is recommended that an additional round of product sampling be conducted focusing on products that are primarily used in the bathroom, but are not stored in the bathroom.

Sampling efforts at U2-8003 indicated that room-by-room sampling was not without failings. Even when sampling efforts indicated a room of interest which had a high potential for containing an indoor source, sampling did not locate any potential sources.

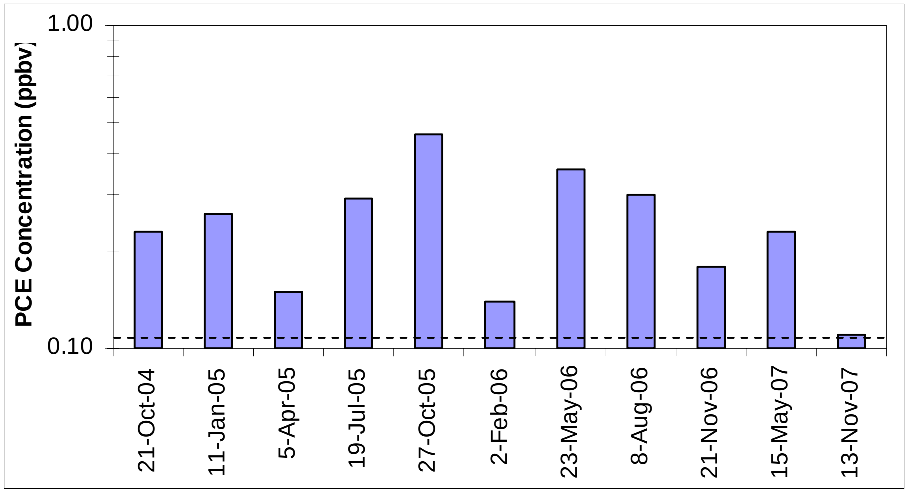

Figure 23. Historic indoor air PCE concentrations at U2-8003 dashed line represents MDL of 0.105 ppbv.

Sampling results after the installation of the VRS further suggested that the contaminants were caused by an indoor source. Although room-by-room sampling is effective in determining a room of interest, identifying a specific source of the COC can be difficult. It is suggested that an additional round of sampling be conducted to determine if products used in the bathroom, but that are not stored in the bathroom could be the source of contamination.

U8-8050

Residence U8-8050 is located in Layton, Utah, south of Hill AFB above the OU 8 contamination plume. Historic sampling performed by Hill AFB indicated that 1,2 DCA was the primary COC for the residence (Figure 24) due to recent indoor air sampling. TCE was potentially of interest, however indoor air concentrations decreased below the detection limit after installation of a VRS that occurred prior to August of 2005. Since a VRS had been installed it was predicted that 1,2 DCA detections were caused by one or more indoor sources.

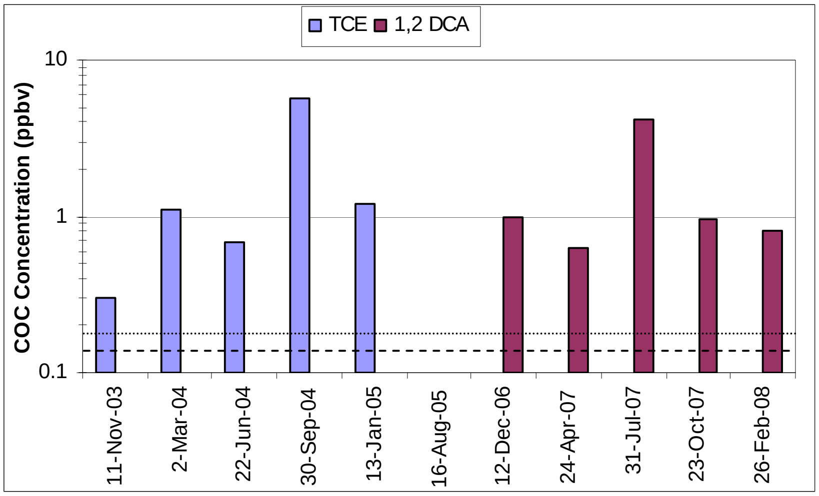

Figure 24. Historic indoor air TCE and 1,2 DCA concentrations at U8-8050
dashed line represents MDL of TCE of 0.14 ppbv
dotted line represents MDL of 1,2 DCA of 0.18 ppbv.

Sampling for residence U8-8050 for this thesis research (performed on September 26, 2007 and October 31, 2007) indicated significant amounts of 1,2 DCA in the basement bathroom and den (Figures E 8 and E 9). The return visit confirmed the location of 1,2 DCA, however there were no apparent sources of contamination.

None of the solid and liquid samples obtained contained measureable amounts of the COC. It was hypothesized that sealants used in a large fish tank which was stored in the den could be the source of the contamination; however, due to difficulty in reaching the homeowner for further sampling events, none could be scheduled. Although sampling efforts at U8-8050 were not successful in determining a source of 1,2 DCA contamination, they did provide useful information for future sampling efforts. The homeowner's lack of interest in results made sampling difficult to arrange. For successful source determination in a private residence, it is important to have a resident with interest in the results as well as one that is willing to be contacted.

U8-8170

Residence U8-8170 is located in Layton, Utah, south of Hill AFB above the OU 8 contamination plume. Sampling performed by Hill AFB indicated that 1,2 DCA was the primary COC for U8-8170 (Figure 25).

Sampling began on February 7, 2008 and concluded on June 27, 2008 after two sampling visits. The first sampling visit did not lead to the determination of a room of concern since the HVAC system had been active throughout the day which mixed the residences' air. Results from the second sampling visit indicated that the indoor air concentrations had risen significantly from the previous visit with indoor concentrations ranging from 2 to 12 ppbv (Figures E 10, E 11, and E 12). The upstairs and main floor had the highest concentrations of 1,2 DCA; however, the relative small differences in concentration between rooms did not clearly indicate a potential source room.

Since the collected data were not sufficient to determine a room of interest or products to be sampled, additional sampling visits were not scheduled. It is likely that current product use is contributing to overall residence concentrations of 1,2 DCA. Hill AFB is in the process of obtaining a portable GC/MS unit which they are planning to use in this residence to further investigate potential sources. Sampling efforts at U8-8170 indicated that there could be potential problems in the sampling protocols. Although the resident confirmed that the HVAC system had been shut off and that movement had been restricted, no source room could be determined. It is recommended that when a room of interest cannot be determined that products used throughout the residence be tested to determine if product use is the cause of COC detections.

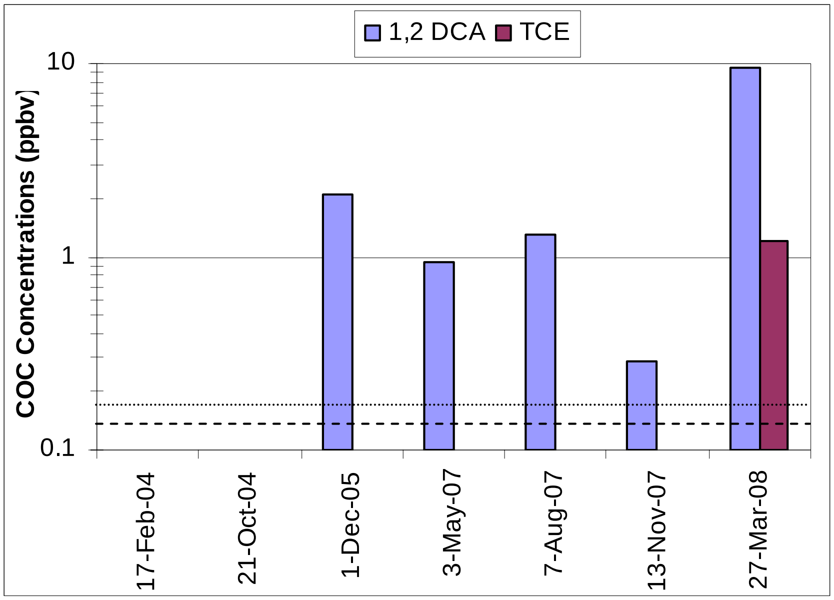

Figure 25. Historic indoor air TCE and 1,2 DCA concentrations at U8-8170 dashed line represents MDL of TCE of 0.14 ppbv dotted line represents MDL of 1,2 DCA of 0.17 ppbv.

U8-8244

Residence U8-8244 is located in Layton, Utah, south of Hill AFB above the OU 8 contamination plume. Historic sampling performed by Hill AFB indicated that 1,2 DCA was the primary COC for U8-8244 (Figure 26). Indoor air concentrations from sampling on July 31, 2007 were significantly higher than previous samples causing interest in this residence.

Sampling began on February 12, 2008 and concluded on May 28, 2008. Similar to residence U8-8170, the initial sampling event was not used in determination for a source location due to mixing caused by the HVAC system. A second sampling visit was performed after ensuring that the HVAC system was off for at least 3 hours. Results from this sampling effort (Figures E 13 and E 14) indicated that the garage was a room of interest.

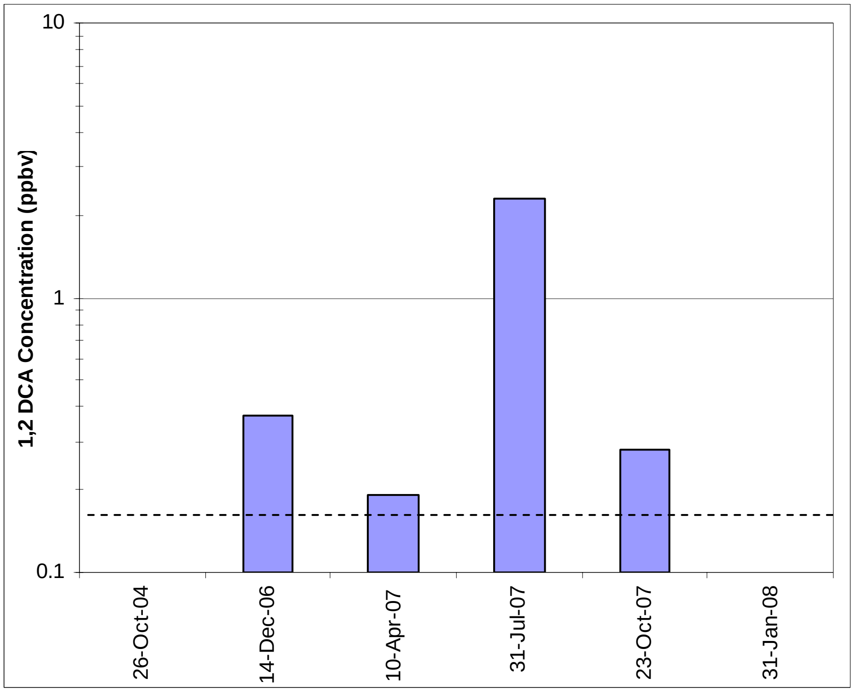

Figure 26. Historic indoor air 1,2 DCA concentrations at U8-8244 dashed line represents MDL of 0.17 ppbv.

Although sampling did indicate a room of interest, no repeat sampling visits were performed due to difficulties in scheduling with the homeowner. Even though the homeowner was interested in the results, cancellations of sampling appointments and difficulty in contacting the homeowner made repeat sampling extremely difficult. Due to this difficulty, sampling efforts focused on residences that were less problematic.

It is recommended that future sampling for this resident be scheduled such that sampling could be performed in one day such that repeat visits and therefore repeat cancellations can be avoided. Additionally, if repeat visits are conducted, it is recommended that samples of multiple areas in the garage be obtained to determine an area of interest within the garage. These results could then be used to select products that will be sampled to determine potential sources.

U6-8016

Residence U6-8016 is located in Riverdale, Utah, north of Hill AFB above the OU 6 contamination plume. Historic sampling performed by Hill AFB indicated that TCE was the contaminant of concern for U6-8016 (Figure 27). After initial sampling performed by Hill AFB it was determined that this residence had a potential for VI to be occurring and a VRS was installed. Further sampling determined that TCE was still present in the residence. Continued investigation performed by Hill AFB determined that a model glue which was being used by the resident had listed TCE as an ingredient. After removal of the glue, the TCE concentrations still persisted in the residence. It was presumed that these continued detections of TCE were due to an additional indoor source which had not been identified.

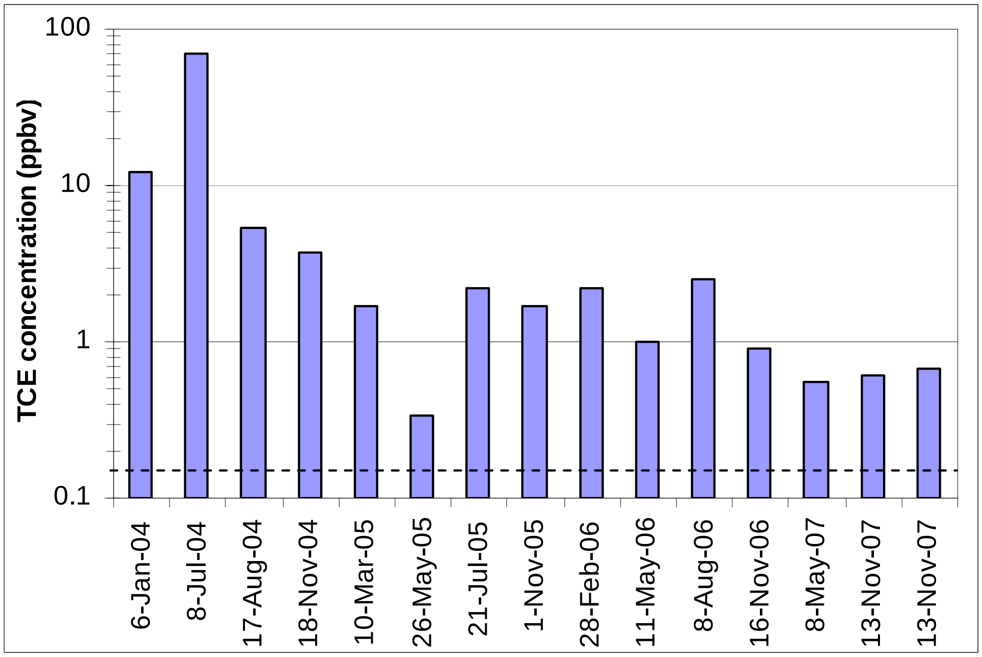

Figure 27. Historic indoor air TCE concentrations at U6-8016
dashed line represents MDL of 0.13 ppbv.

Sampling began on February 19, 2008 and concluded on June 24, 2008 after three sampling visits. Results were not conclusive in determining a room of interest (Figures E 15 and E 16). It was predicted that even though the HVAC system had been inactive for several hours prior to the first sampling visit, the residence air was still relatively well-mixed similar to other residences mentioned earlier (U8-8244 and U8-8170). Additional sampling visits performed after the HVAC system was turned off still did not provide conclusive results indicating a room of interest.

The second visit to the home included sub-slab sampling. Two holes were drilled through the basement slab; however there was some doubt concerning complete penetration of the slab, and sampling tubes contained high levels of bromodichloromethane indicating that the bentonite seal had leaked. Although there was leakage, the sub slab Tenax© tubes did contain TCE levels that were approximately 100 times larger than those from the rest of the residence indicating that VI could be occurring. Further, indoor air concentrations dropped nearly one order of magnitude from previously measured values which cast some doubt on the ability to locate a room of interest.

Since bromodichloromethane was detected in the sub-slab samples, a repeat sampling event was conducted to ensure that the slab was penetrated and a true sub-slab sample was obtained. Additional holes were drilled near the previous locations, and one of the samples (in the workshop) did not contain any bromodichloromethane indicating that the slab was penetrated; however TCE concentrations in each of the samples were lower than those in the indoor air. Since previous sampling contained measureable amounts of bromodichloromethane, it is likely that the associated concentrations of TCE that were 100 times higher than indoor air measurements were likely not true sub-slab sampling results. The sub-slab sample for the workshop was below the MDL indicating that indoor concentrations of TCE were not influenced by VI at the time of sampling.

Indoor air concentrations of TCE were highest in the model room that contains hundreds of models that have been assembled by the homeowner. Many of the models were assembled with glue that contained TCE. A model and the same glue that the resident used were purchased. The air directly above the glue was sampled and TCE was not detected. Additionally, the MSDS sheet for the glue no longer includes TCE as an ingredient, indicating that the manufacturer has changed the glue’s formulation.

It is likely that each of the models that were assembled with the TCE containing glue is acting as a point source of TCE. Based on the decrease in historic concentrations, it is assumed that their emissions are slowly decreasing. Over time, these emissions will approach zero, causing indoor air concentrations to decrease further until they are below the MDL. It is recommended that the homeowner place several of these models in boxes within the residence, and the air within the boxes be tested to determine if the models are emitting significant amounts of TCE.

U8-8452

Residence U8-8452 is located in Layton, Utah, south of Hill AFB above the OU 8 contamination plume. Historic sampling performed by Hill AFB indicated that 1,2 DCA was the contaminant of concern for this residence (Figure 28). 1,2 DCA concentrations have increased significantly since initial testing performed by Hill AFB. Since Hill AFB groundwater testing indicated that TCE was more abundant that 1,2 DCA it was predicted that there was an indoor source of 1,2 DCA in the residence.

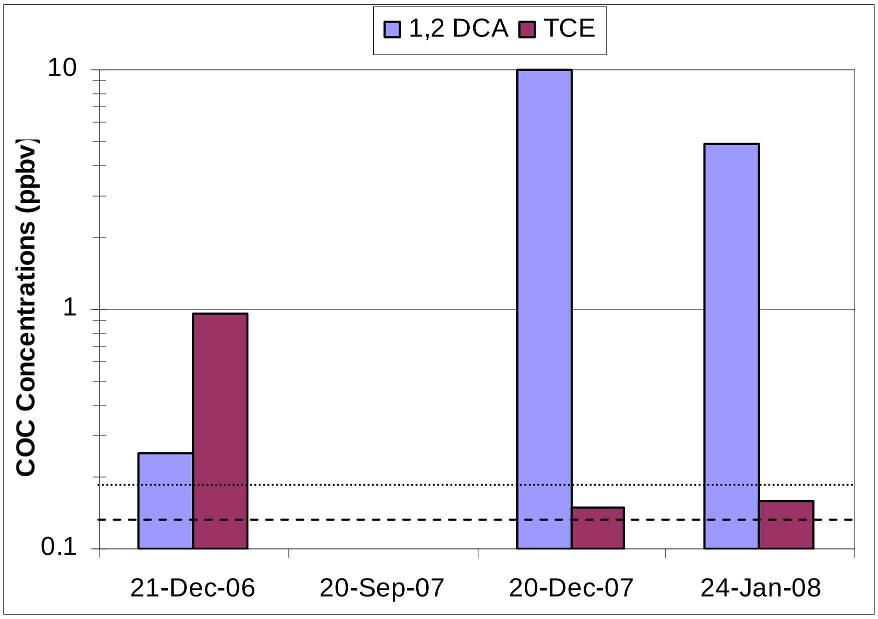

Figure 28. Historic indoor air TCE and 1,2 DCA concentrations at U8-8452
dashed line represents MDL of TCE of 0.13 ppbv
dotted line represents MDL of 1,2 DCA and 0.18 ppbv.

Sampling for this thesis research began on May 20, 2008 and concluded on July 17, 2008 after five sampling visits. Initial results indicated that concentrations were highest in the northwest room in the basement (Figures E 17 and E 18). Items were transferred from that room to the garage and sampling was repeated 3 days later. After this visit, half of the items removed were returned to the basement room and areas were sampled again 2 days later.

Results from the removal sampling indicated that the source or sources were contained in boxes removed from the room (primarily Tupperware #3). The boxes that had been stored in the Northwest room were placed in a shed behind the residence for storage. Removal of the boxes resulted in indoor air concentrations that were below Hill AFB's MAL.

Items from Tupperware #3 were removed and tested in the emission chamber developed for this thesis research. Emission measurements indicated that a small hand-painted Christmas ornament (surface area of 72.6 cm^2) was emitting 2,644 ng of 1,2 DCA per minute with a 95 percent confidence interval of 34.2. All other objects tested did not emit significant amounts of 1,2 DCA. Since many of the boxes in the northwest basement room did contain Christmas decorations, it is likely that other ornaments were also emitting significant amounts of 1,2 DCA; however, additional ornaments were not tested from this residence. Portions of the ornament were also sampled to determine the source of the 1,2 DCA. Sampled portions included: red and white paint, dark brown paint, light brown lacquer, and the inside material of the ornament. Samples were weighed prior to extraction. The paints and lacquer were extracted by placing the samples in 3 mL of methanol, and 5 mL of methanol were used for the inner samples.

One-µL aliquots of the methanol were spiked onto Tenax© tubes that were analyzed using the techniques mentioned previously. 1,2 DCA concentrations were highest in the inner material (Table 12). It is possible that the 1,2 DCA in other samples was primarily from the inner material since some of it was removed with each sample.

Sampling at U8-8452 confirmed that room-by-room sampling can be used effectively to determine a room of interest that may contain potential sources. After removal of objects in the room, concentrations decreased significantly, indicating that the source had been removed. Further, since it is likely that sources can be found in storage areas as was the case in U8-8452, it may be difficult to determine an exact source. Boxes were sampled according to the samplers' best judgment for potential sources, which led to multiple boxes with similar contents.

Conclusion

Room-by-room sampling is effective for determining significant indoor point sources of the COC. Sampling at U8-8211, and U8-8452 indicated a room or rooms of concern which led to the identification of indoor sources for each residence. Sampling at U12-8017 did not indicate a room of concern but did lead to testing various household cleaners and products that had been used throughout the home that located a source.

Table 12. Concentrations of 1,2 DCA in portions of the U8-8452 ornament

Sample	Concentration (mg 1,2 DCA per g sample)	95 Percent Confidence Interval
Red/White Paint	0.362	0.148
Dark Brown Paint	0.738	0.285
Light Brown Lacquer	0.625	0.064
Inner Material	2.333	0.424

Throughout sampling efforts, several factors have emerged as being important in successful determination of indoor sources of COC. First, the homeowner must be interested in the results or at least be willing to submit to multiple sampling efforts. At U8-8050 and U8-8244, there was difficulty in contacting the homeowner and frequent cancellations of programmed sampling visits, and repeat sampling became nearly impossible. Second, the source must be “significant.” This means that the source or sources must be able to influence one room more than another (so that a room of interest can be determined) and must reach measureable concentrations. Additionally, since non-point and small point sources can cause multiple rooms to have high concentrations of COC or a mix of concentrations within a room (rather than a defined removable source), it is difficult to determine non-point sources through room-by-room sampling. When residence concentrations are approximately equal in multiple rooms of a residence and an indoor source is suspected, sampling of cleaning and other products which are used throughout the residence should be performed in order to determine whether they could be potential sources. Although this product sampling is recommended, efforts would likely be time and analysis intensive since initial sampling may not lead to the source (see results for U2-8003). To reduce these problems, it is further recommended that a portable GC/MS be used to sample the air above or around potential sources to reduce the amount of products that need to be sampled.

Sampling efforts also indicated that while effective in some situations, room-by-room sampling does not always result in source identification. Where product sampling is required, sampling efforts may not always be able to locate a source (see U2-8003) Further, when VI is the primary source of indoor air contamination, room-by-room sampling may be ineffective in leading to a conclusive determination as such; however, since no residences were tested with VI as a presumed source, it is recommended that an additional study be performed to determine if sampling protocols can lead to determining that VI as a source of indoor air contamination. When room-by-room sampling is ineffective in determining a room of interest, product sampling may be required. Since a residence may contain hundreds of different products which could be tested, it is difficult to determine whether all potential sources of COC have been tested. Further, room-by-room sampling is time and analysis intensive. Since many samples must be taken in order to determine a room of concern, it is possible that sampling would not be cost effective unless used at residences that were likely to contain an indoor source. If a portable GC/MS with low detection limits is available or a micro gas analyzer is developed, cost could potentially be reduced over a long term by eliminating the need for Tenax© tubes and analysis, making room-by-room sampling more cost effective. Additionally, a portable GC/MS unit with sufficient sensitivity could be used to test multiple predicted sources/locations and obtain results much quicker than when using Tenax© tubes. This quick turn around would likely help reduce sampling costs by reducing the need for multiple repeat sampling events.

Although efforts did indicate that the sampling methods produced from this thesis are effective in locating rooms with potential sources, additionally studies should be performed to fill information gaps that currently exist. Additional studies might include the following: Determining the significance of beading in the emission of PCE over long periods of time from materials dry-cleaned with PCE; determining if glues containing COC will continue emitting the COC over long periods of time (greater than a few months), and studying the effect of multiple sources on room and residence indoor air concentrations.

ENGINEERING SIGNIFICANCE

Model residence results indicated that an indoor source can contribute significantly to indoor air contaminant concentrations and source rooms can be differentiated from rooms without sources. Significant point sources of COC (those that contribute or cause indoor air COC concentrations above Hill AFB's MAL) can be identified by room-by-room sampling. The results obtained from the model residence also correspond with measurements in the field indicating that rooms containing significant point sources can often be differentiated from others based on the sampling strategy developed. The model residence results also confirmed that the sampling strategy developed for this thesis research is effective in reducing indoor air mixing and can therefore be used to locate rooms that would contain potential sources. It is recommended that an additional study be performed using conditions similar to those experiences in the field. This study would place a source in a residence and after allowing for a period of mixing, shutting off the HVAC system, and after more than 3 hours, sampling the rooms. This study will further indicate if room-by-room will be effective in field studies.

In addition to model residence results, the EPA RISK Model was used to determine if measured indoor air concentrations could be modeled effectively when the HVAC system is in use. Although potentially promising, model calculations were significantly lower than those measured at the model residence. While possible that the discrepancy was caused by the assumptions made, adjustment in model inputs did not significantly change results. It is recommended that additional measurements (i.e., measurement of room concentrations over larger time intervals and measurement of

HVAC and room-to-room air flow rates) be performed in the test residence to determine if assumptions made for this thesis were the cause of model and measurement discrepancies. If further studies indicate that the model can be effectively used in the test residence, it is recommended that the model be used to determine the lowest emission rate of COC that would cause indoor air concentrations to be over Hill AFB's MAL. These emission rates could potentially then be scaled to determine rates in residences near Hill AFB. Additionally, these rates coupled with emission chamber sampling of household products would be able to show that household products can significantly affect indoor air concentrations of the COC.

Emission chamber measurements of sources located in room-to-room sampling indicated that significant emissions of COC can come from household items. Removal of these sources has caused indoor air concentrations of COC to drop significantly further indicating that household items can significantly impact the indoor air. It is recommended that a TCE emitter with an emission rate similar to tested household products be placed in the model residence. Sampling from before and after the source was placed in the residence could then be used to further indicate the impact of indoor sources on air concentrations within the residence.

Overall, thesis sampling results show that room-by-room sampling is effective in determining significant point sources of COC, but is ineffective when dealing with emissions caused by product use, multiple indoor sources, and/or VI which exhibits non-point source characteristics. Additionally, due to the amount of time required for sampling, it is necessary that the resident or building owner be interested in the results so that repeat sampling visits can be coordinated effectively. It is recommended that room-by-room sampling be primarily used when an indoor source is expected rather than in every event where VI is occurring since sampling is time and analysis intensive. A portable GC/MS, if sufficiently sensitive, may be used in place of Tenax© tubes to minimize return sampling events and produce results more quickly.

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APPENDICES

Appendix A – Sack et al. Product Classifications

Table A 1. Products and product classifications from Sack et al. (1992)

Automotive Products

- Carburetor and choke cleaner
- Engine cleaner
- Automotive undercoat
- Battery cleaners/protectors
- Brake quieters/cleaners
- Gasket adhesives/removers
- Belt lubricants/dressings
- Ignition wire dryers
- Tire puncture sealers
- Starting fluid spray
- Windshield degreaser
- Door spray/lubricant
- Chrome protector/wax
- Vinyl top spray
- Upholstery cleaner
- Water pump lubricant
- Transmission cleaner
- Automotive sealant
- Liquid exterior car cleaner
- Tire cleaner/tire paint

Cleaners for Electric Equipment

- Electric shaver cleaner
- Record cleaner
- Record player cleaner
- Tape recorder cleaner
- VCR cleaner
- TV/computer screen cleaner
- Circuit board cleaner

Oils, Greases, and Lubricants

- Lubricant
- Silicone Lubricant

Adhesive related products

- Adhesive
- Wallpaper removers/adhesive
- Adhesive removers

Household Cleaners/Polishes

- Stain remover
- Furniture polish
- Floor wax
- Wax stripper
- Wood cleaner
- Deodorizer/ disinfectant
- Oven Cleaner
- Laundry pre-soak
- Spray starch
- Rug cleaner
- Window cleaner
- Bathroom cleaner
- Dip metal cleaner
- Drain cleaner (not-acid)
- General purpose spray cleaners/degreasers

Fabric and Leather Treatments

- Spray shoe polish
- Suede protector
- Water repellant
- Fabric finisher
- Spot remover
- Anti-static spray

Paint-related Products

- Paint remover
- Paint thinner
- Primer and special primer
- Wood stains, varnishes and finishes

Miscellaneous Products

- Specialized cleaner
- Rust remover
- All purpose liquid cleaner
- Caulking
- Misc. non automotive
- Correction fluid

Appendix B – Standard Operating Procedures

Resident Sampling Standard Operating Procedure

1. Locate the room or area of the home in which you want to sample.
2. Pick a sampling location in that room or area that is flat and stable and large enough to fit the equipment comfortably. (the floor is a normal location)
3. Take out the ring stand and put it together, then place it in the sampling area.
4. Set the SKC Airchek Sampler pump close to the ring stand.
5. Take out the Tenax© tubes and connect two together with the S's pointing up using a male to male Swagelok. Air should flow through the tube starting at the S in Swagelok printed on the tubes.
6. Record the numbers of each of the tubes and indicate whether or not it is the top (front) tube or the bottom (back) tube.
7. Using a clamp on the ring stand clamp the set (set = two Tenax© connected by a male to male Swagelok fitting in series) of Tenax© tubes approximately 8 inches.
8. Take off the bottom brass fitting of the back Tenax© tube and connect the sampling pump to the bottom of the set of Tenax© tubes (air should always be pulled down through tubes).
9. Wrap the pump tubing around the ring stand so that no kinking occurs and the air can be pulled freely.
10. Take off the top brass fitting of the top Tenax© tube and connect the intake tubing of the Alltech Digital Flow Check (air flow meter) to the top of the Tenax© tubes.
11. Turn on the flow meter and then turn on the sampling pump while simultaneously starting the stop watch.
12. Adjust the flow of the sampling pump to reach desired flow rate indicated on the Alltech flow meter and then record the flow rate.
13. Take the intake tubing of the Alltech flow meter off the top of the top Tenax© tube so that the air in the room can be pulled through the Tenax© tubes.
14. Let the pump run for the desired amount of time.
15. During this sampling time record the pump number, date of sampling and location of the sample.
16. Shortly before time is up turn on the Alltech flow meter and connect to the top of the front Tenax© tube and note the flow rate.
17. Then disconnect the flow meter and let the sample pump run until time is up.
18. Once the desired sampling time has been achieved, turn off the sampling pump and remove the sample pump tubing off the bottom of the bottom Tenax© tube.
19. Take the Tenax© tubes out of the ring stand clamp and separate the set of tubes then replace the brass fitting on the Tenax© tubes.
20. Replace all the equipment in the cooler including the tubes (make sure the tubes are stored in a separate container for better protection while in the cooler).

Emission Chamber Standard Operating Procedure

1. Open emission chamber (i.e. pressure cooker) by loosening the clamps and lifting off the lid.
2. Place a watch glass in the center on the bottom of the emission chamber, then place the item being tested on the watch glass. Unless running a pre-control or post control in which case the chamber should be left empty.
3. Replace the lid of the emission chamber and tighten it down by twisting the clamps as tight as possible (make sure all tubing and wiring is out of the way when replacing the lid).
4. Plug in the mixing fans
5. Open Compressed Nitrogen or Air tank and set inlet rotameter to desired flow rate (normally 4 LPM).
6. Plug in the outlet pump. The outlet rotameter should be adjusted so that the pressure gauge attached to the emission chamber reads zero (normally ~ 4 LPM). The outlet rotameter should be adjusted as needed in order to obtain zero pressure in the emission chamber as indicated by the pressure gauge throughout each sampling event.
7. Allow gas to circulate in the emission chamber for sufficient time to allow at least 7 air exchanges to occur without Tenax© tubes.
8. Connect the SKC Airchek sampling pump to the outlet tubes from the two Aalborg Mass Flowmeters.
9. Take out the Tenax© tubes and connect two together with the S's in Swagelok pointing up using a male to male Swagelok (inlet gas should always flow through the tube starting from the S in Swagelok).
10. Record the numbers of each of the tubes and indicate which is the top (front) tube or the bottom (back) tube and whether it will be placed on the right side or the left side of the sampling apparatus.
11. Attach each of the two sets (one set = two tubes attached in series with a 3/8 inch male to male Swagelok adapter) of the Tenax© tubes to the two tygon intake tubes which are connected to the Aalborg mass flow meters.
12. Attach the other end of the Tenax© tubes to the emission chamber's stainless steel outlet tubes. The tubes should be aligned so that the left side tubes are drawn through the left side mass flow meter, and the right side tubes are drawn through the right side mass flow meter.
13. Turn on the sampling pump and open the Swagelok valve to allow emission chamber air to be sub sampled through the Tenax© tubes. Sampling time begins when the Swagelok valve is opened (i.e. the stopwatch should be started).
14. Make sure mass flow rate meters indicate the desired sampling pump flow rate and record this initial flow rate.
15. Allow the system to run for the desired sampling time amount. During this time record the date, a short description of the sample, the flow rate of gas through the system, the sampling pump number, and an ID for the person sampling.
16. Just before the desired sampling time is reached record the flow rate indicated by the mass flow meters.

17. When the desired sampling time is reached, close the Swagelok Valve (Stopwatch should simultaneously be stopped).
18. Turn off the SKC Airchek Sampler pump, unplug the outlet pump and close the compressed nitrogen or air valve.
19. Remove the Tenax© tubes and replace the brass caps.
20. Note down the amount of time sampled.
21. Relieve system pressure by opening Swagelok valve until the pressure gauge shows zero pressure.
22. Then open the emission chamber by releasing the clamps and taking off the lid then remove both the item being sampled and the watch glass.

Between Sampling Events, the following flush out steps should be followed:

1. Replace the lid and retighten the clamps
2. Remove all items out of the emission chamber, close and tighten the lid.
3. Instead of connecting the Tenax© tubes, connect the tygon Aalbrog Mass Flowmeter tubes straight to the emission chamber’s stainless steel outlet tubes.
4. Plug in the outlet pump, the sampling pump and open the air tank as mentioned previously.
5. Let the system run until 7 air exchanges have occurred.
6. After desired time is reached turn off system as mentioned previously and loosen the lid and remove it. This will allow the system to air out even further until another test is performed.

Appendix C – Spike Recovery Data

Table C 1. Spike recovery information for flow through study

Location	TCE (pg) on trap Control corrected	1,2-DCA (pg) on trap Control corrected	PCE (pg) on trap Control corrected
Control	<MDL	<MDL	1676.25
Control	<MDL	<MDL	1369.86
Control	<MDL	<MDL	1513.22
AVERAGE	0.00	0.00	1519.78
Std Dev	0.00	0.00	153.30

Location	TCE (pg) on trap Control corrected	1,2-DCA (pg) on trap Control corrected	PCE (pg) on trap Control corrected
CCV	2219.46	2149.41	2083.71
CCV	2048.91	2307.18	2129.17
AVERAGE	2134.19	2228.30	2106.44
Std Dev	120.597062	111.56	32.15

Location	TCE (pg) on trap Control corrected	1,2-DCA (pg) on trap Control corrected	PCE (pg) on trap Control corrected
Spike	2124.04	2022.01	3677.63
Spike	2231.72	2059.01	3836.75
Spike	2236.49	2181.41	3708.87
AVERAGE	2197.42	2087.48	3741.08
Std Dev	63.5907983	83.43	84.31
Control Corrected	2197.42	2087.48	2221.31
Spike Recovery	103.0%	93.7%	105.5%

Appendix D – Floor Plans of Model Residence UWRL-1

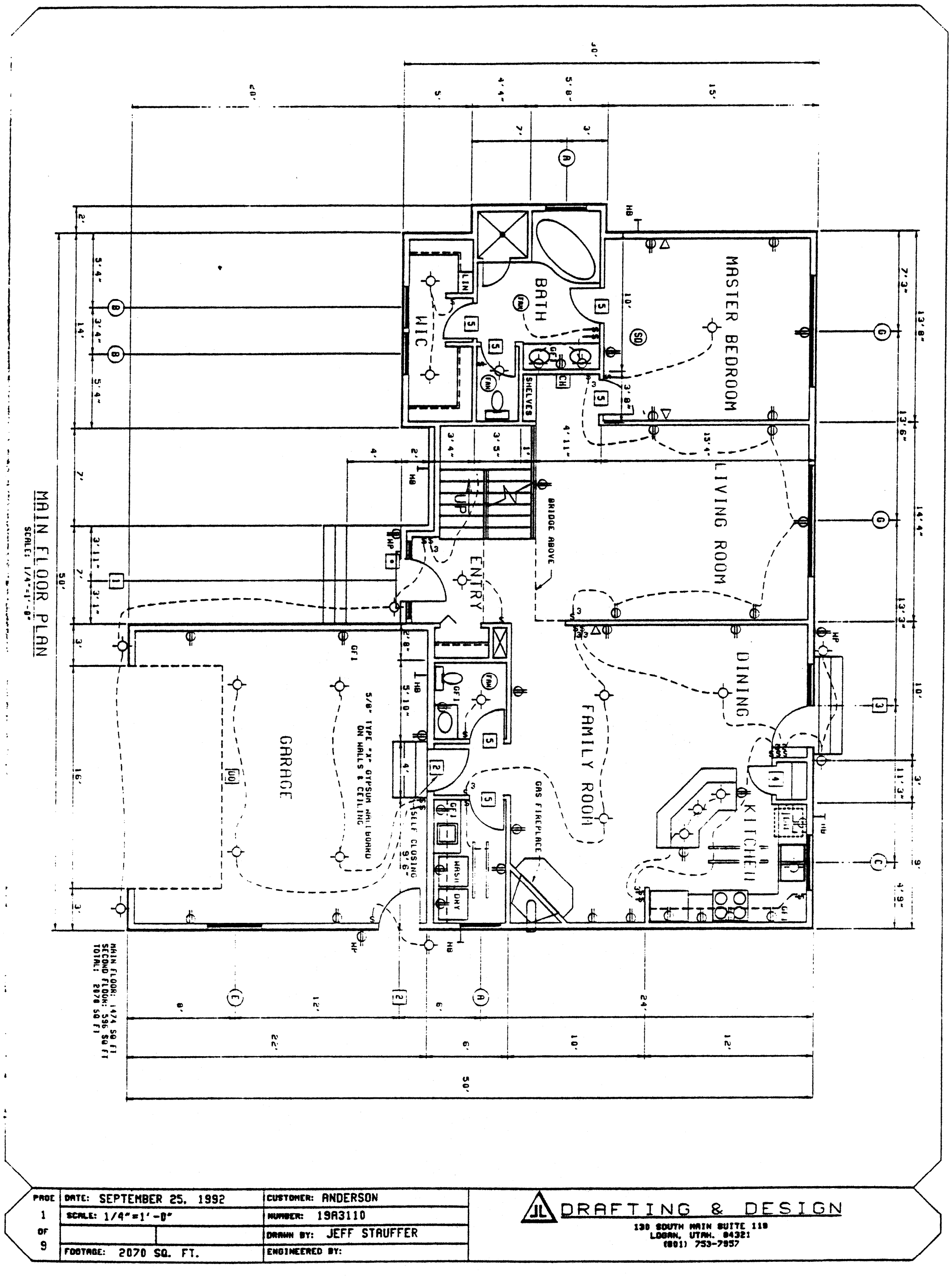


Figure D 1. Floor plan of the main floor of UWRL-1.

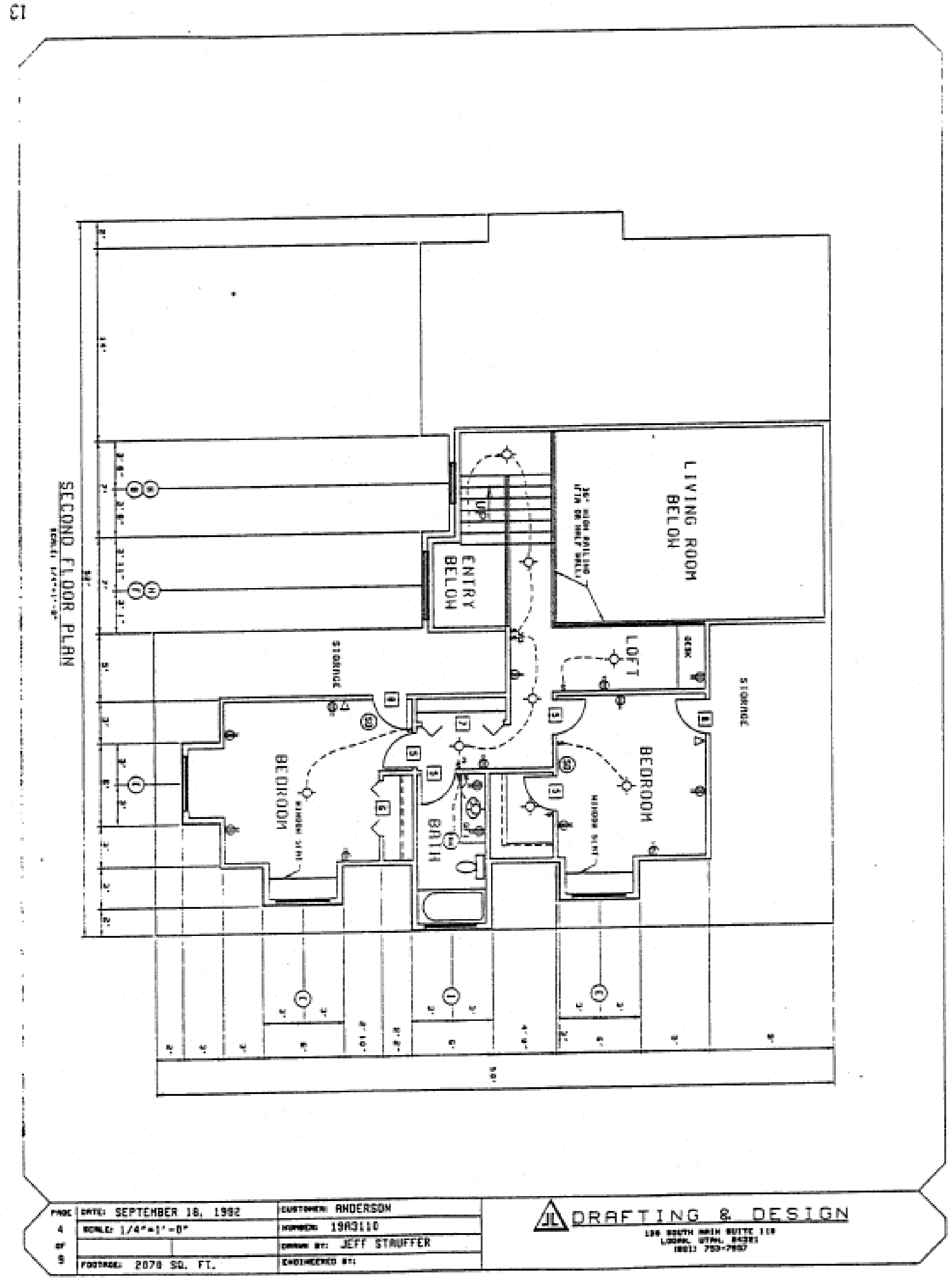


Figure D 2. Floor plan of the upstairs of UWRL-1.

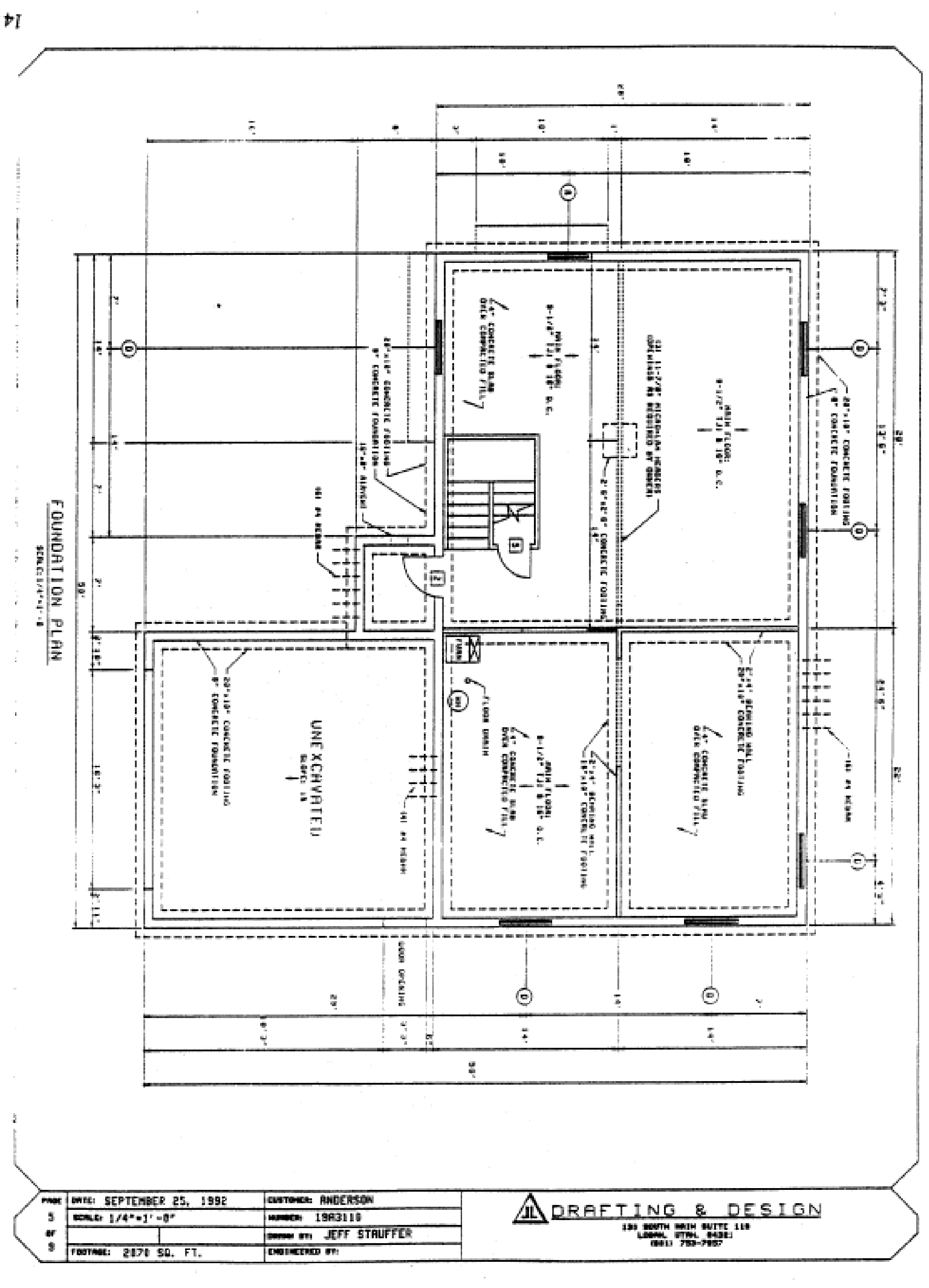
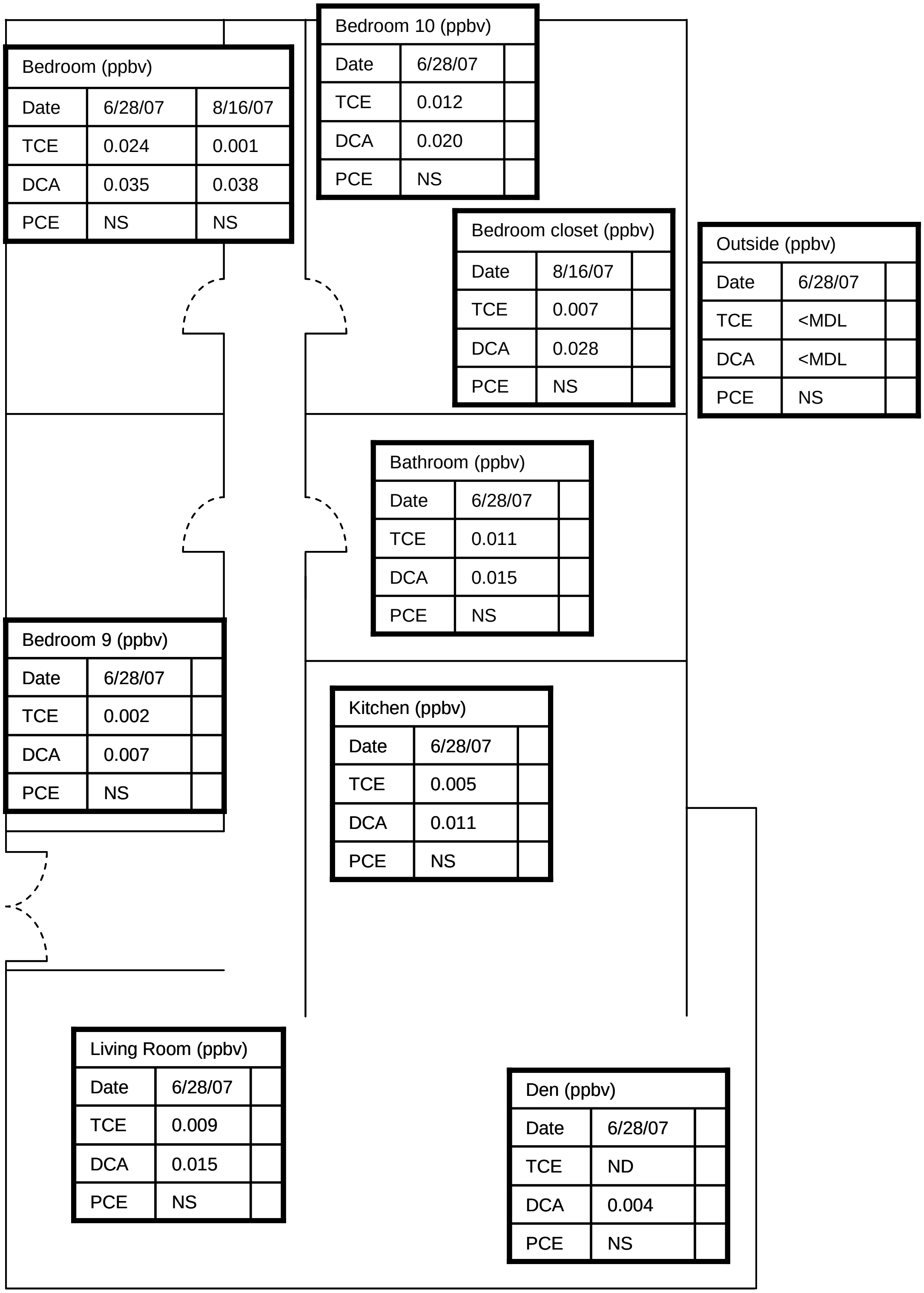


Figure D 3. Floor plan of the downstairs of UWRL-1.

Appendix E – Floor Plans of Sampled Residences with Room Indoor Air Concentrations

U12-8017



Bedroom (ppbv)		
Date	6/28/07	8/16/07
TCE	0.024	0.001
DCA	0.035	0.038
PCE	NS	NS

Bedroom 10 (ppbv)		
Date	6/28/07	
TCE	0.012	
DCA	0.020	
PCE	NS	

Bedroom closet (ppbv)		
Date	8/16/07	
TCE	0.007	
DCA	0.028	
PCE	NS	

Outside (ppbv)		
Date	6/28/07	
TCE	<MDL	
DCA	<MDL	
PCE	NS	

Bathroom (ppbv)		
Date	6/28/07	
TCE	0.011	
DCA	0.015	
PCE	NS	

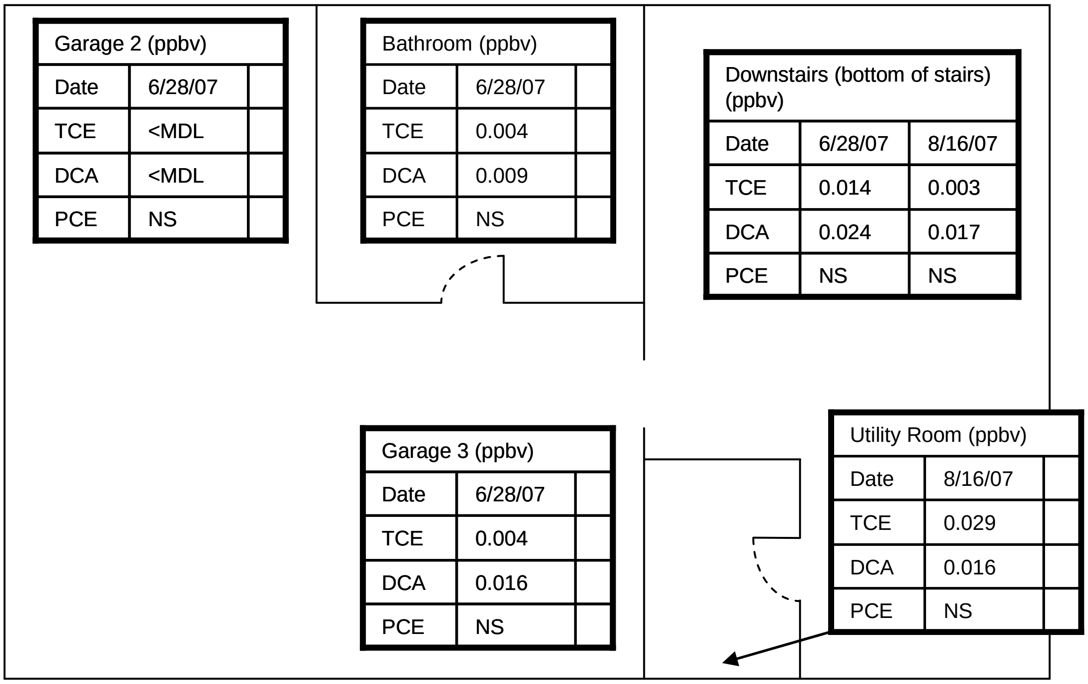
Bedroom 9 (ppbv)		
Date	6/28/07	
TCE	0.002	
DCA	0.007	
PCE	NS	

Kitchen (ppbv)		
Date	6/28/07	
TCE	0.005	
DCA	0.011	
PCE	NS	

Living Room (ppbv)		
Date	6/28/07	
TCE	0.009	
DCA	0.015	
PCE	NS	

Den (ppbv)		
Date	6/28/07	
TCE	ND	
DCA	0.004	
PCE	NS	

Figure E 1. Indoor air sampling results in the top floor of U12-8017.



Garage 2 (ppbv)		
Date	6/28/07	
TCE	<MDL	
DCA	<MDL	
PCE	NS	

Bathroom (ppbv)		
Date	6/28/07	
TCE	0.004	
DCA	0.009	
PCE	NS	

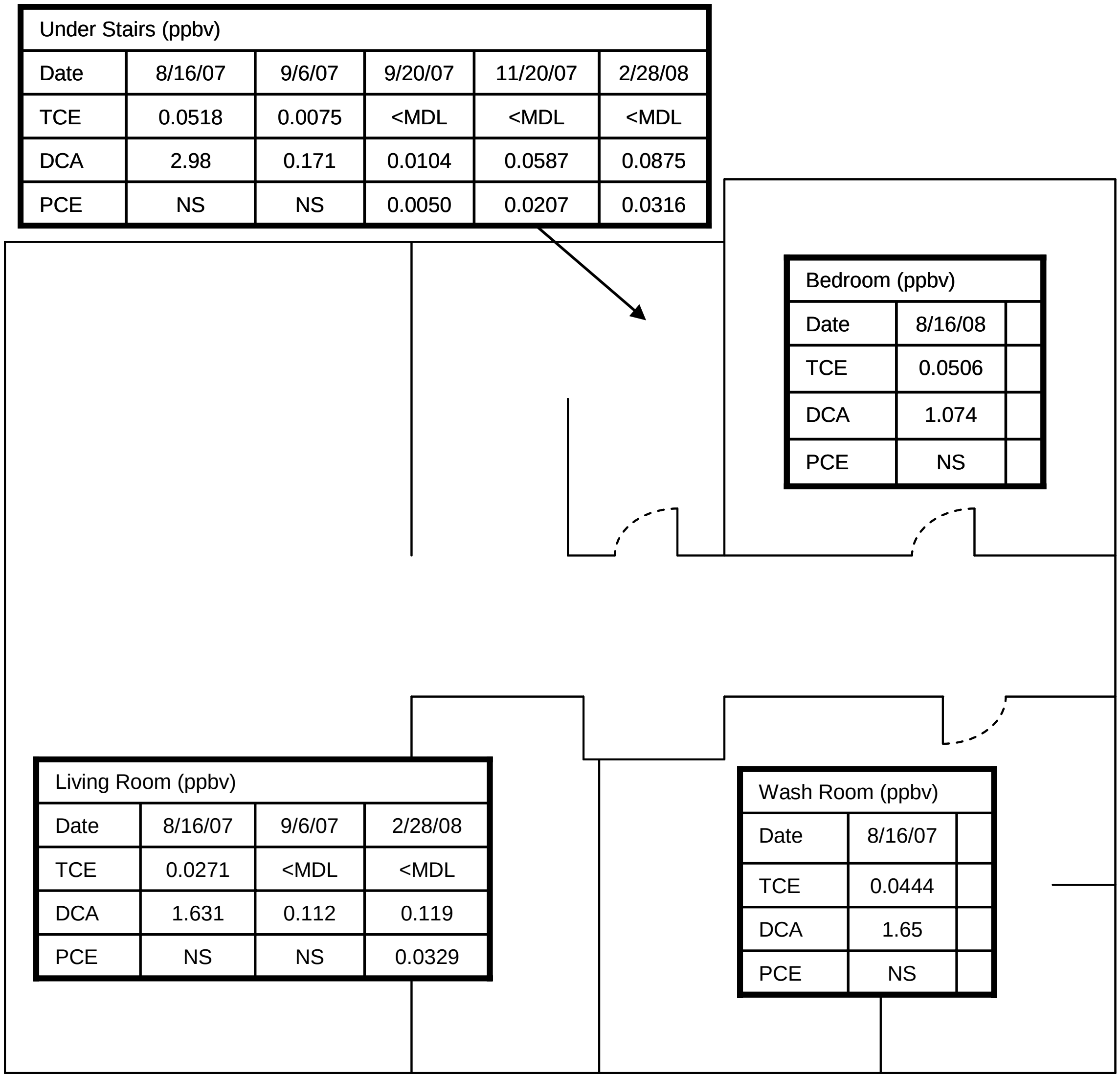
Downstairs (bottom of stairs) (ppbv)		
Date	6/28/07	8/16/07
TCE	0.014	0.003
DCA	0.024	0.017
PCE	NS	NS

Garage 3 (ppbv)		
Date	6/28/07	
TCE	0.004	
DCA	0.016	
PCE	NS	

Utility Room (ppbv)		
Date	8/16/07	
TCE	0.029	
DCA	0.016	
PCE	NS	

Figure E 2. Indoor air sampling results in the basement of U12-8017.

U8-8211



Under Stairs (ppbv)					
Date	8/16/07	9/6/07	9/20/07	11/20/07	2/28/08
TCE	0.0518	0.0075	<MDL	<MDL	<MDL
DCA	2.98	0.171	0.0104	0.0587	0.0875
PCE	NS	NS	0.0050	0.0207	0.0316

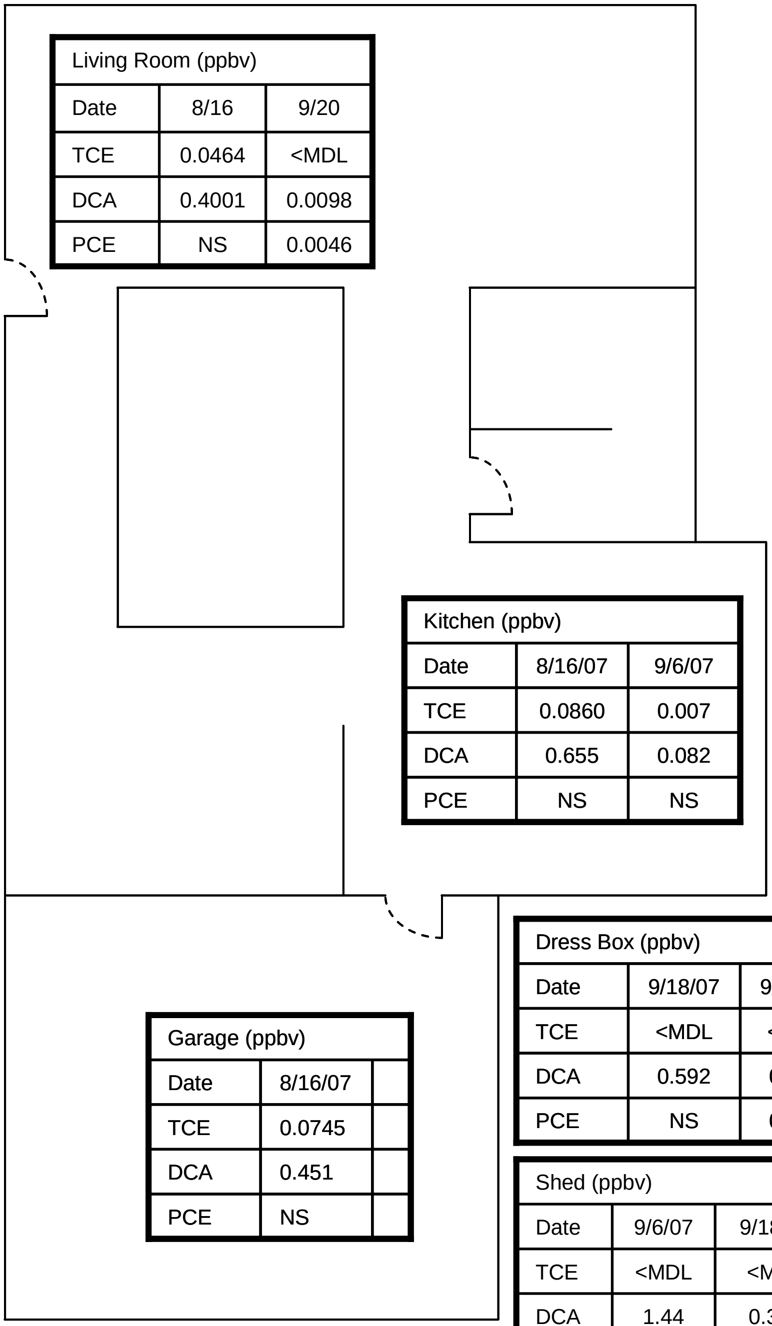
Bedroom (ppbv)		
Date	8/16/08	
TCE	0.0506	
DCA	1.074	
PCE	NS	

Living Room (ppbv)			
Date	8/16/07	9/6/07	2/28/08
TCE	0.0271	<MDL	<MDL
DCA	1.631	0.112	0.119
PCE	NS	NS	0.0329

Wash Room (ppbv)		
Date	8/16/07	
TCE	0.0444	
DCA	1.65	
PCE	NS	

Figure E 3. Indoor air concentrations in the basement of U8-8211.

Outside (ppbv)						
Date	8/16/07	9/6/07	9/18/07	9/20/07	11/20/07	2/28/08
TCE	0.0345	<MDL	0.0014	<MDL	<MDL	<MDL
DCA	0.0152	0.0216	0.0051	<MDL	0.0238	0.0192
PCE	NS	NS	NS	<MDL	0.0167	0.0159



Living Room (ppbv)		
Date	8/16	9/20
TCE	0.0464	<MDL
DCA	0.4001	0.0098
PCE	NS	0.0046

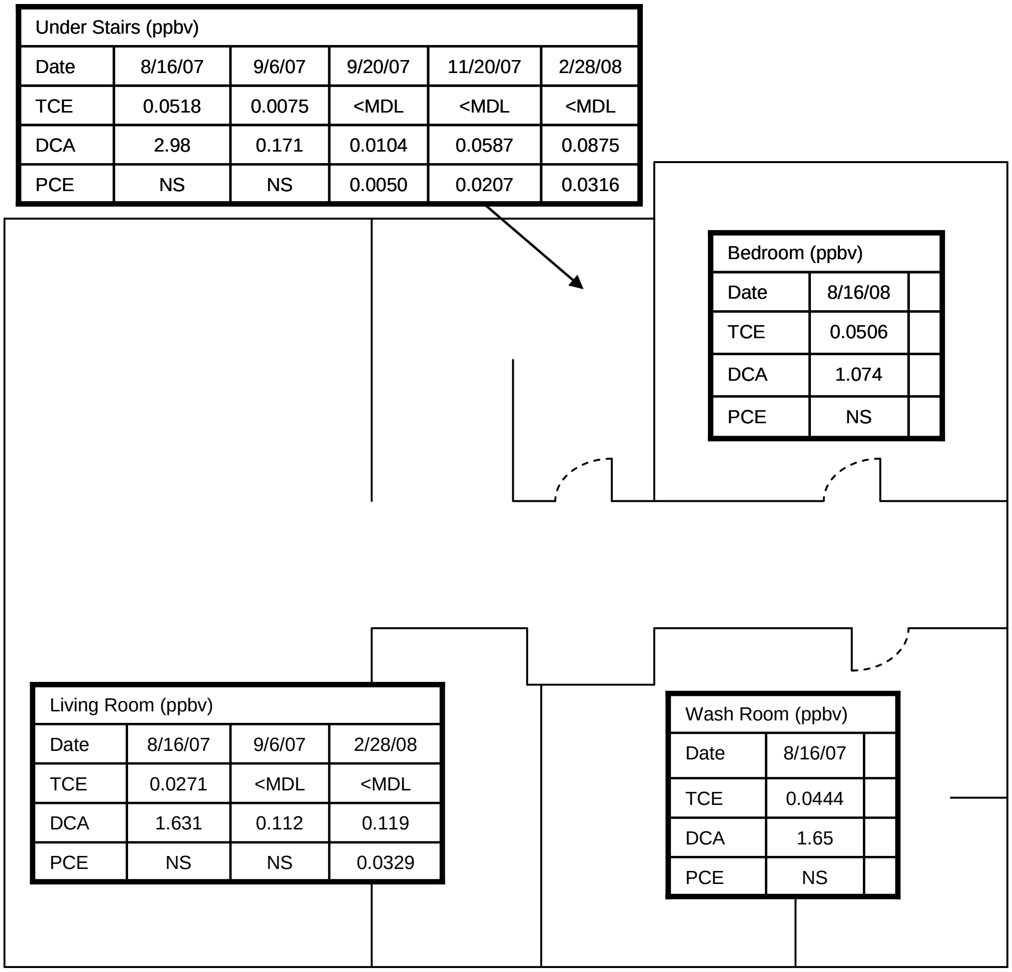
Kitchen (ppbv)		
Date	8/16/07	9/6/07
TCE	0.0860	0.007
DCA	0.655	0.082
PCE	NS	NS

Dress Box (ppbv)		
Date	9/18/07	9/20/07
TCE	<MDL	<MDL
DCA	0.592	0.122
PCE	NS	0.577

Garage (ppbv)		
Date	8/16/07	
TCE	0.0745	
DCA	0.451	
PCE	NS	

Shed (ppbv)				
Date	9/6/07	9/18/07	9/20/07	11/20/07
TCE	<MDL	<MDL	<MDL	<MDL
DCA	1.44	0.369	1.06	0.31
PCE	NS	NS	<MDL	0.017

Figure E 4. Indoor air concentrations in the main floor of U8-8211.



Under Stairs (ppbv)					
Date	8/16/07	9/6/07	9/20/07	11/20/07	2/28/08
TCE	0.0518	0.0075	<MDL	<MDL	<MDL
DCA	2.98	0.171	0.0104	0.0587	0.0875
PCE	NS	NS	0.0050	0.0207	0.0316

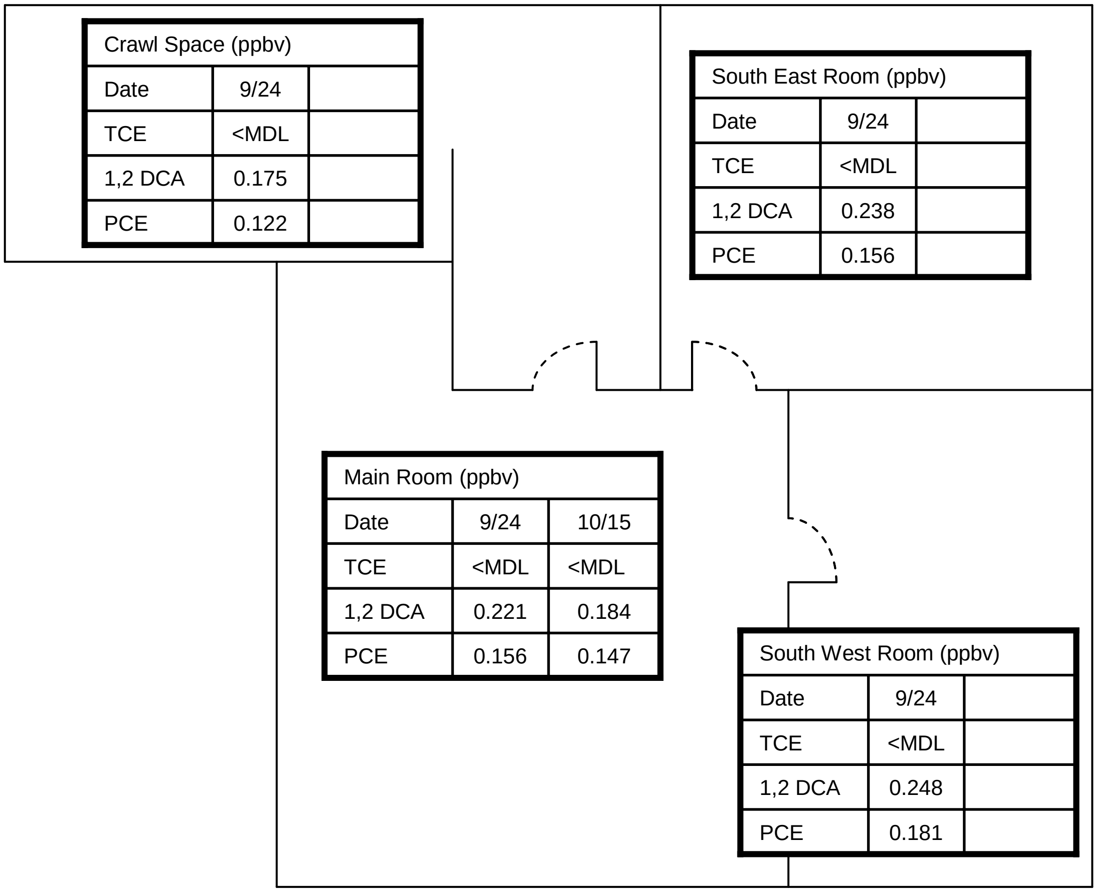
Bedroom (ppbv)		
Date	8/16/08	
TCE	0.0506	
DCA	1.074	
PCE	NS	

Living Room (ppbv)			
Date	8/16/07	9/6/07	2/28/08
TCE	0.0271	<MDL	<MDL
DCA	1.631	0.112	0.119
PCE	NS	NS	0.0329

Wash Room (ppbv)		
Date	8/16/07	
TCE	0.0444	
DCA	1.65	
PCE	NS	

Figure E 5. Indoor air concentrations in the upstairs of U8-8211.

U2-8003



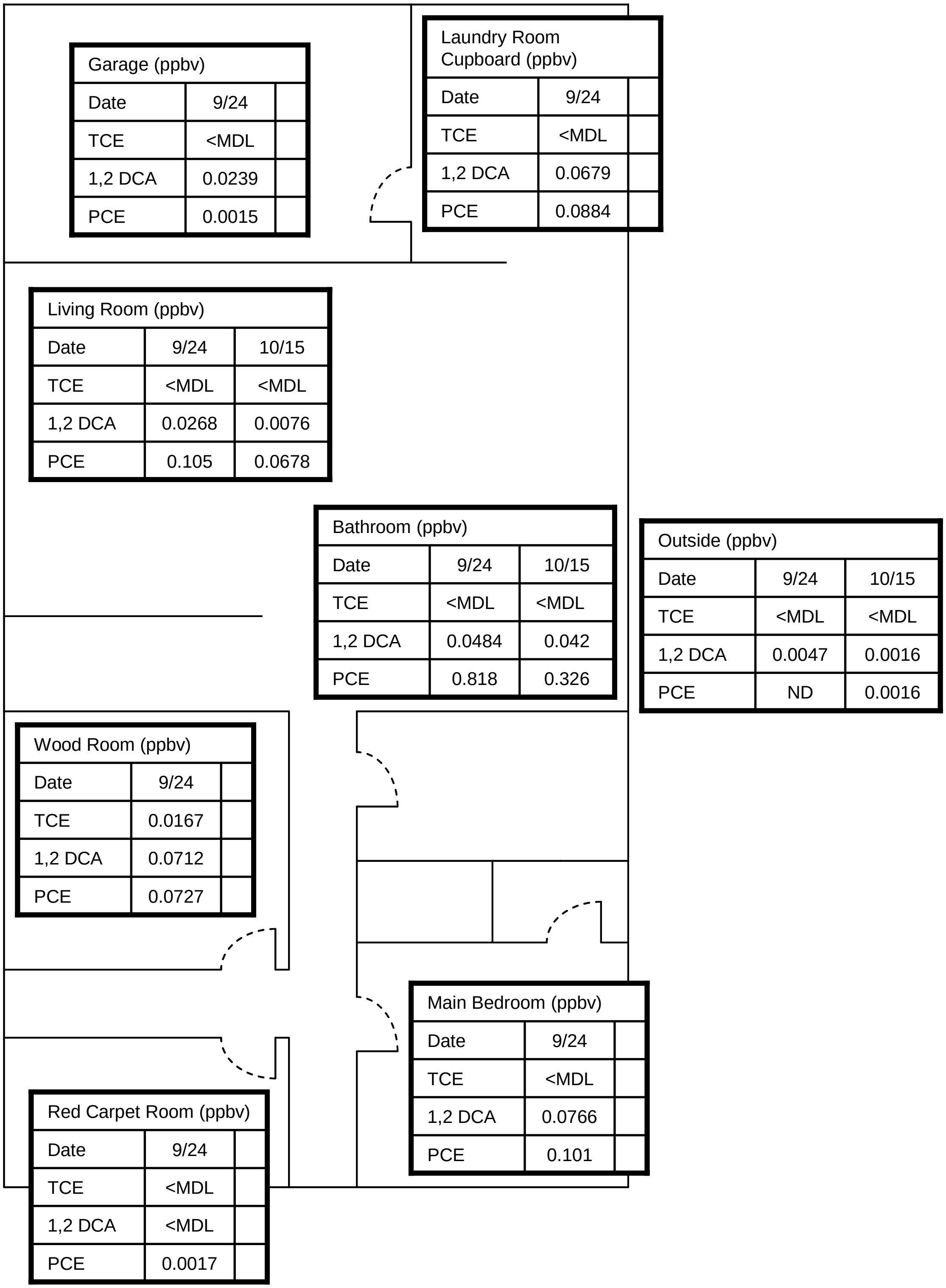
Crawl Space (ppbv)		
Date	9/24	
TCE	<MDL	
1,2 DCA	0.175	
PCE	0.122	

South East Room (ppbv)		
Date	9/24	
TCE	<MDL	
1,2 DCA	0.238	
PCE	0.156	

Main Room (ppbv)		
Date	9/24	10/15
TCE	<MDL	<MDL
1,2 DCA	0.221	0.184
PCE	0.156	0.147

South West Room (ppbv)		
Date	9/24	
TCE	<MDL	
1,2 DCA	0.248	
PCE	0.181	

Figure E 6. Indoor air concentrations in the basement of U2-8003.



Garage (ppbv)		
Date	9/24	
TCE	<MDL	
1,2 DCA	0.0239	
PCE	0.0015	

Laundry Room Cupboard (ppbv)		
Date	9/24	
TCE	<MDL	
1,2 DCA	0.0679	
PCE	0.0884	

Living Room (ppbv)		
Date	9/24	10/15
TCE	<MDL	<MDL
1,2 DCA	0.0268	0.0076
PCE	0.105	0.0678

Bathroom (ppbv)		
Date	9/24	10/15
TCE	<MDL	<MDL
1,2 DCA	0.0484	0.042
PCE	0.818	0.326

Outside (ppbv)		
Date	9/24	10/15
TCE	<MDL	<MDL
1,2 DCA	0.0047	0.0016
PCE	ND	0.0016

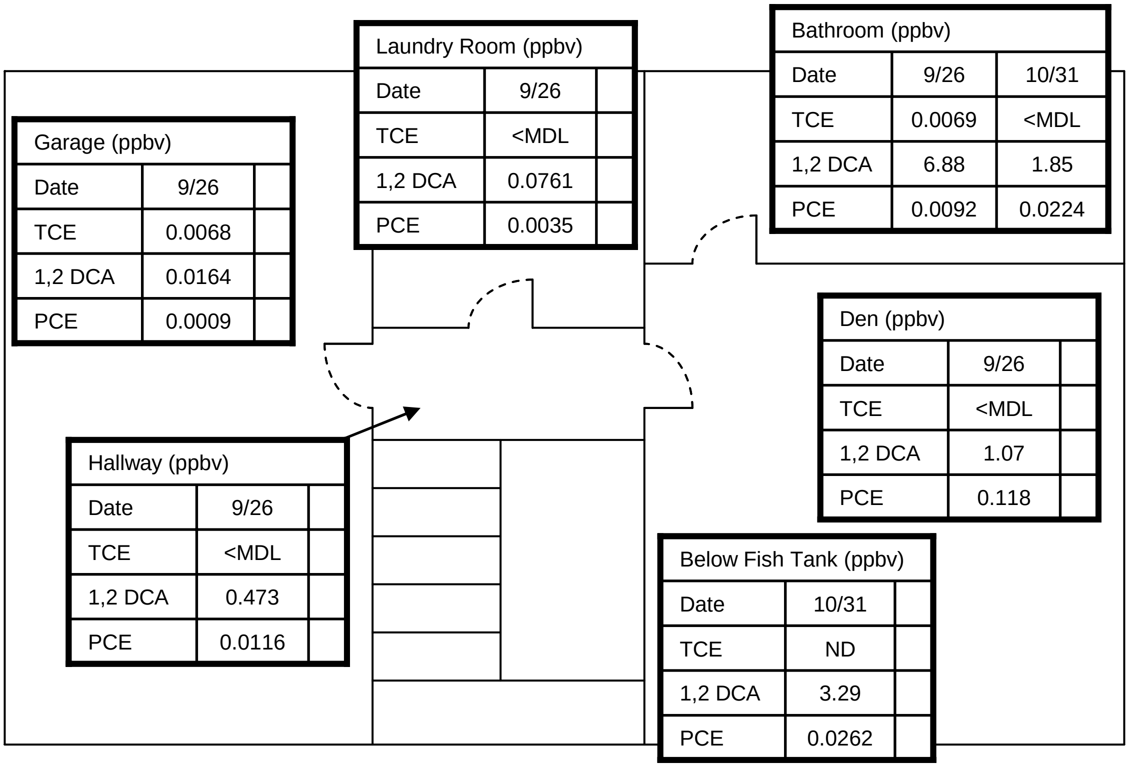
Wood Room (ppbv)		
Date	9/24	
TCE	0.0167	
1,2 DCA	0.0712	
PCE	0.0727	

Main Bedroom (ppbv)		
Date	9/24	
TCE	<MDL	
1,2 DCA	0.0766	
PCE	0.101	

Red Carpet Room (ppbv)		
Date	9/24	
TCE	<MDL	
1,2 DCA	<MDL	
PCE	0.0017	

Figure E 7. Indoor air concentrations in the main floor of U2-8003.

U8-8050



Laundry Room (ppbv)		
Date	9/26	
TCE	<MDL	
1,2 DCA	0.0761	
PCE	0.0035	

Bathroom (ppbv)		
Date	9/26	10/31
TCE	0.0069	<MDL
1,2 DCA	6.88	1.85
PCE	0.0092	0.0224

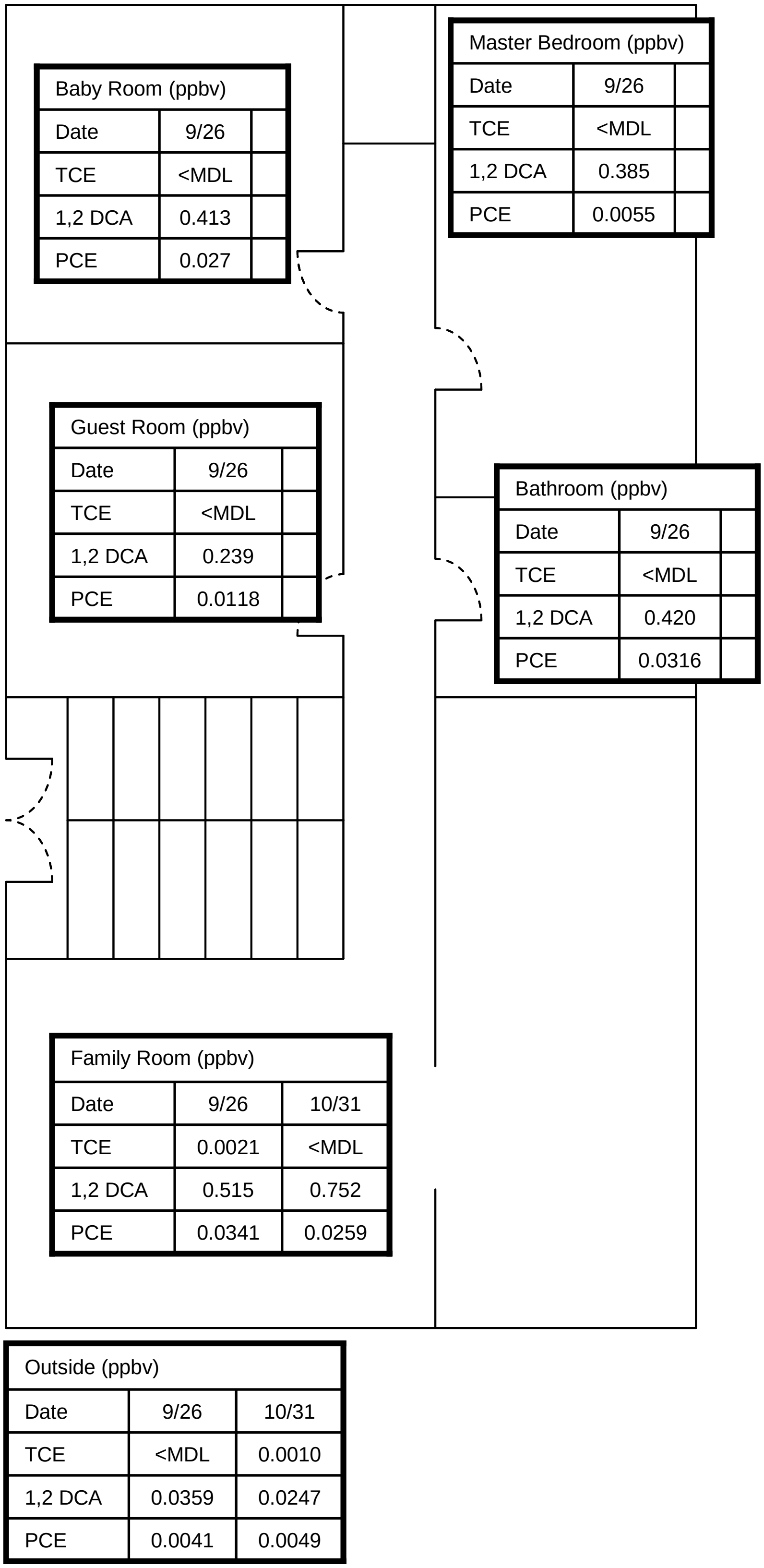
Garage (ppbv)		
Date	9/26	
TCE	0.0068	
1,2 DCA	0.0164	
PCE	0.0009	

Den (ppbv)		
Date	9/26	
TCE	<MDL	
1,2 DCA	1.07	
PCE	0.118	

Hallway (ppbv)		
Date	9/26	
TCE	<MDL	
1,2 DCA	0.473	
PCE	0.0116	

Below Fish Tank (ppbv)		
Date	10/31	
TCE	ND	
1,2 DCA	3.29	
PCE	0.0262	

Figure E 8. Indoor air concentrations in the basement of U8-8050.



Baby Room (ppbv)		
Date	9/26	
TCE	<MDL	
1,2 DCA	0.413	
PCE	0.027	

Master Bedroom (ppbv)		
Date	9/26	
TCE	<MDL	
1,2 DCA	0.385	
PCE	0.0055	

Guest Room (ppbv)		
Date	9/26	
TCE	<MDL	
1,2 DCA	0.239	
PCE	0.0118	

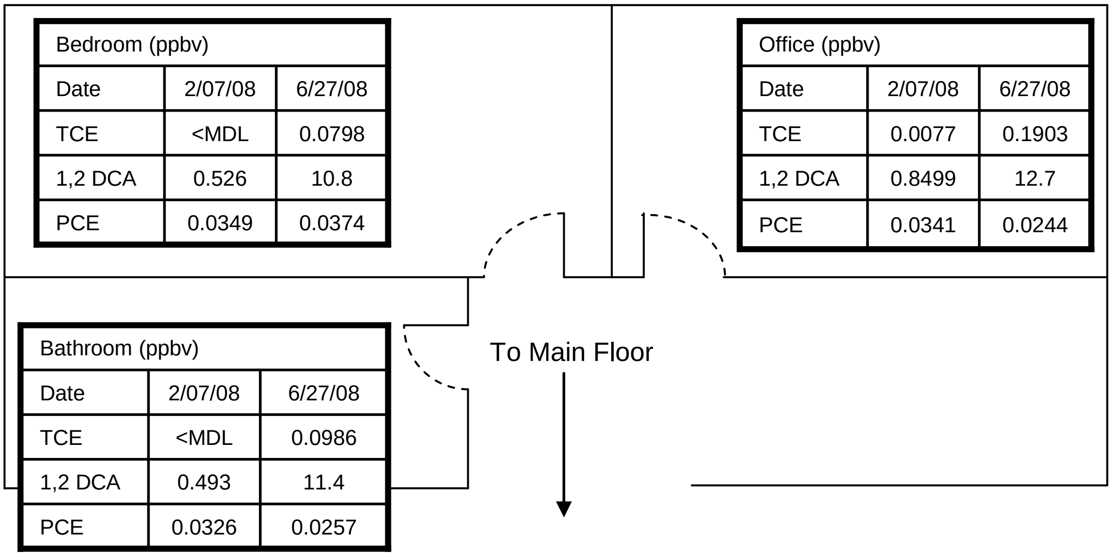
Bathroom (ppbv)		
Date	9/26	
TCE	<MDL	
1,2 DCA	0.420	
PCE	0.0316	

Family Room (ppbv)		
Date	9/26	10/31
TCE	0.0021	<MDL
1,2 DCA	0.515	0.752
PCE	0.0341	0.0259

Outside (ppbv)		
Date	9/26	10/31
TCE	<MDL	0.0010
1,2 DCA	0.0359	0.0247
PCE	0.0041	0.0049

Figure E 9. Indoor air concentrations in the main floor of U8-8050.

U8-8170

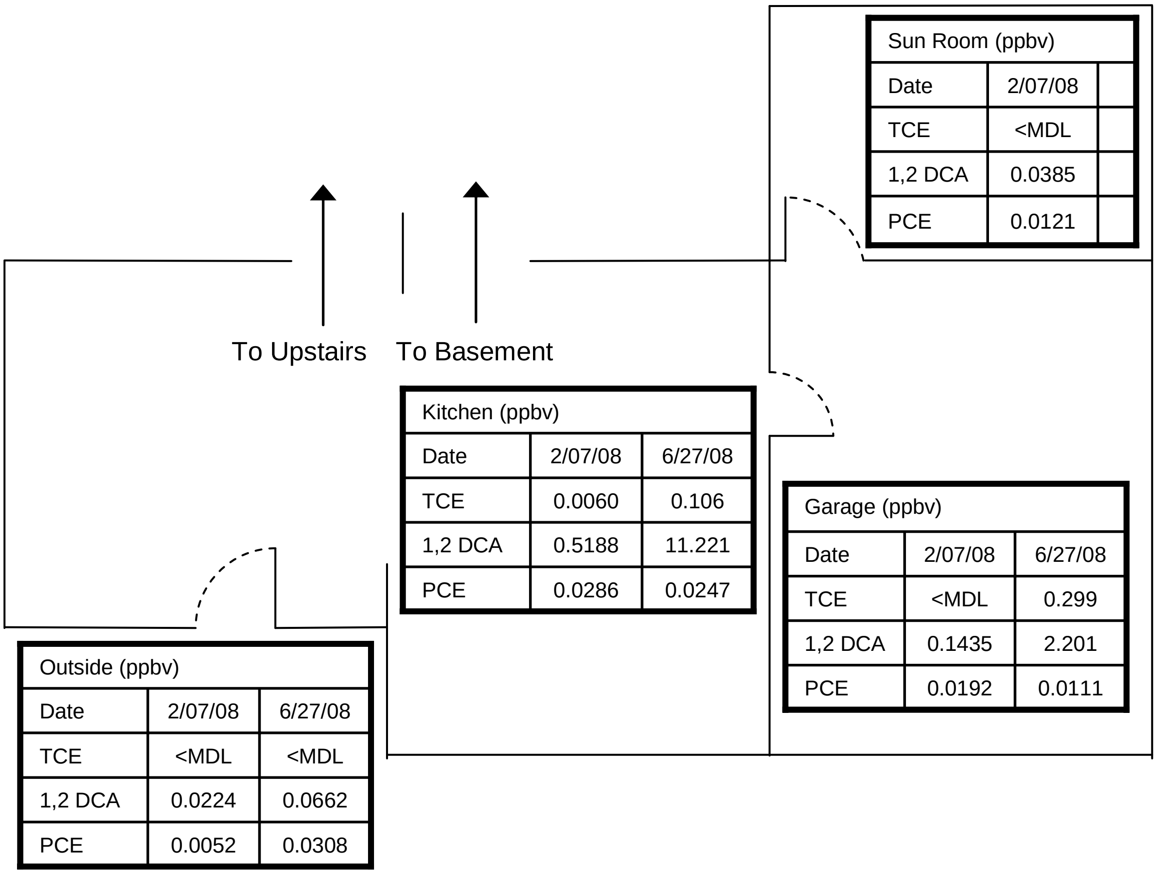


Bedroom (ppbv)		
Date	2/07/08	6/27/08
TCE	<MDL	0.0798
1,2 DCA	0.526	10.8
PCE	0.0349	0.0374

Office (ppbv)		
Date	2/07/08	6/27/08
TCE	0.0077	0.1903
1,2 DCA	0.8499	12.7
PCE	0.0341	0.0244

Bathroom (ppbv)		
Date	2/07/08	6/27/08
TCE	<MDL	0.0986
1,2 DCA	0.493	11.4
PCE	0.0326	0.0257

Figure E 10. Indoor air concentrations in the basement of U8-8170.



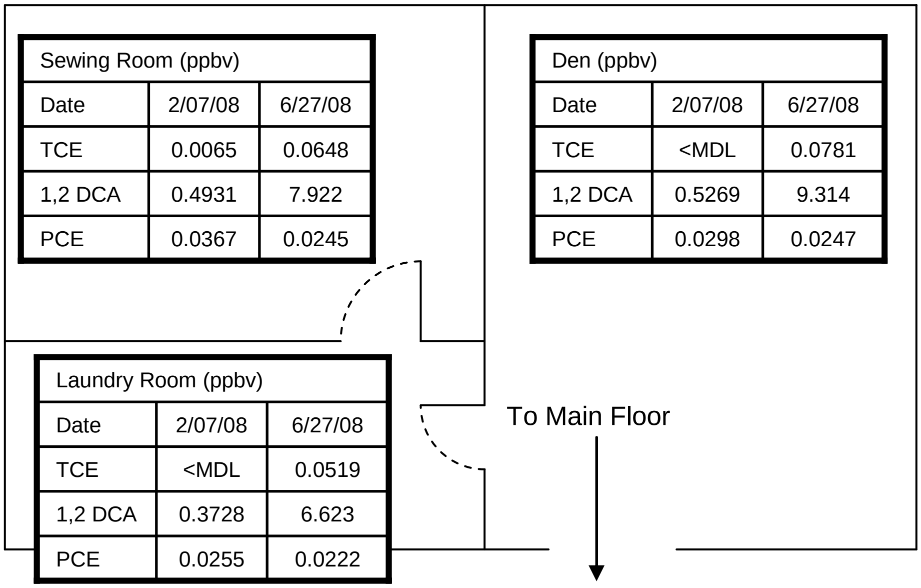
Sun Room (ppbv)		
Date	2/07/08	
TCE	<MDL	
1,2 DCA	0.0385	
PCE	0.0121	

Kitchen (ppbv)		
Date	2/07/08	6/27/08
TCE	0.0060	0.106
1,2 DCA	0.5188	11.221
PCE	0.0286	0.0247

Garage (ppbv)		
Date	2/07/08	6/27/08
TCE	<MDL	0.299
1,2 DCA	0.1435	2.201
PCE	0.0192	0.0111

Outside (ppbv)		
Date	2/07/08	6/27/08
TCE	<MDL	<MDL
1,2 DCA	0.0224	0.0662
PCE	0.0052	0.0308

Figure E 11. Indoor air concentrations in the main floor of U8-8170.



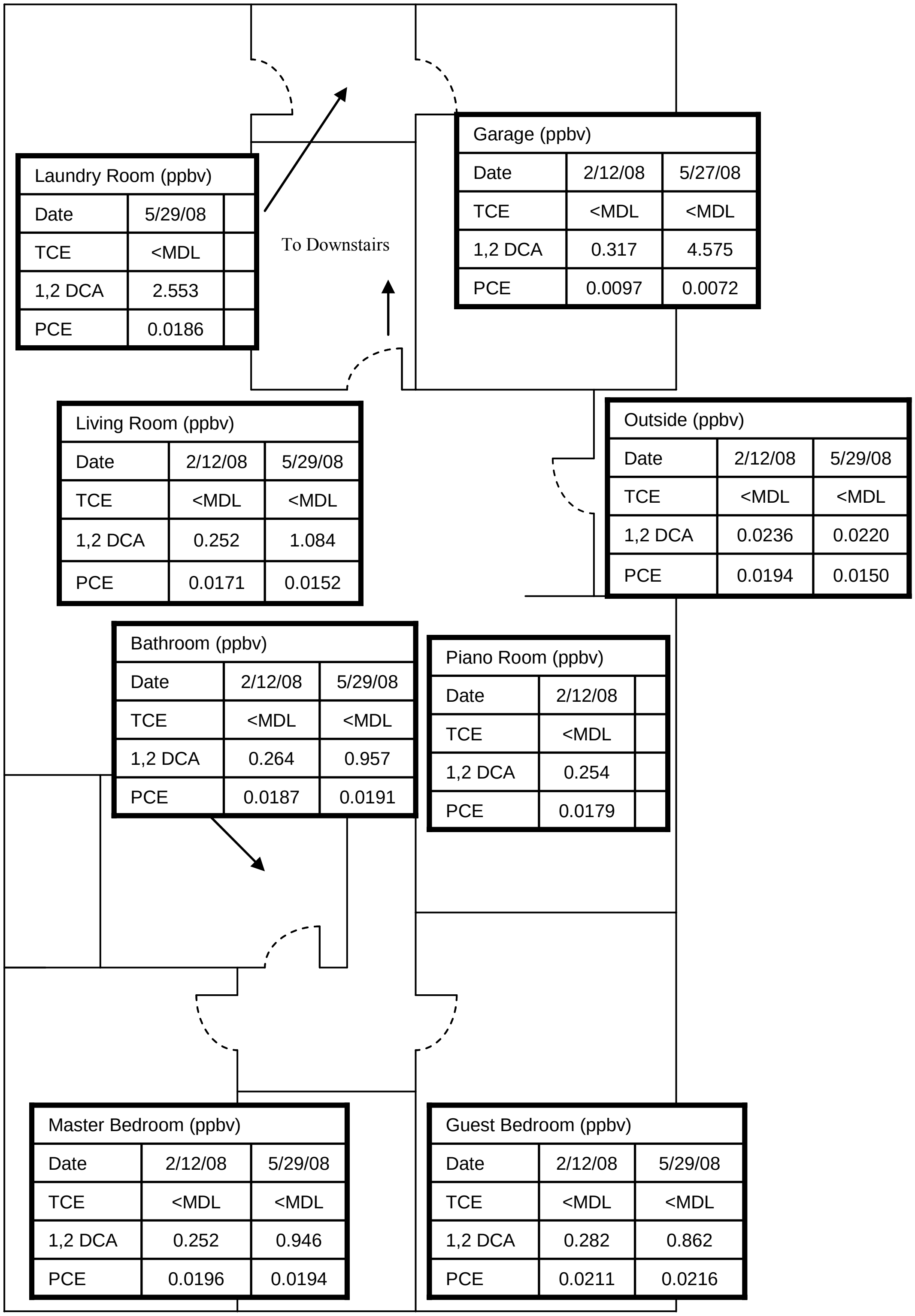
Sewing Room (ppbv)		
Date	2/07/08	6/27/08
TCE	0.0065	0.0648
1,2 DCA	0.4931	7.922
PCE	0.0367	0.0245

Den (ppbv)		
Date	2/07/08	6/27/08
TCE	<MDL	0.0781
1,2 DCA	0.5269	9.314
PCE	0.0298	0.0247

Laundry Room (ppbv)		
Date	2/07/08	6/27/08
TCE	<MDL	0.0519
1,2 DCA	0.3728	6.623
PCE	0.0255	0.0222

Figure E 12. Indoor air concentrations in the top floor of U8-8170.

U8-8244



Laundry Room (ppbv)		
Date	5/29/08	
TCE	<MDL	
1,2 DCA	2.553	
PCE	0.0186	

Garage (ppbv)		
Date	2/12/08	5/27/08
TCE	<MDL	<MDL
1,2 DCA	0.317	4.575
PCE	0.0097	0.0072

Living Room (ppbv)		
Date	2/12/08	5/29/08
TCE	<MDL	<MDL
1,2 DCA	0.252	1.084
PCE	0.0171	0.0152

Outside (ppbv)		
Date	2/12/08	5/29/08
TCE	<MDL	<MDL
1,2 DCA	0.0236	0.0220
PCE	0.0194	0.0150

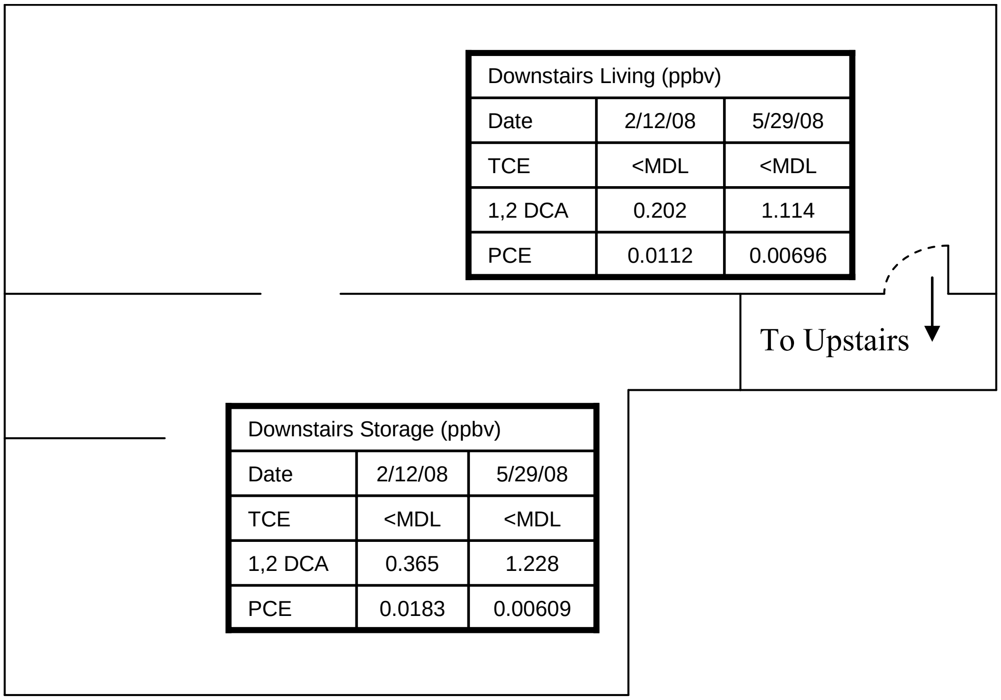
Bathroom (ppbv)		
Date	2/12/08	5/29/08
TCE	<MDL	<MDL
1,2 DCA	0.264	0.957
PCE	0.0187	0.0191

Piano Room (ppbv)		
Date	2/12/08	
TCE	<MDL	
1,2 DCA	0.254	
PCE	0.0179	

Master Bedroom (ppbv)		
Date	2/12/08	5/29/08
TCE	<MDL	<MDL
1,2 DCA	0.252	0.946
PCE	0.0196	0.0194

Guest Bedroom (ppbv)		
Date	2/12/08	5/29/08
TCE	<MDL	<MDL
1,2 DCA	0.282	0.862
PCE	0.0211	0.0216

Figure E 13. Indoor air concentrations in the main floor of U8-8244.

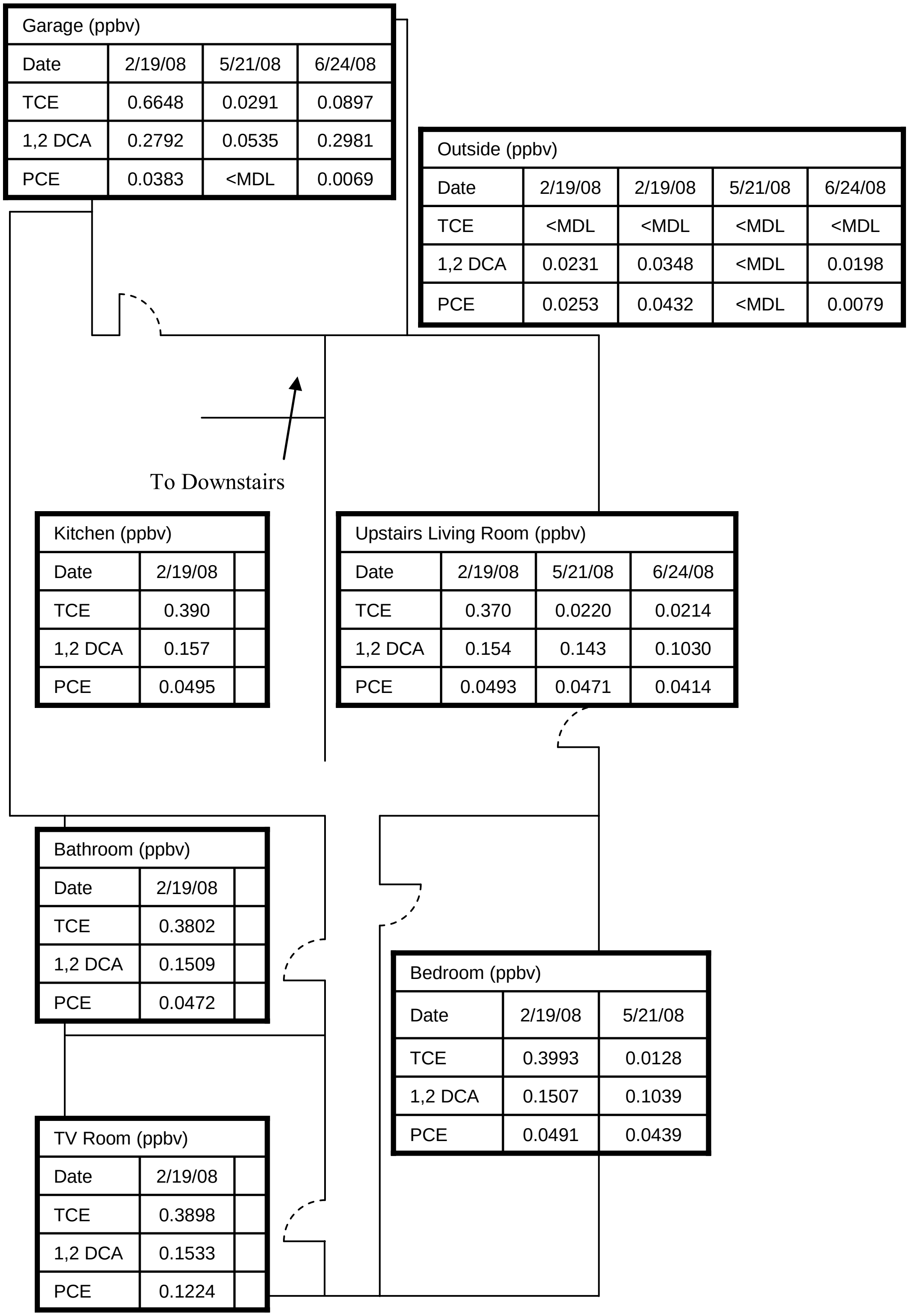


Downstairs Living (ppbv)		
Date	2/12/08	5/29/08
TCE	<MDL	<MDL
1,2 DCA	0.202	1.114
PCE	0.0112	0.00696

Downstairs Storage (ppbv)		
Date	2/12/08	5/29/08
TCE	<MDL	<MDL
1,2 DCA	0.365	1.228
PCE	0.0183	0.00609

Figure E 14. Indoor air concentrations in the basement of U8-8244.

U6-8016



Garage (ppbv)			
Date	2/19/08	5/21/08	6/24/08
TCE	0.6648	0.0291	0.0897
1,2 DCA	0.2792	0.0535	0.2981
PCE	0.0383	<MDL	0.0069

Outside (ppbv)				
Date	2/19/08	2/19/08	5/21/08	6/24/08
TCE	<MDL	<MDL	<MDL	<MDL
1,2 DCA	0.0231	0.0348	<MDL	0.0198
PCE	0.0253	0.0432	<MDL	0.0079

Kitchen (ppbv)		
Date	2/19/08	
TCE	0.390	
1,2 DCA	0.157	
PCE	0.0495	

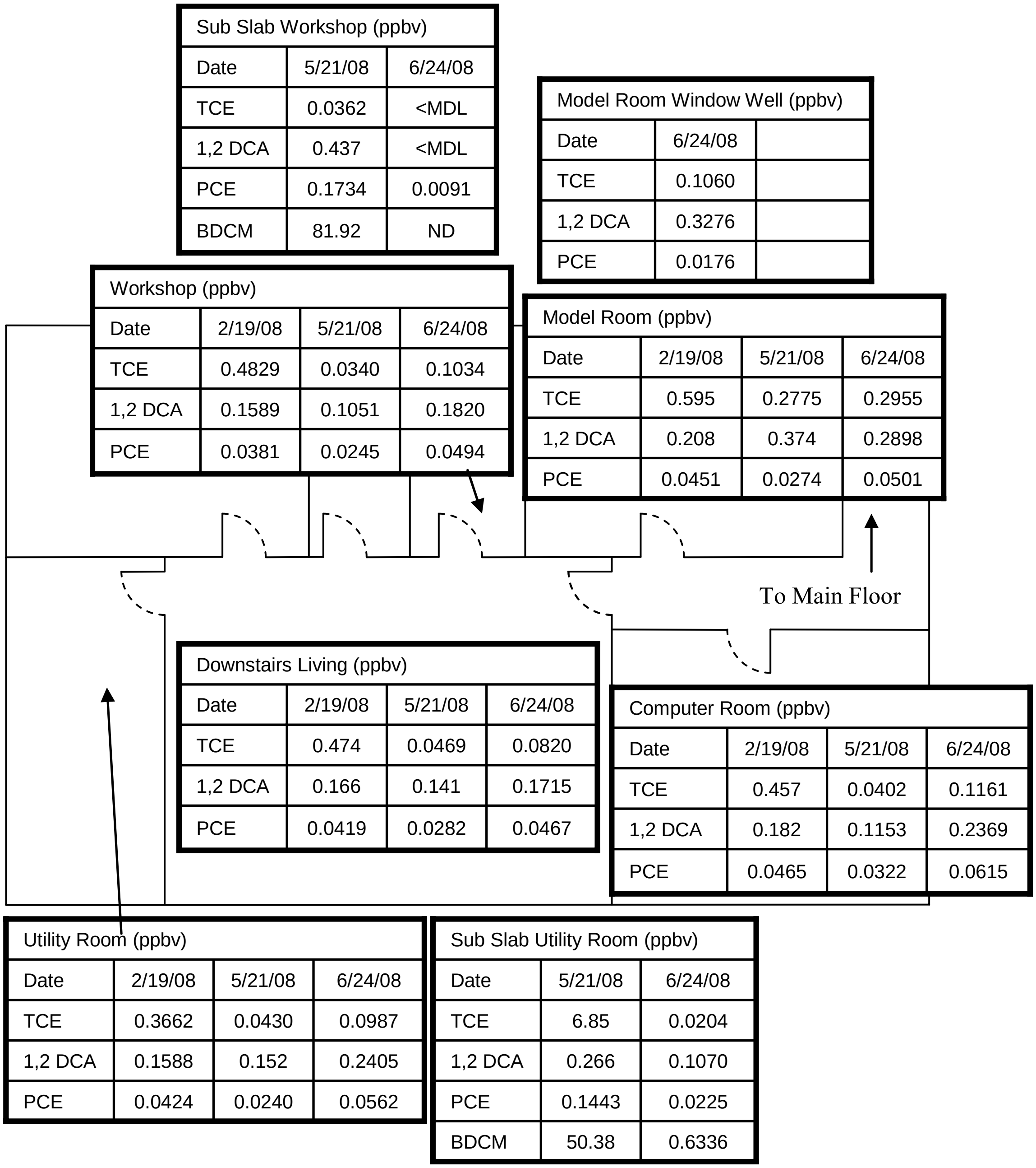
Upstairs Living Room (ppbv)			
Date	2/19/08	5/21/08	6/24/08
TCE	0.370	0.0220	0.0214
1,2 DCA	0.154	0.143	0.1030
PCE	0.0493	0.0471	0.0414

Bathroom (ppbv)		
Date	2/19/08	
TCE	0.3802	
1,2 DCA	0.1509	
PCE	0.0472	

Bedroom (ppbv)		
Date	2/19/08	5/21/08
TCE	0.3993	0.0128
1,2 DCA	0.1507	0.1039
PCE	0.0491	0.0439

TV Room (ppbv)		
Date	2/19/08	
TCE	0.3898	
1,2 DCA	0.1533	
PCE	0.1224	

Figure E 15. Indoor air concentrations in the main floor of U6-8016.



Sub Slab Workshop (ppbv)		
Date	5/21/08	6/24/08
TCE	0.0362	<MDL
1,2 DCA	0.437	<MDL
PCE	0.1734	0.0091
BDCM	81.92	ND

Model Room Window Well (ppbv)		
Date	6/24/08	
TCE	0.1060	
1,2 DCA	0.3276	
PCE	0.0176	

Workshop (ppbv)			
Date	2/19/08	5/21/08	6/24/08
TCE	0.4829	0.0340	0.1034
1,2 DCA	0.1589	0.1051	0.1820
PCE	0.0381	0.0245	0.0494

Model Room (ppbv)			
Date	2/19/08	5/21/08	6/24/08
TCE	0.595	0.2775	0.2955
1,2 DCA	0.208	0.374	0.2898
PCE	0.0451	0.0274	0.0501

Downstairs Living (ppbv)			
Date	2/19/08	5/21/08	6/24/08
TCE	0.474	0.0469	0.0820
1,2 DCA	0.166	0.141	0.1715
PCE	0.0419	0.0282	0.0467

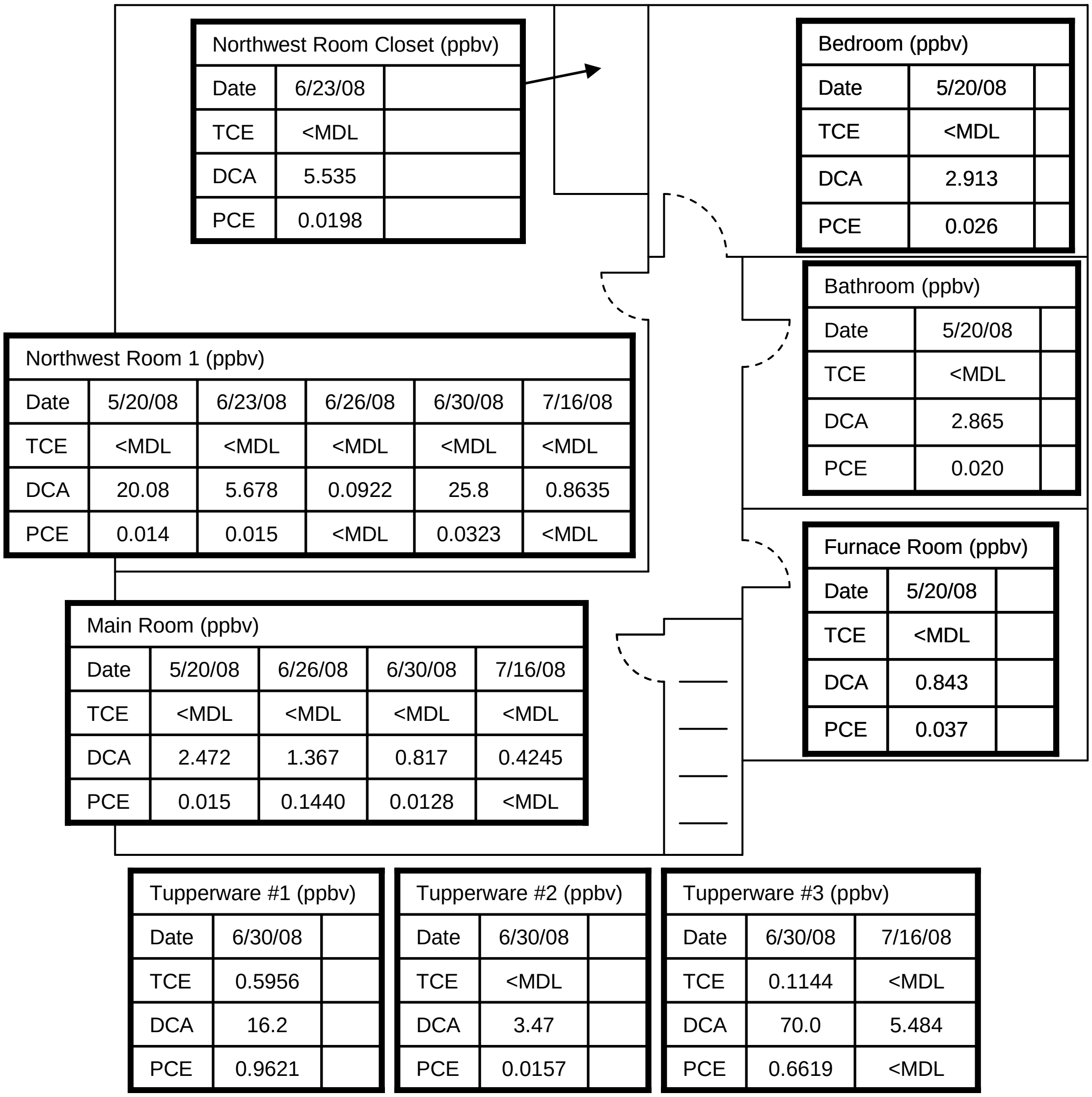
Computer Room (ppbv)			
Date	2/19/08	5/21/08	6/24/08
TCE	0.457	0.0402	0.1161
1,2 DCA	0.182	0.1153	0.2369
PCE	0.0465	0.0322	0.0615

Utility Room (ppbv)			
Date	2/19/08	5/21/08	6/24/08
TCE	0.3662	0.0430	0.0987
1,2 DCA	0.1588	0.152	0.2405
PCE	0.0424	0.0240	0.0562

Sub Slab Utility Room (ppbv)		
Date	5/21/08	6/24/08
TCE	6.85	0.0204
1,2 DCA	0.266	0.1070
PCE	0.1443	0.0225
BDCM	50.38	0.6336

Figure E 16. Indoor air concentrations in the basement of U6-8016.

U8-8452



Northwest Room Closet (ppbv)		
Date	6/23/08	
TCE	<MDL	
DCA	5.535	
PCE	0.0198	

Bedroom (ppbv)		
Date	5/20/08	
TCE	<MDL	
DCA	2.913	
PCE	0.026	

Bathroom (ppbv)		
Date	5/20/08	
TCE	<MDL	
DCA	2.865	
PCE	0.020	

Northwest Room 1 (ppbv)					
Date	5/20/08	6/23/08	6/26/08	6/30/08	7/16/08
TCE	<MDL	<MDL	<MDL	<MDL	<MDL
DCA	20.08	5.678	0.0922	25.8	0.8635
PCE	0.014	0.015	<MDL	0.0323	<MDL

Furnace Room (ppbv)		
Date	5/20/08	
TCE	<MDL	
DCA	0.843	
PCE	0.037	

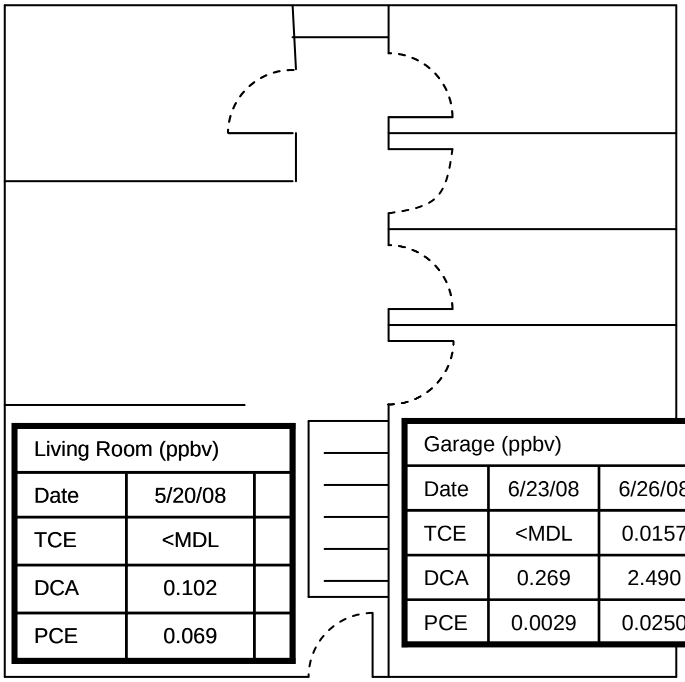
Main Room (ppbv)				
Date	5/20/08	6/26/08	6/30/08	7/16/08
TCE	<MDL	<MDL	<MDL	<MDL
DCA	2.472	1.367	0.817	0.4245
PCE	0.015	0.1440	0.0128	<MDL

Tupperware #1 (ppbv)		
Date	6/30/08	
TCE	0.5956	
DCA	16.2	
PCE	0.9621	

Tupperware #2 (ppbv)		
Date	6/30/08	
TCE	<MDL	
DCA	3.47	
PCE	0.0157	

Tupperware #3 (ppbv)		
Date	6/30/08	7/16/08
TCE	0.1144	<MDL
DCA	70.0	5.484
PCE	0.6619	<MDL

Figure E 17. Indoor air concentrations in the basement of U8-8452.



Wardrobe Box #1 (ppbv)

Date	6/26/08	
TCE	<MDL	
DCA	3.863	
PCE	0.0148	

Living Room (ppbv)

Date	5/20/08	
TCE	<MDL	
DCA	0.102	
PCE	0.069	

Garage (ppbv)

Date	6/23/08	6/26/08	6/30/08
TCE	<MDL	0.0157	<MDL
DCA	0.269	2.490	1.71
PCE	0.0029	0.0250	0.0094

Wardrobe Box #2 (ppbv)

Date	6/30/08	
TCE	<MDL	
DCA	4.51	
PCE	0.1342	

Outside (ppbv)

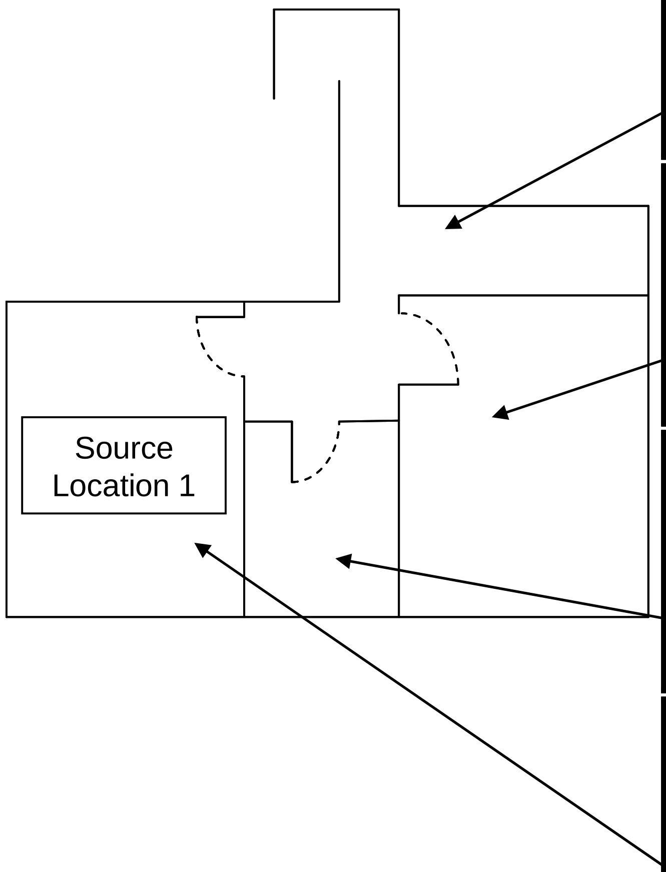
Date	5/20/08	6/23/08	6/26/08	6/30/08	7/16/08
TCE	<MDL	<MDL	<MDL	<MDL	<MDL
DCA	0.073	0.0303	5.150	0.0515	<MDL
PCE	0.083	0.0016	0.023	0.0050	<MDL

Rubbermaid Box (ppbv)

Date	6/26/08	
TCE	<MDL	
DCA	0.6169	
PCE	0.0653	

Figure E 18. Indoor air concentrations in the main floor of U8-8452.

UWRL-1



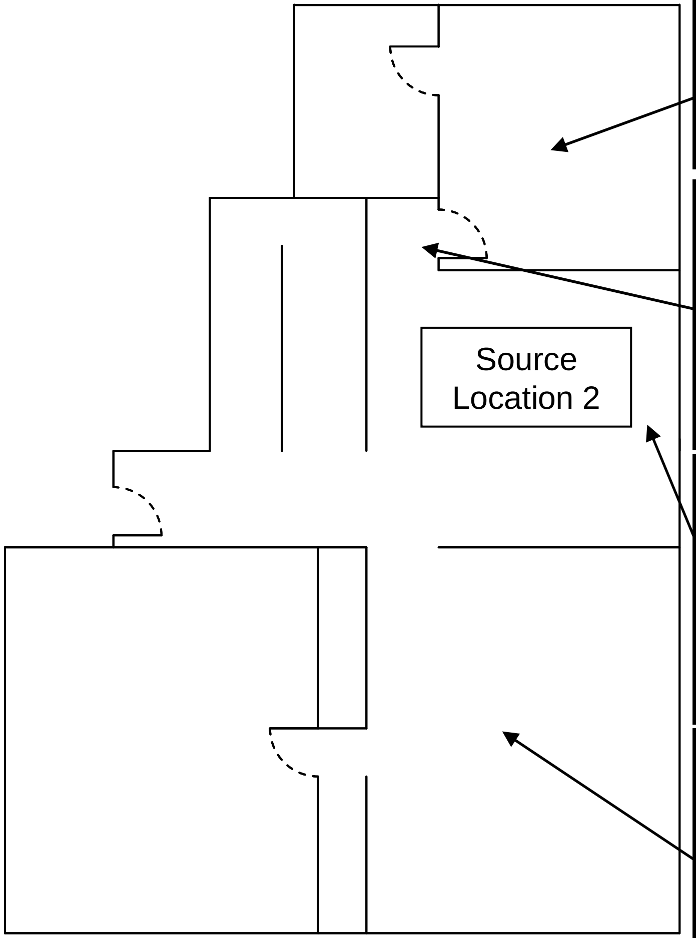
US Hallway						
Source Location	1 – No Fan	1 – Fan	2a – No Fan	2a – Fan	2b – No Fan	2b – Fan
Average Conc. (ppbv)	1355.9	1198.0	2052.8	691.9	2806.2	934.70
95 % Confidence Interval	25.06	17.75	44.46	11.82	57.42	3.66

US North Bedroom						
Source Location	1 – No Fan	1 – Fan	2a – No Fan	2a – Fan	2b – No Fan	2b – Fan
Average Conc. (ppbv)	1303.6	953.9	462.9	507.7	444.15	704.6
95 % Confidence Interval	13.42	3.59	43.34	0.72	21.92	3.20

US Bathroom						
Source Location	1 – No Fan	1 – Fan	2a – No Fan	2a – Fan	2b – No Fan	2b – Fan
Average Conc. (ppbv)	1492.7	724.3	1491.2	571.8	2274.8	848.1
95 % Confidence Interval	20.38	13.72	3.92	0.62	9.47	0.62

US South Bedroom						
Source Location	1 – No Fan	1 – Fan	2a – No Fan	2a – Fan	2b – No Fan	2b – Fan
Average Conc. (ppbv)	7250.7	2035	377.9	561.3	552.9	853.6
95 % Confidence Interval	351.8	269.5	6.69	0.51	1.50	0.96

Figure E 19. Indoor air concentrations of SF_6 in the upstairs of UWRL-1.



Main Bedroom

Source Location	1 – No Fan	1 – Fan	2a – No Fan	2a – Fan	2b – No Fan	2b – Fan
Average Conc. (ppbv)	Not Sampled	Not Sampled	145.8	624.3	131.69	853.2
95 % Confidence Interval	Not Sampled	Not Sampled	8.12	1.34	4.46	0.74

Main Living Room West Wall

Source Location	1 – No Fan	1 – Fan	2a – No Fan	2a – Fan	2b – No Fan	2b – Fan
Average Conc. (ppbv)	Not Sampled	Not Sampled	2288.9	799.5	2573.5	906.8
95 % Confidence Interval	Not Sampled	Not Sampled	47.51	13.97	69.26	3.28

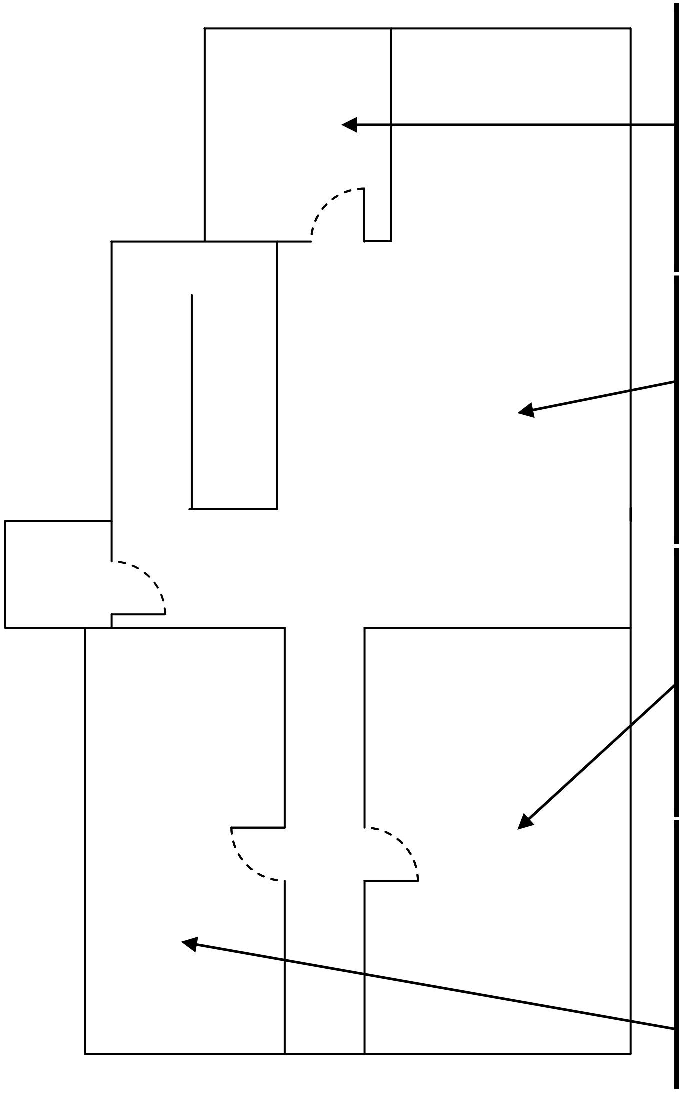
Main Living Room North Wall

Source Location	1 – No Fan	1 – Fan	2a – No Fan	2a – Fan	2b – No Fan	2b – Fan
Average Conc. (ppbv)	991.3	1102.9	3973.2	1069.5	4666.3	1867.8
95 % Confidence Interval	34.01	21.11	876.5	79.56	826.6	1514.1

Kitchen

Source Location	1 – No Fan	1 – Fan	2a – No Fan	2a – Fan	2b – No Fan	2b – Fan
Average Conc. (ppbv)	958.0	854.14	1372.2	685.1	2114.6	827.8
95 % Confidence Interval	23.92	10.73	41.93	3.49	79.44	3.77

Figure E 20. Indoor air concentrations of SF_6 in the main floor at UWRL-1.



Office						
Source Location	1 – No Fan	1 – Fan	2a – No Fan	2a – Fan	2b – No Fan	2b – Fan
Average Conc. (ppbv)	Not Sampled	Not Sampled	505.3	158.5	<DL	698.2
95 % Confidence Interval	Not Sampled	Not Sampled	9.94	30.87	<DL	3.25

Downstairs Living						
Source Location	1 – No Fan	1 – Fan	2a – No Fan	2a – Fan	2b – No Fan	2b – Fan
Average Conc. (ppbv)	277.4	887.3	363.2	320.2	165.08	1100.6
95 % Confidence Interval	5.17	12.15	29.83	18.44	11.98	3.91

Downstairs Bedroom						
Source Location	1 – No Fan	1 – Fan	2a – No Fan	2a – Fan	2b – No Fan	2b – Fan
Average Conc. (ppbv)	Not Sampled	Not Sampled	41.08	305.7	<DL	783.3
95 % Confidence Interval	Not Sampled	Not Sampled	1.44	0.98	<DL	18.05

Weight Room						
Source Location	1 – No Fan	1 – Fan	2a – No Fan	2a – Fan	2b – No Fan	2b – Fan
Average Conc. (ppbv)	Not Sampled	Not Sampled	56.83	300.7	<DL	730.7
95 % Confidence Interval	Not Sampled	Not Sampled	0.93	1.56	<DL	21.52

Figure E 21. Indoor air concentrations of SF_6 in the basement at UWRL-1.

Appendix F – Room Air Exchange Calculation Information

LAD 001-037

MIRAN® SapphIRe Analyzer for Ventilation Studies Using Tracer Gas

INTRODUCTION

With today's energy efficient buildings, measurement of ventilation has become important. Since little natural ventilation exists in a building, mechanical ventilation is critical for the removal of many indoor air pollutants such as volatile organic compounds, dusts, allergens, micro-organisms, and naturally occurring gases such as carbon dioxide.

Condensation, which promotes the growth of bacteria, and radon are also components that need to be "flushed" out of buildings by either mechanical or natural means.

The need for make-up air to flush out potentially hazardous chemicals is also critical. Predicting the actual air exchange rate in all areas of a room during actual operations is vital for understanding the dynamics of the air flow pattern and determining the ability of the ventilation system to flush out the contaminants

Ventilation is typically quantified as either the outdoor air supply requirement or the outdoor air exchange rate. We will discuss the outdoor air exchange rate.

This value is defined as the volume of outdoor air entering the room per hour compared with the volume of the room. For example, if the room is 16,000 ft^3 and the ventilation system is supplying 24,000 ft^3/h, the air exchange rate would be 1.5 changes/hour.

Ventilation is also quantified as the outdoor air supply requirement. The value is defined as the recommended volume of outdoor air each person in the enclosure should receive per unit of time. Typical values in hospitals range from one to four changes per hour - operating room should have four outside air changes per hour.

AIR EXCHANGE RATE METHODS

There are two basic methods that accurately define air exchange rates. In each method the basic equation is:

Change in the amount of tracer in the room	=	Amount of tracer introduced into room	Amount of tracer which has left room

CONCENTRATION-DECAY METHOD

This method, the simplest to perform, involves introducing a fixed quantity of gas into the room at time 0. The gas is then shut off and removed, and fans are used to ensure good mixing of the tracer. Before starting the test, spot measurements should be taken throughout the room to ensure that the mixing is complete.

The concentration is then measured several times over the test duration. Once the measurements are complete, a plot of the natural log of concentration versus time is made. The slope of the line is the air exchange rate. If the plot is not a straight line, the air is considered not well mixed and the results are invalid.

The equation for computing exchange rate is

$$N = \ln(C_s) - \ln(C_t)$$

where

N = Air exchange rate
C_s = Concentration of tracer gas at start time
C_t = Concentration of tracer gas at t1
T = Elapsed time in hours

PROCEDURE

The procedure for the concentration-decay method is as follows:

1. Determine the volume of the room. This is done to identify the amount of tracer gas to eject into the room. It is important to introduce gases that are not beyond the calibrated range of the equipment. The starting concentration should be targeted at about 1000 times the detection limit of the analyzer. With the SapphIRe analyzer, this will result in values about 10 ppm. Going to a higher concentration is not a problem, however.

2. Shut down the air intake system in the room being tested. A simple means to accomplish this is to simply block off the air intakes with paper. This is important because if the intake is open, it will be difficult to get a stable concentration to begin the test.
3. With the SapphIRe warmed up and measuring the tracer gas, begin to eject the gas into the room. You immediately notice the concentration rising. A mixing fan can now be used to ensure that the tracer gas is equally distributed. For a room of about 200mf3 this should take only a few minutes.
4. Take spot measurements of the tracer gas at ALL areas in the room to ensure that there is even distribution of the gas.
5. Remove the paper coverings over the air intake and begin to record the values. Logging data via the SapphIRe analyzer's internal logging memory or simply recording a value every minute is acceptable.
6. Record data for a minimum of 3-5 minutes. A maximum of 20 minutes worth of data is enough to prove a completely linear relationship between the Natural Logarithm of the concentration versus time.

EXPERIMENTAL EXAMPLE

A SapphIRe was calibrated for 0-30ppm Sulfur Hexafluoride. In the first run, gas was ejected from a cylinder for about 30 seconds. After equilibration, the concentration in the room was approximately 60 ppm. We then removed the paper covering from the intake to evacuate the tracer from the room. In about 10 minutes the tracer concentration fell within the range of the analyzer (starting concentration 28 ppm). At this point we began to collect the data from the center of the room. We repeated these experiments two other times at different locations. The concentration of tracer gas at the start of the other two experiments was 20 ppm and 23 ppm. Each run was conducted for 20 minutes with the following final concentrations of 4.5 ppm, 3.0 ppm and 3.4 ppm, respectively. See Figures 1, 2, and 3 for data describing the experiments.

In our example three separate runs yielded virtually identical room air exchange rates. Analyses were conducted at table height at the farthest point from the air intake, the center of the room, and directly below the air intake system.

In the second and third runs we ejected Sulfur Hexafluoride at a pressure of 5 psi for about 5 seconds into a room about 200 m3 in size. This resulted in a concentration of about 20 ppm. Theoretically, ejecting 3 liters of the pure gas in this room would yield 15 ppm. This is an ideal concentration to start the analysis.

Although the data was collected over a 20-minute period, the room air exchange rate was stable after about 10 minutes. Even after 2 minutes the Room Air Exchange Rate was yielding values that were within 10% of the final value.

CONSTANT EMISSION METHOD

This method is used for long term air exchange rates or for measurement of air flow through ventilation ducts. It requires the introduction of a constant amount of the tracer gas for the duration of the test. This method is similar to the concentration-decay method that the gas should be evenly distributed throughout the room with fans and should be uniform throughout the room. An accurate means of ensuring that the flow is evenly delivered, such as a flow meter, is required. The equation is as follows:

$$N = \frac{F}{VC}$$

where

N = Air exchange rate (changes/hour)
F = Introduction rate of the tracer - ft^3/h
V = Volume of room - ft^3
C = Concentration of tracer gas in room

CHOOSING A TRACER GAS

Several criteria should be examined when choosing a tracer gas - density, toxicity, detectability, and explosivity. The following table shows how the various gases meet the requirements above.

Gas	Density compared to air	Maximum Concentration		SapphIRe detection limit (ppm)
		Tracer test	Safety levels	
CO_2	1.53	640	5000	0.40
SF_6	5.11	83	1000	0.02
N_2O	1.53	640	25	0.06
R-13B1	5.13	83	100	0.12

* This value defines the concentration above which the air/tracer mixture would differ by 0.03%. This density difference is not expected to affect the air flow.

CONCLUSION

The advantages of measuring air flow by tracer gas techniques via an infrared analyzer are as follows:

- Air exchange rate is measured instantaneously.
- The equipment is very simple
- The user has the ability to identify air flow patterns in real life setups; i.e. with personnel and equipment present.
- The user can investigate specific locations of an exchange as opposed to simply measuring CFM at the air intake.

The MIRAN SapphIRe Portable Ambient Air Analyzers are ideal for determining air flow patterns in buildings. They are easy to use, sensitive, and accurate. MIRAN Ambient Air Analyzers have long been used by government agencies and private companies to study air flow patterns. Their ease of use, sensitivity, and accuracy make them the industry standard for air flow measurement.

Time (min)	SF6 (ppm)	ln (ppm)	AER-calc* (hours)
0	28.0	3.33	–
1	26.0	3.26	4.4
2	23.6	3.16	5.1
3	22.0	3.09	4.8
4	20.7	3.03	4.8
5	18.8	2.93	4.8
6	17.0	2.83	5.0
7	15.4	2.73	5.1
8	14.0	2.64	5.2
9	12.6	2.53	5.3
11	10.2	2.32	5.5
12	9.6	2.26	5.4
13	8.8	2.17	5.3
14	7.9	2.07	5.4
15	7.1	1.96	5.5
16	6.4	1.8	5.5
17	5.9	1.77	5.5
18	5.3	1.67	5.6
19	4.8	1.57	5.6
20	4.5	1.50	5.5

*AER-calc = Air Exchange Rate calculated per period

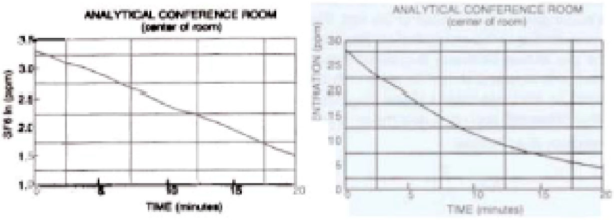


Figure 1

Time (min)	SF6 (ppm)	ln (ppm)	AER-calc* (hours)
0	20.5	3.02	
1	16.8	2.82	5.8
2	17.1	2.84	5.4
3	15.6	2.75	5.8
4	14.3	2.66	5.4
5	12.7	2.54	5.7
6	11.8	2.47	5.8
7	11.2	2.42	5.2
8	9.6	2.26	5.7
9	8.9	2.19	5.8
10	8.2	2.10	5.8
11	7.2	1.97	5.7
12	6.6	1.89	5.8
13	6.1	1.81	5.8
14	5.4	1.69	5.7
15	4.9	1.59	5.7
16	4.5	1.50	5.7
17	4.2	1.44	5.6
18	3.7	1.31	5.7
19	3.3	1.19	5.5
20	3.0	1.10	5.6

*AER-calc = Air Exchange Rate calculated per period

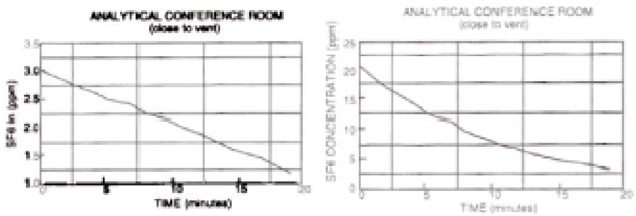


Figure 2

Time (min)	SF6 (ppm)	ln (ppm)	AER-calc* (hours)
0	22.9	3.13	–
1	20.5	3.02	6.6
2	17.1	2.84	5.8
3	15.4	2.73	6.0
4	14.3	2.66	5.7
5	12.6	2.53	6.0
6	11.8	2.47	5.7
7	9.8	2.28	6.4
8	9.1	2.21	6.2
9	8.8	2.17	5.7
10	7.9	2.07	5.8
11	7.1	1.96	5.9
12	7.1	1.96	5.9
13	6.2	1.82	6.0
14	5.7	1.74	6.0
15	5.5	1.70	5.7
16	5.0	1.61	5.7
17	4.3	1.46	5.9
18	4.0	1.39	5.8
19	3.7	1.31	5.8
20	3.4	1.22	5.7

*AER-calc = Air Exchange Rate calculated per period

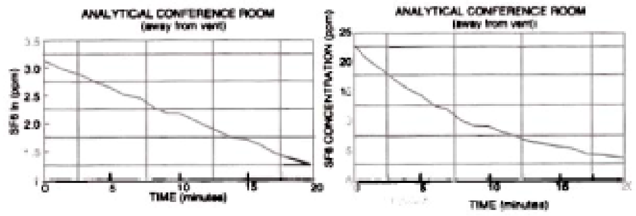


Figure 3

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Appendix G – Indoor Air Sampling Data

U12-8017

Table G 1. Indoor air sampling results for U12-8017

Sample Name	Tube Position Front/Back	Sample Date	TCE air (ppbv)	1,2-DCA air (ppbv)	PCE air (ppbv)
Garage #2	F	6/28/2007	<MDL	<MDL	Not Analyzed
Garage #2	B	6/28/2007	<MDL	<MDL	Not Analyzed
Garage #3	F	6/28/2007	<MDL	<MDL	Not Analyzed
Garage #3	B	6/28/2007	<MDL	<MDL	Not Analyzed
DS Bath #4	F	6/28/2007	<MDL	<MDL	Not Analyzed
DS Bed #5	F	6/28/2007	Computer Crash - Lost Sample		
US Bed #7	F	6/28/2007	2.42E-02	<MDL	Not Analyzed
US Bed #7	B	6/28/2007	<MDL	<MDL	Not Analyzed
US Bath #8	F	6/28/2007	1.14E-02	<MDL	Not Analyzed
US Bed #9	F	6/28/2007	<MDL	<MDL	Not Analyzed
US Bed #10	F	6/28/2007	1.23E-02	<MDL	Not Analyzed
US Kitch #11	F	6/28/2007	<MDL	<MDL	Not Analyzed
US LR/Den #12	F	6/28/2007	<MDL	<MDL	Not Analyzed
US Ft Rm #13	F	6/28/2007	1.36E-02	<MDL	Not Analyzed
DS Bottom of Stairs	F	6/28/2007	1.78E-02	<MDL	Not Analyzed
DS Bottom of Stairs	B	6/28/2007	<MDL	<MDL	Not Analyzed
DS Bottom of Stairs	F	6/28/2007	8.87E-03	<MDL	Not Analyzed
DS Bottom of Stairs	B	6/28/2007	<MDL	<MDL	Not Analyzed
US Top of Stairs	F	6/28/2007	<MDL	<MDL	Not Analyzed
outside front porch	F	6/28/2007	<MDL	<MDL	Not Analyzed
Kyle's desk	F	7/24/2007	2.78E-02	<MDL	Not Analyzed
Kyle's desk	B	7/24/2007	<MDL	<MDL	Not Analyzed
Kyle's desk	F	7/24/2007	1.22E-01	<MDL	Not Analyzed
Kyle's desk	B	7/24/2007	<MDL	<MDL	Not Analyzed
Outside	F	8/16/2007	4.13E-02	1.86E-02	Not Analyzed
US BedRm	F	8/16/2007	4.63E-02	6.96E-02	Not Analyzed
US BedRm	B	8/16/2007	4.48E-02	1.24E-02	Not Analyzed
US BR Closet	F	8/16/2007	5.04E-02	5.59E-02	Not Analyzed
DS Stair Bottom	F	8/16/2007	4.66E-02	4.09E-02	Not Analyzed
DS Utility Rm	F	8/16/2007	5.73E-02	4.08E-02	Not Analyzed
DS Utility Rm	B	8/16/2007	5.88E-02	1.57E-02	Not Analyzed

MDLs for each sample varied based on air flow rate and time sampled, average values were: TCE = 0.005-0.013 ppbv, 1,2 DCA = 0.005-0.012 ppbv, PCE = 0.001-0.003 ppbv

U8-8211

Table G 2. Indoor air sampling results for U8-8211

Sample Name	Tube Position Front/Back	Sample Date	TCE air (ppbv)	1,2-DCA air (ppbv)	PCE air (ppbv)
Master BR	F	8/16/2007	1.88E-02	4.27E-01	Not Analyzed
Master BR	B	8/16/2007	1.46E-02	8.60E-02	Not Analyzed
DS Living Rm	F	8/16/2007	2.72E-02	1.63E+00	Not Analyzed
Jordan's Rm	F	8/16/2007	1.98E-02	3.70E-01	Not Analyzed
Jordan's Rm	B	8/16/2007	1.70E-02	1.31E-01	Not Analyzed
DS Closet	F	8/16/2007	2.79E-02	2.60E+00	Not Analyzed
DS Closet	B	8/16/2007	2.39E-02	3.85E-01	Not Analyzed
Laundry Rm	F	8/16/2007	2.86E-02	1.48E+00	Not Analyzed
Laundry Rm	B	8/16/2007	1.36E-02	2.30E-01	Not Analyzed
Laundry Rm	F	8/16/2007	2.80E-02	1.59E+00	Not Analyzed
Laundry Rm	B	8/16/2007	1.87E-02	2.77E-01	Not Analyzed
Jacob's Rm	F	8/16/2007	4.15E-02	4.81E-01	Not Analyzed
Jacob's Rm	B	8/16/2007	4.15E-02	7.00E-02	Not Analyzed
DS Bedroom	F	8/16/2007	5.06E-02	1.07E+00	Not Analyzed
Living Room	F	8/16/2007	4.64E-02	4.00E-01	Not Analyzed
Garage	F	8/16/2007	4.15E-02	2.49E-01	Not Analyzed
Garage	B	8/16/2007	3.30E-02	2.03E-01	Not Analyzed
Front Porch	F	8/16/2007	3.45E-02	1.52E-02	Not Analyzed
Kitchen	F	8/16/2007	4.36E-02	3.85E-01	Not Analyzed
Kitchen	B	8/16/2007	4.24E-02	2.69E-01	Not Analyzed
Upstairs - Top of Stairs	F	9/6/2007	1.37E-02	9.25E-02	Not Analyzed
Upstairs - Top of Stairs	B	9/6/2007	5.35E-03	2.10E-02	Not Analyzed
Outside	F	9/6/2007	6.53E-03	2.16E-02	Not Analyzed
Outside	B	9/6/2007	7.45E-03	2.39E-03	Not Analyzed
Kitchen	F	9/6/2007	1.44E-02	8.12E-02	Not Analyzed
Kitchen	B	9/6/2007	1.76E-02	1.65E-02	Not Analyzed
Shed	F	9/6/2007	6.36E-03	7.84E-01	Not Analyzed
Shed	B	9/6/2007	<MDL	6.58E-01	Not Analyzed
DS Living Room	F	9/6/2007	<MDL	1.12E-01	Not Analyzed
DS Living Room	B	9/6/2007	<MDL	1.34E-02	Not Analyzed
DS Below Stairs	F	9/6/2007	1.50E-02	1.71E-01	Not Analyzed
DS Below Stairs	B	9/6/2007	6.87E-03	7.45E-03	Not Analyzed
Shed	F	9/18/2007	1.37E-02	3.69E-01	Not Analyzed
Shed	B	9/18/2007	1.81E-02	1.35E-01	Not Analyzed
Wedding Dress	F	9/18/2007	3.10E-02	5.29E-01	Not Analyzed
Wedding Dress	B	9/18/2007	5.31E-03	7.72E-02	Not Analyzed
Backyard (outside)	F	9/18/2007	3.08E-02	5.11E-03	Not Analyzed
Backyard (outside)	B	9/18/2007	3.77E-02	<MDL	Not Analyzed
Outside	F	9/20/2007	<MDL	<MDL	<MDL
Outside	B	9/20/2007	<MDL	<MDL	<MDL
Main Floor Living Room	F	9/20/2007	<MDL	9.83E-03	4.58E-03
Main Floor Living Room	B	9/20/2007	<MDL	<MDL	<MDL

MDLs for each sample varied based on air flow rate and time sampled, average values were: TCE = 0.005-0.013 ppbv, 1,2 DCA = 0.005-0.012 ppbv, PCE = 0.001-0.003 ppbv

Table G-2 cont.

Downstairs Under stairs	F	9/20/2007	<MDL	1.04E-02	4.99E-03
Downstairs Under stairs	B	9/20/2007	<MDL	<MDL	<MDL
Shed	F	9/20/2007	<MDL	5.45E-01	<MDL
Shed	B	9/20/2007	<MDL	5.14E-01	<MDL
Dress	F	9/20/2007	<MDL	1.25E-01	6.25E-01
Dress	B	9/20/2007	<MDL	<MDL	<MDL
Dress Duplicate	F	9/20/2007	<MDL	1.18E-01	5.28E-01
Dress Duplicate	B	9/20/2007	<MDL	<MDL	<MDL
Outside	F	11/20/2007	<MDL	2.38E-02	1.67E-02
Outside	B	11/20/2007	<MDL	<MDL	<MDL
Under stairs	F	11/20/2007	<MDL	6.96E-02	2.25E-02
Under stairs	B	11/20/2007	<MDL	<MDL	<MDL
Under stairs Duplicate	F	11/20/2007	<MDL	4.78E-02	1.89E-02
Under stairs Duplicate	B	11/20/2007	<MDL	<MDL	<MDL
Shed	F	11/20/2007	<MDL	2.91E-01	1.70E-02
Shed	B	11/20/2007	<MDL	1.86E-02	<MDL
DS Living	F	2/28/2008	<MDL	1.19E-01	3.33E-02
DS Living	B	2/28/2008	<MDL	<MDL	<MDL
DS Living Duplicate	F	2/28/2008	<MDL	1.19E-01	3.24E-02
DS Living Duplicate	B	2/28/2008	<MDL	<MDL	<MDL
Outside	F	2/28/2008	<MDL	2.03E-02	1.58E-02
Outside	B	2/28/2008	<MDL	<MDL	<MDL
Outside Duplicate	F	2/28/2008	<MDL	1.81E-02	1.58E-02
Outside Duplicate	B	2/28/2008	<MDL	<MDL	<MDL
Under Stairs	F	2/28/2008	<MDL	8.75E-02	3.17E-02
Under Stairs	B	2/28/2008	<MDL	<MDL	<MDL
Under Stairs Duplicate	F	2/28/2008	<MDL	1.05E-01	3.15E-02
Under Stairs Duplicate	B	2/28/2008	<MDL	<MDL	<MDL
DS Living	F	5/13/2008	1.35E-02	1.07E-01	3.06E-02
DS Living	B	5/13/2008	<MDL	<MDL	<MDL
Outside	F	5/13/2008	<MDL	2.26E-02	4.18E-03
Outside	B	5/13/2008	<MDL	<MDL	<MDL
Under Stairs	F	5/13/2008	1.03E-02	9.27E-02	2.61E-02
Under Stairs	B	5/13/2008	<MDL	8.10E-03	<MDL

MDLs for each sample varied based on air flow rate and time sampled, average values were: TCE = 0.005-0.013 ppbv, 1,2 DCA = 0.005-0.012 ppbv, PCE = 0.001-0.003 ppbv

U2-8003

Table G 3. Indoor air sampling results for U2-8003

Sample Name	Tube Position Front/Back	Sample Date	TCE air (ppbv)	1,2-DCA air (ppbv)	PCE air (ppbv)
Outside	F	9/24/2007	<MDL	<MDL	<MDL
Outside	B	9/24/2007	<MDL	<MDL	<MDL
Garage	F	9/24/2007	<MDL	2.39E-02	1.51E-03
Garage	B	9/24/2007	<MDL	<MDL	<MDL
Main Bedroom	F	9/24/2007	<MDL	7.66E-02	1.01E-01
Main Bedroom	B	9/24/2007	<MDL	<MDL	<MDL
Wood Room	F	9/24/2007	1.66E-02	7.12E-02	7.27E-02
Wood Room	B	9/24/2007	<MDL	<MDL	<MDL
Red Carpet Room	F	9/24/2007	<MDL	<MDL	1.70E-03
Red Carpet Room	B	9/24/2007	<MDL	<MDL	<MDL
Upstairs Bathroom	F	9/24/2007	<MDL	4.84E-02	8.18E-01
Upstairs Bathroom	B	9/24/2007	<MDL	<MDL	<MDL
Laundry Room Cupboard	F	9/24/2007	<MDL	6.79E-02	8.84E-02
Laundry Room Cupboard	B	9/24/2007	<MDL	<MDL	<MDL
Living Room	F	9/24/2007	<MDL	2.68E-02	1.05E-01
Living Room	B	9/24/2007	<MDL	<MDL	<MDL
Main Downstairs Room	F	9/24/2007	<MDL	2.21E-01	1.56E-01
Main Downstairs Room	B	9/24/2007	<MDL	<MDL	<MDL
Downstairs SE Room	F	9/24/2007	<MDL	2.38E-01	1.56E-01
Downstairs SE Room	B	9/24/2007	<MDL	<MDL	<MDL
Crawl Space Room	F	9/24/2007	<MDL	1.75E-01	1.22E-01
Crawl Space Room	B	9/24/2007	<MDL	<MDL	<MDL
DS SW Room	F	9/24/2007	<MDL	2.84E-01	1.81E-01
DS SW Room	B	9/24/2007	<MDL	<MDL	<MDL
East Side Bathroom	F	10/15/2007	<MDL	2.54E-02	3.74E-01
East Side Bathroom	B	10/15/2007	<MDL	<MDL	<MDL
Under Bathroom Sink	F	10/15/2007	<MDL	7.73E-02	2.47E-01
Under Bathroom Sink	B	10/15/2007	<MDL	<MDL	<MDL
Near Bathroom Door	F	10/15/2007	<MDL	2.33E-02	3.57E-01
Near Bathroom Door	B	10/15/2007	<MDL	<MDL	<MDL
Living Room	F	10/15/2007	<MDL	7.64E-03	6.78E-02
Living Room	B	10/15/2007	<MDL	<MDL	<MDL
Downstairs	F	10/15/2007	<MDL	1.84E-01	1.47E-01
Downstairs	B	10/15/2007	<MDL	<MDL	<MDL
Outside	F	10/15/2007	<MDL	<MDL	1.62E-03
Outside	B	10/15/2007	<MDL	<MDL	<MDL

MDLs for each sample varied based on air flow rate and time sampled, average values were: TCE = 0.005-0.013 ppbv, 1,2 DCA = 0.005-0.012 ppbv, PCE = 0.001-0.003 ppbv

U8-8050

Table G 4. Indoor air sampling results for U8-8050

Sample Name	**Tube Position Front/Back**	**Sample Date**	**TCE air (ppbv)**	**1,2-DCA air (ppbv)**	**PCE air (ppbv)**
Outside	F	9/26/2007	<MDL	3.59E-02	4.13E-03
Outside	B	9/26/2007	<MDL	<MDL	<MDL
Upstairs Spare Bedroom	F	9/26/2007	<MDL	2.39E-01	1.18E-02
Upstairs Spare Bedroom	B	9/26/2007	<MDL	<MDL	<MDL
Baby Room Front	F	9/26/2007	<MDL	4.13E-01	2.70E-02
Baby Room Front	B	9/26/2007	<MDL	<MDL	<MDL
Family Room Upstairs	F	9/26/2007	<MDL	5.15E-01	3.41E-02
Family Room Upstairs	B	9/26/2007	1.50E-02	<MDL	<MDL
Upstairs Bathroom	F	9/26/2007	<MDL	4.20E-01	3.16E-02
Upstairs Bathroom	B	9/26/2007	<MDL	<MDL	<MDL
Master Bedroom	F	9/26/2007	<MDL	3.58E-01	5.48E-02
Master Bedroom	B	9/26/2007	<MDL	9.79E-03	5.84E-03
Laundry Room	F	9/26/2007	<MDL	7.61E-02	3.16E-03
Laundry Room	B	9/26/2007	<MDL	<MDL	<MDL
Downstairs Den	F	9/26/2007	<MDL	1.07E+01	1.18E-02
Downstairs Den	B	9/26/2007	1.05E-02	3.21E-01	<MDL
Downstairs Bathroom	F	9/26/2007	6.91E-03	6.88E+00	9.16E-03
Downstairs Bathroom	B	9/26/2007	2.25E-02	1.99E-01	<MDL
Downstairs Hallway	F	9/26/2007	<MDL	4.73E-01	1.16E-02
Downstairs Hallway	B	9/26/2007	<MDL	2.28E-02	<MDL
Garage	F	9/26/2007	6.79E-03	1.64E-02	<MDL
Garage	B	9/26/2007	<MDL	<MDL	<MDL
Downstairs Den Below Fishtank	F	10/31/2007	<MDL	3.29E+00	2.62E-02
Downstairs Den Below Fishtank	B	10/31/2007	<MDL	3.17E-01	<MDL
Downstairs Den Main	F	10/31/2007	<MDL	3.11E+00	2.11E-02
Downstairs Den Main	B	10/31/2007	<MDL	1.49E-01	<MDL
Downstairs in Shower	F	10/31/2007	<MDL	1.89E+00	2.21E-02
Downstairs in Shower	B	10/31/2007	<MDL	6.89E-02	<MDL
Downstairs Bathroom Main	F	10/31/2007	<MDL	1.80E+00	2.27E-02
Downstairs Bathroom Main	B	10/31/2007	<MDL	2.89E-02	<MDL
Upstairs Main Room	F	10/31/2007	<MDL	7.52E-01	2.59E-02
Upstairs Main Room	B	10/31/2007	<MDL	3.98E-02	<MDL
Outside	F	10/31/2007	<MDL	2.47E-02	4.86E-03
Outside	B	10/31/2007	<MDL	<MDL	<MDL

MDLs for each sample varied based on air flow rate and time sampled, average values were: TCE = 0.005-0.013 ppbv, 1,2 DCA = 0.005-0.012 ppbv, PCE = 0.001-0.003 ppbv

U8-8170

Table G 5. Indoor air sampling results for U8-8170

Sample Name	Tube Position Front/Back	Sample Date	TCE air (ppbv)	1,2-DCA air (ppbv)	PCE air (ppbv)
Office	F	2/7/2008	7.73E-03	8.50E-01	3.41E-02
Office	B	2/7/2008	<MDL	4.23E-02	3.88E-03
Bedroom	F	2/7/2008	<MDL	5.26E-01	3.49E-02
Bedroom	B	2/7/2008	<MDL	4.39E-02	<MDL
Bathroom	F	2/7/2008	<MDL	4.93E-01	3.26E-02
Bathroom	B	2/7/2008	<MDL	6.81E-02	<MDL
Sewing Room	F	2/7/2008	6.50E-03	4.93E-01	3.67E-02
Sewing Room	B	2/7/2008	<MDL	2.28E-02	<MDL
Laundry Room	F	2/7/2008	<MDL	3.73E-01	2.55E-02
Laundry Room	B	2/7/2008	<MDL	2.91E-02	<MDL
Den	F	2/7/2008	<MDL	5.27E-01	2.98E-02
Den	B	2/7/2008	<MDL	2.94E-02	<MDL
Kitchen	F	2/7/2008	5.96E-03	5.19E-01	2.86E-02
Kitchen	B	2/7/2008	<MDL	5.07E-02	<MDL
Garage	F	2/7/2008	<MDL	1.44E-01	1.92E-02
Garage	B	2/7/2008	<MDL	<MDL	<MDL
Sun Room	F	2/7/2008	<MDL	3.85E-02	1.21E-02
Sun Room	B	2/7/2008	<MDL	<MDL	<MDL
Outside	F	2/7/2008	<MDL	2.24E-02	5.17E-03
Outside	B	2/7/2008	<MDL	<MDL	<MDL
Sewing Room	F	6/27/2008	6.48E-02	7.36E+00	2.45E-02
Sewing Room	B	6/27/2008	<MDL	5.59E-01	<MDL
Laundry	F	6/27/2008	5.19E-02	6.05E+00	2.22E-02
Laundry	B	6/27/2008	<MDL	5.70E-01	<MDL
Den	F	6/27/2008	7.81E-02	8.45E+00	3.13E-02
Den	B	6/27/2008	<MDL	8.69E-01	<MDL
Kitchen	F	6/27/2008	1.06E-01	9.42E+00	2.47E-02
Kitchen	B	6/27/2008	<MDL	1.80E+00	<MDL
Outside	F	6/27/2008	<MDL	6.62E-02	3.08E-02
Outside	B	6/27/2008	<MDL	<MDL	<MDL
Garage	F	6/27/2008	2.99E-01	1.87E+00	1.11E-02
Garage	B	6/27/2008	<MDL	3.34E-01	<MDL
Bathroom	F	6/27/2008	9.86E-02	1.01E+01	2.57E-02
Bathroom	B	6/27/2008	<MDL	1.30E+00	<MDL
Office	F	6/27/2008	1.90E-01	1.19E+01	2.44E-02
Office	B	6/27/2008	<MDL	8.23E-01	<MDL
Bedroom	F	6/27/2008	7.98E-02	1.01E+01	3.74E-02
Bedroom	B	6/27/2008	<MDL	6.36E-01	<MDL

MDLs for each sample varied based on air flow rate and time sampled, average values were: TCE = 0.005-0.013 ppbv, 1,2 DCA = 0.005-0.012 ppbv, PCE = 0.001-0.003 ppbv

U8-8244

Table G 6. Indoor air sampling results for U8-8244

Sample Name	Tube Position Front/Back	Sample Date	TCE air (ppbv)	1,2-DCA air (ppbv)	PCE air (ppbv)
Master Bedroom	F	2/12/2008	<MDL	2.52E-01	1.96E-02
Master Bedroom	B	2/12/2008	<MDL	3.40E-02	<MDL
Guest Bedroom	F	2/12/2008	<MDL	2.82E-01	2.11E-02
Guest Bedroom	B	2/12/2008	<MDL	9.92E-03	<MDL
Living Room 1	F	2/12/2008	<MDL	2.57E-01	1.79E-02
Living Room 1	B	2/12/2008	<MDL	1.58E-02	<MDL
Living Room 2	F	2/12/2008	<MDL	2.47E-01	1.75E-02
Living Room 2	B	2/12/2008	<MDL	2.32E-02	<MDL
Upstairs Bathroom	F	2/12/2008	<MDL	2.64E-01	1.86E-02
Upstairs Bathroom	B	2/12/2008	<MDL	1.92E-02	<MDL
Piano Room	F	2/12/2008	<MDL	2.54E-01	1.79E-02
Piano Room	B	2/12/2008	<MDL	2.10E-02	<MDL
Garage	F	2/12/2008	<MDL	3.17E-01	9.57E-03
Garage	B	2/12/2008	<MDL	<MDL	<MDL
Basement Living Room	F	2/12/2008	<MDL	2.02E-01	1.12E-02
Basement Living Room	B	2/12/2008	<MDL	<MDL	<MDL
Basement Storage	F	2/12/2008	<MDL	3.65E-01	1.18E-02
Basement Storage	B	2/12/2008	<MDL	<MDL	<MDL
Outside	F	2/12/2008	<MDL	2.36E-02	1.19E-02
Outside	B	2/12/2008	<MDL	<MDL	<MDL
Outside	F	5/28/2008	<MDL	2.20E-02	1.50E-02
Outside	B	5/28/2008	<MDL	<MDL	<MDL
Living	F	5/28/2008	<MDL	1.09E+00	1.57E-02
Living	B	5/28/2008	<MDL	3.77E-02	<MDL
Pantry/Laundry	F	5/28/2008	<MDL	2.55E+00	1.87E-02
Pantry/Laundry	B	5/28/2008	<MDL	1.77E-01	<MDL
DS West Room	F	5/28/2008	<MDL	1.11E+00	6.96E-03
DS West Room	B	5/28/2008	<MDL	<MDL	<MDL
Bathroom	F	5/28/2008	<MDL	9.29E-01	1.91E-02
Bathroom	B	5/28/2008	<MDL	2.80E-02	<MDL
Master Bedroom	F	5/28/2008	<MDL	9.17E-01	1.94E-02
Master Bedroom	B	5/28/2008	<MDL	2.91E-02	<MDL
DS East Room	F	5/28/2008	<MDL	1.23E+00	6.09E-03
DS East Room	B	5/28/2008	<MDL	<MDL	<MDL
Guest Room	F	5/28/2008	<MDL	8.15E-01	2.16E-02
Guest Room	B	5/28/2008	<MDL	4.73E-02	<MDL
Garage	F	5/28/2008	<MDL	4.46E+00	7.21E-03
Garage	B	5/28/2008	<MDL	1.19E-01	<MDL
Living Duplicate	F	5/28/2008	<MDL	1.03E+00	1.48E-02
Living Duplicate	B	5/28/2008	<MDL	5.65E-02	<MDL

MDLs for each sample varied based on air flow rate and time sampled, average values were: TCE = 0.005-0.013 ppbv, 1,2 DCA = 0.005-0.012 ppbv, PCE = 0.001-0.003 ppbv

U6-8016

Table G 7. Indoor air sampling results from U6-8016

Sample Name	Tube Position Front/Back	Sample Date	TCE air (ppbv)	1,2-DCA air (ppbv)	PCE air (ppbv)
Outside	F	2/19/2008	<MDL	2.23E-02	2.53E-02
Outside	B	2/19/2008	<MDL	<MDL	<MDL
Outside Duplicate	F	2/19/2008	<MDL	3.48E-02	4.32E-02
Outside Duplicate	B	2/19/2008	<MDL	<MDL	<MDL
Computer Room	F	2/19/2008	4.57E-01	1.82E-01	4.65E-02
Computer Room	B	2/19/2008	<MDL	<MDL	<MDL
Garage	F	2/19/2008	6.65E-01	2.79E-01	3.83E-02
Garage	B	2/19/2008	<MDL	<MDL	<MDL
Kitchen	F	2/19/2008	3.90E-01	1.57E-01	4.95E-02
Kitchen	B	2/19/2008	<MDL	<MDL	<MDL
Upstairs Living Room	F	2/19/2008	3.70E-01	1.54E-01	4.93E-02
Upstairs Living Room	B	2/19/2008	<MDL	<MDL	<MDL
Model Room	F	2/19/2008	5.95E-01	2.08E-01	4.45E-02
Model Room	B	2/19/2008	<MDL	<MDL	<MDL
Downstairs Living Room	F	2/19/2008	4.74E-01	1.66E-01	4.19E-02
Downstairs Living Room	B	2/19/2008	<MDL	6.96E-03	<MDL
Upstairs Bedroom	F	2/19/2008	3.99E-01	1.51E-01	4.92E-02
Upstairs Bedroom	B	2/19/2008	<MDL	<MDL	<MDL
Workshop	F	2/19/2008	4.83E-01	1.59E-01	3.81E-02
Workshop	B	2/19/2008	<MDL	<MDL	<MDL
Upstairs Bathroom	F	2/19/2008	3.80E-01	1.51E-01	4.72E-02
Upstairs Bathroom	B	2/19/2008	<MDL	7.78E-03	<MDL
Utility Room	F	2/19/2008	3.66E-01	1.59E-01	4.24E-02
Utility Room	B	2/19/2008	<MDL	<MDL	<MDL
TV Room	F	2/19/2008	3.90E-01	1.53E-01	1.22E-01
TV Room	B	2/19/2008	<MDL	<MDL	<MDL
Sub Slab Utility Room	F	5/21/2008	6.06E+00	2.66E-01	1.44E-01
Sub Slab Utility Room	B	5/21/2008	8.04E-01	<MDL	<MDL
Sub Slab Workshop	F	5/21/2008	3.62E-02	4.73E-01	1.73E-01
Sub Slab Workshop	B	5/21/2008	<MDL	<MDL	<MDL
Computer Room	F	5/21/2008	4.02E-02	1.15E-01	3.22E-02
Computer Room	B	5/21/2008	<MDL	<MDL	<MDL
Workshop	F	5/21/2008	3.40E-02	1.05E-01	2.25E-02
Workshop	B	5/21/2008	<MDL	<MDL	<MDL
Utility Room	F	5/21/2008	4.30E-02	1.52E-01	2.40E-02
Utility Room	B	5/21/2008	<MDL	<MDL	<MDL
Model Room	F	5/21/2008	2.77E-01	3.74E-01	2.74E-02
Model Room	B	5/21/2008	<MDL	<MDL	<MDL
Outside	F	5/21/2008	<MDL	<MDL	<MDL
Outside	B	5/21/2008	<MDL	<MDL	<MDL

MDLs for each sample varied based on air flow rate and time sampled, average values were: TCE = 0.005-0.013 ppbv, 1,2 DCA = 0.005-0.012 ppbv, PCE = 0.001-0.003 ppbv

Table G 7 cont.

Garage	F	5/21/2008	2.91E-02	5.35E-02	<MDL
Garage	B	5/21/2008	<MDL	<MDL	<MDL
Downstairs Living	F	5/21/2008	4.47E-02	1.41E-01	2.82E-02
Downstairs Living	B	5/21/2008	<MDL	<MDL	<MDL
Upstairs Bedroom	F	5/21/2008	1.28E-02	1.04E-01	4.39E-02
Upstairs Bedroom	B	5/21/2008	<MDL	<MDL	<MDL
Upstairs Living	F	5/21/2008	2.20E-02	1.43E-01	4.71E-02
Upstairs Living	B	5/21/2008	<MDL	<MDL	<MDL
Storage Room	F	6/24/2008	9.88E-02	2.41E-01	5.62E-02
Storage Room	B	6/24/2008	<MDL	1.13E-02	<MDL
Storage Room Sub Slab	F	6/24/2008	2.04E-02	1.07E-01	2.26E-02
Storage Room Sub Slab	B	6/24/2008	<MDL	<MDL	<MDL
Hobby Room	F	6/24/2008	1.03E-01	1.82E-01	4.94E-02
Hobby Room	B	6/24/2008	<MDL	1.64E-02	<MDL
Hobby Room Sub Slab	F	6/24/2008	<MDL	<MDL	9.18E-03
Hobby Room Sub Slab	B	6/24/2008	<MDL	<MDL	<MDL
Window Well	F	6/24/2008	1.06E-01	3.28E-01	1.77E-02
Window Well	B	6/24/2008	<MDL	2.26E-02	<MDL
Model Room	F	6/24/2008	2.95E-01	2.90E-01	5.01E-02
Model Room	B	6/24/2008	<MDL	1.80E-02	<MDL
Computer Room	F	6/24/2008	1.16E-01	2.37E-01	6.15E-02
Computer Room	B	6/24/2008	<MDL	1.15E-02	<MDL
DS Living Room	F	6/24/2008	8.20E-02	1.71E-01	4.67E-02
DS Living Room	B	6/24/2008	<MDL	1.38E-02	<MDL
US Living	F	6/24/2008	2.14E-02	1.03E-01	4.15E-02
US Living	B	6/24/2008	<MDL	1.17E-02	<MDL
Garage	F	6/24/2008	8.97E-02	2.98E-01	6.98E-03
Garage	B	6/24/2008	<MDL	2.27E-02	<MDL
Outside	F	6/24/2008	<MDL	1.98E-02	7.98E-03
Outside	B	6/24/2008	<MDL	<MDL	<MDL

MDLs for each sample varied based on air flow rate and time sampled, average values were: TCE = 0.005-0.013 ppbv, 1,2 DCA = 0.005-0.012 ppbv, PCE = 0.001-0.003 ppbv

U8-8452

Table G 8. Indoor air sampling results from U8-8452

Sample Name	Tube Position Front/Back	Sample Date	TCE air (ppbv)	1,2-DCA air (ppbv)	PCE air (ppbv)
X-mas Room 1	F	5/20/2008	<MDL	1.96E+01	1.38E-02
X-mas Room 1	B	5/20/2008	<MDL	4.11E-02	<MDL
X-mas Room 2	F	5/20/2008	<MDL	2.05E+01	1.38E-02
X-mas Room 2	B	5/20/2008	<MDL	2.51E-02	<MDL
Furnace	F	5/20/2008	<MDL	8.43E-01	3.66E-02
Furnace	B	5/20/2008	<MDL	<MDL	<MDL
Outside	F	5/20/2008	<MDL	7.28E-02	8.32E-02
Outside	B	5/20/2008	<MDL	<MDL	<MDL
DS Main Room	F	5/20/2008	<MDL	2.47E+00	1.49E-02
DS Main Room	B	5/20/2008	<MDL	<MDL	<MDL
UpS Living	F	5/20/2008	<MDL	1.02E-01	6.90E-02
UpS Living	B	5/20/2008	<MDL	<MDL	<MDL
DS Bedroom	F	5/20/2008	<MDL	2.91E+00	2.64E-02
DS Bedroom	B	5/20/2008	<MDL	3.73E-02	<MDL
DS Bathroom	F	5/20/2008	<MDL	2.87E+00	2.01E-02
DS Bathroom	B	5/20/2008	<MDL	<MDL	<MDL
X-mas Room	F	6/30/2008	<MDL	2.26E+01	3.24E-02
X-mas Room	B	6/30/2008	<MDL	3.17E+00	<MDL
Outside	F	6/30/2008	<MDL	4.97E-02	5.01E-03
Outside	B	6/30/2008	<MDL	<MDL	<MDL
Wardrobe Box #2	F	6/30/2008	<MDL	2.23E+00	1.34E-01
Wardrobe Box #2	B	6/30/2008	<MDL	2.23E+00	4.92E-03
Garage	F	6/30/2008	<MDL	1.23E+00	9.43E-03
Garage	B	6/30/2008	<MDL	4.88E-01	<MDL
Tupperware Large #1	F	6/30/2008	5.96E-01	1.32E+01	9.62E-01
Tupperware Large #1	B	6/30/2008	<MDL	2.97E+00	4.52E-02
Tupperware Small #2	F	6/30/2008	<MDL	3.06E+00	1.57E-02
Tupperware Small #2	B	6/30/2008	<MDL	4.16E-01	<MDL
Tupperware Small #3	F	6/30/2008	1.14E-01	6.11E+01	6.62E-01
Tupperware Small #3	B	6/30/2008	<MDL	8.91E+00	<MDL
Main Room DS	F	6/30/2008	<MDL	7.84E-01	1.28E-02
Main Room DS	B	6/30/2008	<MDL	3.27E-02	<MDL
Outside sidewalk	F	6/30/2008	<MDL	2.83E-02	8.59E-03
Outside sidewalk	B	6/30/2008	<MDL	2.51E-02	<MDL
X-mas Room	F	6/26/2008	<MDL	9.22E-02	<MDL
X-mas Room	B	6/26/2008	<MDL	2.58E-02	<MDL
Outside	F	6/26/2008	<MDL	5.15E+00	3.23E-02
Outside	B	6/26/2008	<MDL	7.51E-01	<MDL
Wardrobe Box	F	6/26/2008	<MDL	3.86E+00	1.49E-02
Wardrobe Box	B	6/26/2008	<MDL	1.16E+00	<MDL

MDLs for each sample varied based on air flow rate and time sampled, average values were: TCE = 0.005-0.013 ppbv, 1,2 DCA = 0.005-0.012 ppbv, PCE = 0.001-0.003 ppbv

Table G 8 cont.

Garage	F	6/26/2008	1.57E-02	2.49E+00	2.51E-02
Garage	B	6/26/2008	<MDL	6.01E-01	<MDL
Rubbermaid Box	F	6/26/2008	<MDL	6.17E-01	6.53E-02
Rubbermaid Box	B	6/26/2008	<MDL	3.03E-02	3.32E-03
Lrg Basement Room	F	6/26/2008	<MDL	1.37E+00	1.44E-01
Lrg Basement Room	B	6/26/2008	<MDL	4.01E-02	<MDL
X-mas Room	F	6/23/2008	<MDL	5.68E+00	1.51E-02
X-mas Room	B	6/23/2008	<MDL	1.07E-01	<MDL
X-mas Room Closet	F	6/23/2008	<MDL	5.53E+00	1.98E-02
X-mas Room Closet	B	6/23/2008	<MDL	4.54E-02	<MDL
Outside	F	6/23/2008	<MDL	3.04E-02	1.57E-03
Outside	B	6/23/2008	<MDL	8.02E-03	<MDL
Garage	F	6/23/2008	<MDL	2.69E-01	2.94E-03
Garage	B	6/23/2008	<MDL	6.75E-02	<MDL
Box #3	F	7/16/2008	<MDL	5.48E+00	<MDL
Box #3	B	7/16/2008	<MDL	3.85E-01	<MDL
DS Living Room	F	7/16/2008	<MDL	4.25E-01	<MDL
DS Living Room	B	7/16/2008	<MDL	<MDL	<MDL
X-mas Room	F	7/16/2008	<MDL	8.64E-01	<MDL
X-mas Room	B	7/16/2008	<MDL	<MDL	<MDL
Outside	F	7/16/2008	<MDL	<MDL	<MDL
Outside	B	7/16/2008	<MDL	<MDL	<MDL

MDLs for each sample varied based on air flow rate and time sampled, average values were: TCE = 0.005-0.013 ppbv, 1,2 DCA = 0.005-0.012 ppbv, PCE = 0.001-0.003 ppbv

QA/QC Data

Table G 9. Quality assurance/quality control indoor air sampling results

Hill AFB Loc. Code	Sample Name	Sample Date	TCE on tube (pg)	1,2-DCA on tube (pg)	PCE on tube (pg)
U8-8452	CCV 2000	5/20/2008	2025.64	1.99E+03	2.00E+03
U8-8452	Blank	5/20/2008	<MDL	<MDL	<MDL
U8-8452	CCV 2000	5/20/2008	1902.91	1.89E+03	1.91E+03
U8-8452	Blank	5/20/2008	<MDL	<MDL	<MDL
U8-8452	Closed Field Blank	5/20/2008	<MDL	<MDL	<MDL
U8-8452	Closed Field Blank	5/20/2008	<MDL	<MDL	<MDL
U8-8452	Closed Field Blank	5/20/2008	<MDL	<MDL	<MDL
U8-8452	Closed Field Blank	5/20/2008	<MDL	<MDL	<MDL
U8-8452	CCV 2000	5/20/2008	1790.50	1.82E+03	1.79E+03
U8-8452	Blank	5/20/2008	<MDL	<MDL	<MDL
U8-8050	Lab Blank	10/31/2007	<MDL	<MDL	<MDL
U8-8050	Open Field Blank	10/31/2007	<MDL	<MDL	<MDL
U8-8050	Open Field Blank	10/31/2007	<MDL	<MDL	<MDL
U8-8050	Closed Field Blank	10/31/2007	223.87	<MDL	<MDL
U8-8050	Closed Field Blank	10/31/2007	<MDL	<MDL	<MDL
U8-8050	Lab Blank	10/31/2007	<MDL	<MDL	<MDL
U8-8050	Open Field Blank	9/26/2007	<MDL	<MDL	<MDL
U8-8050	Closed Field Blank	9/26/2007	<MDL	<MDL	<MDL
U8-8050	Lab Blank	9/26/2007	<MDL	<MDL	<MDL
U8-8050	Open Field Blank	9/26/2007	<MDL	<MDL	<MDL
U8-8050	Closed Field Blank	9/26/2007	<MDL	<MDL	<MDL
U8-8050	Lab Blank 9/20	9/26/2007	<MDL	<MDL	<MDL
U8-8050	Closed Field Blank	9/26/2007	<MDL	<MDL	<MDL
U8-8050	Closed Field Blank	9/26/2007	<MDL	<MDL	<MDL
U8-8050	Closed Field Blank	9/26/2007	<MDL	<MDL	<MDL
U8-8050	Closed Field Blank	9/26/2007	<MDL	<MDL	<MDL
U8-8244	CCV 995	2/12/2008	847.34	8.88E+02	1.06E+03
U8-8244	Lab Blank	2/12/2008	<MDL	<MDL	<MDL
U8-8244	CCV 995	2/12/2008	743.78	8.15E+02	9.65E+02
U8-8244	Lab Blank	2/12/2008	<MDL	<MDL	<MDL
U8-8244	CCV 995	2/12/2008	851.98	8.25E+02	1.00E+03
U8-8244	Lab Blank	2/12/2008	<MDL	<MDL	<MDL
U8-8244	CCV 995	5/28/2008	1657.36	1.74E+03	1.69E+03
U8-8244	Lab Blank	5/28/2008	<MDL	<MDL	<MDL
U8-8244	CCV 995	5/28/2008	1558.60	1.64E+03	1.62E+03
U8-8244	Lab Blank	5/28/2008	<MDL	<MDL	<MDL
U8-8170	CCV 995	2/7/2008	901.60	9.25E+02	1.06E+03
U8-8170	Lab Blank	2/7/2008	<MDL	<MDL	<MDL
U8-8170	CCV 995	2/7/2008	936.94	9.05E+02	1.02E+03
U8-8170	Lab Blank	2/7/2008	<MDL	<MDL	<MDL
U8-8170	Open Field Blank	2/7/2008	<MDL	<MDL	<MDL
U8-8170	Closed Field Blank	2/7/2008	<MDL	<MDL	<MDL
U8-8170	Open Field Blank	2/7/2008	<MDL	<MDL	<MDL

Table G 9 cont.

MDLs for each sample varied based on air flow rate and time sampled, average values were: TCE = 0.005-0.013 ppbv, 1,2 DCA = 0.005-0.012 ppbv, PCE = 0.001-0.003 ppbv

U8-8170	Closed Field Blank	2/7/2008	<MDL	<MDL	<MDL
U2-8003	Open Field Blank	10/15/2007	<MDL	<MDL	<MDL
U2-8003	Closed Field Blank	10/15/2007	<MDL	<MDL	<MDL
U2-8003	Living Room Spike	10/15/2007	500.62	8.59E+02	3.19E+03
U2-8003	Living Room Spike	10/15/2007	<MDL	<MDL	<MDL
U2-8003	Open Field Blank	10/15/2007	<MDL	<MDL	<MDL
U2-8003	Closed Field Blank	10/15/2007	<MDL	<MDL	<MDL
U2-8003	Outside Spike	10/15/2007	637.17	9.29E+02	9.45E+02
U2-8003	Outside Spike	10/15/2007	<MDL	<MDL	<MDL
U2-8003	Closed Field Spike	10/15/2007	538.90	7.53E+02	6.93E+02
U2-8003	Closed Field Spike	10/15/2007	581.59	6.79E+02	6.90E+02
U2-8003	Lab Blank	9/24/2007	<MDL	<MDL	<MDL
U2-8003	Closed Field Blank	9/24/2007	<MDL	<MDL	<MDL
U2-8003	Closed Field Blank	9/24/2007	<MDL	<MDL	<MDL
U2-8003	Open Field Blank	9/24/2007	95.76	<MDL	<MDL
U2-8003	Open Field Blank	9/24/2007	<MDL	<MDL	<MDL
U2-8003	Lab Blank 9/20/07	9/24/2007	<MDL	<MDL	<MDL
U2-8003	Open Field Blank	9/24/2007	146.59	<MDL	<MDL
U2-8003	Open Field Blank	9/24/2007	75.76	<MDL	<MDL
U2-8003	Lab Blank 9/20/07	9/24/2007	262.78	<MDL	<MDL
U6-8016	CCV	2/19/2008	1667.73	1.61E+03	1.83E+03
U6-8016	Blank	2/19/2008	<MDL	<MDL	<MDL
U6-8016	CCV	2/19/2008	1498.56	1.53E+03	1.78E+03
U6-8016	Blank	2/19/2008	<MDL	<MDL	<MDL
U6-8016	CCV	2/19/2008	1507.96	1.46E+03	1.70E+03
U6-8016	Blank	2/19/2008	<MDL	<MDL	<MDL
U6-8016	Field Blank	2/19/2008	<MDL	<MDL	<MDL
U6-8016	Field Blank	2/19/2008	<MDL	<MDL	<MDL
U6-8016	Field Blank	2/19/2008	<MDL	<MDL	<MDL
U6-8016	Field Blank	2/19/2008	<MDL	<MDL	<MDL
U6-8016	CCV	2/19/2008	3116.96	2.78E+03	3.46E+03
U6-8016	Blank	2/19/2008	<MDL	<MDL	<MDL
U6-8016	CCV 2000	5/21/2008	1792.75	1.78E+03	1.81E+03
U6-8016	Blank	5/21/2008	<MDL	<MDL	<MDL
U6-8016	CCV 2000	5/21/2008	1571.96	1.60E+03	1.59E+03
U6-8016	Blank	5/21/2008	<MDL	<MDL	<MDL
U6-8016	CCV 2000	5/21/2008	1598.09	1.66E+03	1.61E+03
U6-8016	Blank	5/21/2008	<MDL	<MDL	<MDL
U6-8016	CCV 2000	5/21/2008	1624.09	1.67E+03	1.63E+03
U6-8016	Blank	5/21/2008	<MDL	<MDL	<MDL
U8-8211	Lab Blank	11/20/2007	<MDL	<MDL	<MDL
U8-8211	CCV 995 pg	11/20/2007	926.54	9.32E+02	9.98E+02
U8-8211	Field Blank	11/20/2007	<MDL	<MDL	<MDL
U8-8211	CCV 995 pg	11/20/2007	448.08	9.65E+02	9.92E+02
U8-8211	Field Blank	11/20/2007	<MDL	<MDL	<MDL
U8-8211	Field Blank	11/20/2007	<MDL	<MDL	<MDL
U8-8211	Field Blank	11/20/2007	<MDL	<MDL	<MDL

MDLs for each sample varied based on air flow rate and time sampled, average values were: TCE = 0.005-0.013 ppbv, 1,2 DCA = 0.005-0.012 ppbv, PCE = 0.001-0.003 ppbv

Table G 9 cont.

U8-8211	Field Blank	11/20/2007	<MDL	<MDL	<MDL
U8-8211	Field Blank	11/20/2007	<MDL	<MDL	<MDL
U8-8211	Field Blank	11/20/2007	<MDL	<MDL	<MDL
U8-8211	Field Blank	11/20/2007	<MDL	<MDL	<MDL
U8-8211	Lab Blank 1	9/6/2007	138.76	<MDL	Not Analyzed
U8-8211	Lab Blank 2	9/6/2007	141.14	<MDL	Not Analyzed
U8-8211	Lab Blank 3	9/6/2007	159.16	<MDL	Not Analyzed
U8-8211	Lab Blank 4	9/6/2007	163.97	<MDL	Not Analyzed
U8-8211	Closed Field Blank 1	9/6/2007	104.03	<MDL	Not Analyzed
U8-8211	Closed Field Blank 2	9/6/2007	191.01	<MDL	Not Analyzed
U8-8211	Closed Field Blank 3	9/6/2007	194.83	<MDL	Not Analyzed
U8-8211	CCV @ 2000pg/L	9/6/2007	2026.78	2.18E+03	Not Analyzed
U8-8211	Closed Field Blank 5	9/6/2007	183.94	2.63E+01	Not Analyzed
U8-8211	Kitchen Field Blank (Closed)	9/6/2007	184.77	<MDL	Not Analyzed
U8-8211	Kitchen Field Blank (Closed)	9/6/2007	230.48	<MDL	Not Analyzed
U8-8211	Dstairs Living Open Field Blank	9/6/2007	212.01	<MDL	Not Analyzed
U8-8211	Dstairs Living Open Field Blank	9/6/2007	229.80	1.20E+01	Not Analyzed
U8-8211	CCV @ 2000 pg/L	9/6/2007	1917.78	1.99E+03	Not Analyzed
U8-8211	Field Blank Closed 6	9/6/2007	124.05	<MDL	Not Analyzed
U8-8211	Field Blank Closed 7	9/6/2007	183.39	<MDL	Not Analyzed
U8-8211	Field Blank Closed 8	9/6/2007	183.10	<MDL	Not Analyzed
U8-8211	Field Blank Closed 9	9/6/2007	242.80	4.97E+01	Not Analyzed
U8-8211	Closed Field Blank 1	9/18/2007	721.33	<MDL	Not Analyzed
U8-8211	Closed Field Blank 2	9/18/2007	952.46	<MDL	Not Analyzed
U8-8211	Closed Field Blank 3	9/18/2007	608.14	<MDL	Not Analyzed
U8-8211	CCV 399	9/18/2007	382.88	2.17E+02	Not Analyzed
U8-8211	CCV 995	9/18/2007	1164.88	6.17E+02	Not Analyzed
U8-8211	Open Field Blank	9/20/2007	<MDL	<MDL	<MDL
U8-8211	Closed Field Blank	9/20/2007	<MDL	<MDL	<MDL
U8-8211	Open Field Blank	9/20/2007	<MDL	<MDL	<MDL
U8-8211	Lab Blank	9/20/2007	<MDL	<MDL	<MDL

MDLs for each sample varied based on air flow rate and time sampled, average values were: TCE = 0.005-0.013 ppbv, 1,2 DCA = 0.005-0.012 ppbv, PCE = 0.001-0.003 ppbv

Table G.9 cont.

U8-8211	Lab Blank	9/20/2007	<MDL	<MDL	<MDL
U8-8211	CCV 2000	2/28/2008	2266.60	1.99E+03	2.00E+03
U8-8211	Blank	2/28/2008	<MDL	<MDL	<MDL
U8-8211	CCV	2/28/2008	2063.53	1.88E+03	1.83E+03
U8-8211	Blank	2/28/2008	<MDL	<MDL	<MDL
U8-8211	Field Blank	2/28/2008	<MDL	<MDL	<MDL
U8-8211	Field Blank	2/28/2008	<MDL	<MDL	<MDL
U8-8211	Field Blank	2/28/2008	<MDL	<MDL	<MDL
U8-8211	Field Blank	2/28/2008	<MDL	<MDL	<MDL
U8-8211	Field Blank	2/28/2008	<MDL	<MDL	<MDL
U8-8211	Field Blank	2/28/2008	<MDL	<MDL	<MDL
U8-8211	Field Blank	2/28/2008	<MDL	<MDL	<MDL
U8-8211	Field Blank	2/28/2008	<MDL	<MDL	<MDL
U8-8211	CCV	2/28/2008	1850.23	1.89E+03	1.83E+03
U8-8211	Blank	2/28/2008	<MDL	<MDL	<MDL
U8-8211	CCV 2000	5/13/2008	2018.20	2.17E+03	2.00E+03
U8-8211	Blank	5/13/2008	<MDL	<MDL	<MDL
U6-8016	Bromo Field Blank	5/21/2008	<MDL	<MDL	<MDL
U6-8016	Bromo Field Blank	5/21/2008	<MDL	<MDL	<MDL
U6-8016	Air Field Blank	5/21/2008	<MDL	<MDL	<MDL
U6-8016	Air Field Blank	5/21/2008	<MDL	<MDL	<MDL
U8-8452	Blank	6/23/2008	<MDL	<MDL	<MDL
U8-8452	CCV 2000	6/23/2008	1.99E+03	2.03E+03	1.99E+03
U8-8452	Blank	6/23/2008	<MDL	<MDL	<MDL
U8-8452	CCV 2000	6/26/2008	1.60E+03	1.96E+03	1.85E+03
U8-8452	Blank	6/26/2008	<MDL	<MDL	<MDL
U8-8452	CCV 2000	6/26/2008	1.64E+03	1.87E+03	1.85E+03
U8-8452	Blank	6/26/2008	<MDL	<MDL	<MDL
U8-8452	CCV 2000	6/30/2008	1.80E+03	1.93E+03	1.93E+03
U8-8452	Blank	6/30/2008	<MDL	<MDL	<MDL
U8-8452	CCV 2000	6/30/2008	1.58E+03	1.81E+03	1.64E+03
U8-8452	Blank	6/30/2008	<MDL	<MDL	<MDL
U8-8452	CCV 2000	6/30/2008	1.61E+03	1.78E+03	1.66E+03
U8-8452	Blank	6/30/2008	<MDL	<MDL	<MDL
U8-8452	MDL	6/30/2008	1.64E+03	1.77E+03	1.68E+03
U8-8452	MDL	6/30/2008	1.73E+03	1.90E+03	1.79E+03
U8-8452	MDL	6/30/2008	1.76E+03	1.87E+03	1.83E+03
U8-8452	MDL	6/30/2008	1.82E+03	1.92E+03	1.96E+03
U8-8452	MDL	6/30/2008	1.94E+03	2.02E+03	1.94E+03
U8-8452	MDL	6/30/2008	<MDL	<MDL	<MDL
U8-8452	MDL	6/30/2008	1.93E+03	2.07E+03	2.02E+03
U8-8170	CCV 2000	6/27/2008	1.68E+03	1.94E+03	1.78E+03
U8-8170	Blank	6/27/2008	<MDL	<MDL	<MDL
U8-8170	CCV 2000	6/27/2008	1.72E+03	1.92E+03	1.83E+03
U8-8170	Blank	6/27/2008	<MDL	<MDL	<MDL
U6-8016	CCV 2000	6/24/2008	2.05E+03	2.13E+03	2.07E+03
U6-8016	Blank	6/24/2008	<MDL	<MDL	<MDL

MDLs for each sample varied based on air flow rate and time sampled, average values were: TCE = 0.005-0.013 ppbv, 1,2 DCA = 0.005-0.012 ppbv, PCE = 0.001-0.003 ppbv

Table G 9 cont.

U6-8016	CCV 2000	6/24/2008	1.85E+03	1.90E+03	1.78E+03
U6-8016	Blank	6/24/2008	<MDL	<MDL	<MDL
U6-8016	CCV 2000	6/24/2008	1.80E+03	1.82E+03	1.76E+03
U6-8016	Blank	6/24/2008	<MDL	<MDL	<MDL
U6-8016	Field Blank	6/24/2008	<MDL	5.91E+02	<MDL
U6-8016	Field Blank	6/24/2008	<MDL	<MDL	<MDL
U6-8016	Field Blank	6/24/2008	<MDL	<MDL	<MDL
U6-8016	Field Blank	6/24/2008	<MDL	<MDL	<MDL
U6-8016	CCV 4000	6/24/2008	3.64E+03	3.64E+03	3.55E+03
U6-8016	Blank	6/24/2008	<MDL	<MDL	<MDL
U8-8452	Field Blank	7/16/2008	<MDL	<MDL	<MDL
U8-8452	Field Blank	7/16/2008	<MDL	<MDL	<MDL

MDLs for each sample varied based on air flow rate and time sampled, average values were: TCE = 0.005-0.013 ppbv, 1,2 DCA = 0.005-0.012 ppbv, PCE = 0.001-0.003 ppbv

Appendix H – Emission Chamber Data

TCE Emitter Data

Table H 1. Emission chamber data for TCE emitters

Sample Name	Trap Position Front/Back	Sample Date	TCE Flux (pg/min)	1,2-DCA Flux (pg/min)	PCE Flux (pg/min)
Pre Control Left	F	7/31/2008	<MDL	<MDL	4.302E+02
Pre Control Left	B	7/31/2008	<MDL	<MDL	<MDL
6 LPM Left (5-10)	F	7/31/2008	4.001E+05	<MDL	7.522E+02
6 LPM Left (5-10)	B	7/31/2008	<MDL	<MDL	<MDL
6 LPM Left (15-20)	F	7/31/2008	4.420E+05	<MDL	<MDL
6 LPM Left (15-20)	B	7/31/2008	<MDL	<MDL	<MDL
6 LPM Left (25-30)	F	7/31/2008	4.567E+05	<MDL	<MDL
6 LPM Left (25-30)	B	7/31/2008	<MDL	<MDL	<MDL
6 LPM Left (35-40)	F	7/31/2008	4.567E+05	<MDL	9.615E+02
6 LPM Left (35-40)	B	7/31/2008	<MDL	<MDL	<MDL
6 LPM Left (45-50)	F	7/31/2008	4.784E+05	<MDL	<MDL
6 LPM Left (45-50)	B	7/31/2008	<MDL	<MDL	<MDL
Post Control Left	F	7/31/2008	<MDL	<MDL	<MDL
Post Control Left	B	7/31/2008	<MDL	<MDL	<MDL
Pre Control Left	F	8/13/2008	7.200E+00	<MDL	9.768E+02
Pre Control Left	B	8/13/2008	<MDL	<MDL	<MDL
4 LPM #1	F	8/13/2008	3.813E+05	<MDL	1.189E+03
4 LPM #1	B	8/13/2008	<MDL	<MDL	<MDL
4 LPM #2	F	8/13/2008	3.261E+05	<MDL	1.211E+03
4 LPM #2	B	8/13/2008	<MDL	<MDL	<MDL
4 LPM #3	F	8/13/2008	3.425E+05	<MDL	1.692E+03
4 LPM #3	B	8/13/2008	<MDL	<MDL	<MDL
Post Control	F	8/13/2008	<MDL	<MDL	7.049E+02
Post Control	B	8/13/2008	<MDL	<MDL	<MDL
Pre Control Left	F	7/28/2008	1.068E+03	<MDL	1.651E+03
Pre Control Left	B	7/28/2008	<MDL	<MDL	<MDL
4 LPM Left (5-10)	F	7/28/2008	3.674E+05	<MDL	2.847E+03
4 LPM Left (5-10)	B	7/28/2008	1.948E+03	<MDL	<MDL
4 LPM Left (15-20)	F	7/28/2008	4.336E+05	<MDL	<MDL
4 LPM Left (15-20)	B	7/28/2008	<MDL	<MDL	<MDL
4 LPM Left (25-30)	F	7/28/2008	4.370E+05	<MDL	<MDL
4 LPM Left (25-30)	B	7/28/2008	<MDL	<MDL	<MDL
4 LPM Left (35-40)	F	7/28/2008	4.327E+05	<MDL	<MDL
4 LPM Left (35-40)	B	7/28/2008	<MDL	<MDL	<MDL
4 LPM Left (45-50)	F	7/28/2008	4.416E+05	<MDL	<MDL
4 LPM Left (45-50)	B	7/28/2008	2.136E+03	<MDL	<MDL
Post Control Left	F	7/28/2008	2.052E+03	<MDL	<MDL
Post Control Left	B	7/28/2008	<MDL	<MDL	<MDL

MDLs for each sample varied based on air flow rate and time sampled, average values were: TCE = 0.005-0.051 pg/min, 1,2 DCA = 0.004-0.036 pg/min, PCE = 0.001-0.014 pg/min

U8-8211 Dress

Table H 2. Emission chamber data for the U8-8211 dress

Sample Name	Trap Position Front/Back	Sample Date	TCE Flux (pg/cm2-min)	1,2-DCA Flux (pg/cm2-min)	PCE Flux (pg/cm2-min)
Box Cardboard Sample	Box Sample	12/21/2007	<MDL	<MDL	<MDL
Top 4 Left	F	12/21/2007	<MDL	<MDL	1.160E+04
Top 4 Right	F	12/21/2007	<MDL	<MDL	1.170E+04
Top 1 Right	F	12/21/2007	<MDL	<MDL	1.766E+04
Top 1 Left	F	12/21/2007	<MDL	<MDL	1.780E+04
Top 3 Left	F	12/21/2007	<MDL	<MDL	2.271E+04
Top 3 Right	F	12/21/2007	<MDL	<MDL	2.309E+04
Top 2 Left	F	12/21/2007	<MDL	<MDL	2.340E+04
Top 2 Right	F	12/21/2007	<MDL	<MDL	2.348E+04
Pre Control Left	F	12/21/2007	<MDL	<MDL	<MDL
Pre Control Left	B	12/21/2007	<MDL	<MDL	<MDL
Pre Control Right	F	12/21/2007	<MDL	<MDL	<MDL
Pre Control Right	B	12/21/2007	<MDL	<MDL	<MDL
Top 1 Left	B	12/21/2007	<MDL	<MDL	<MDL
Top 1 Right	B	12/21/2007	<MDL	<MDL	<MDL
Top 2 Left	B	12/21/2007	<MDL	<MDL	<MDL
Top 2 Right	B	12/21/2007	<MDL	<MDL	<MDL
Top 3 Left	B	12/21/2007	<MDL	<MDL	<MDL
Top 3 Right	B	12/21/2007	<MDL	<MDL	<MDL
Top 4 Left	B	12/21/2007	<MDL	<MDL	<MDL
Top 4 Right	B	12/21/2007	<MDL	<MDL	<MDL
Post Control Left	F	12/21/2007	<MDL	<MDL	<MDL
Post Control Left	B	12/21/2007	<MDL	<MDL	<MDL
Post Control Right	F	12/21/2007	<MDL	<MDL	<MDL
Post Control Right	B	12/21/2007	<MDL	<MDL	<MDL
Post Control Right	F	1/3/2008	<MDL	<MDL	3.883E+01
Post Control Left	F	1/3/2008	<MDL	<MDL	5.389E+01
Top 1 Left	F	1/3/2008	<MDL	1.446E+02	3.073E+03
Top 1 Right	F	1/3/2008	<MDL	<MDL	3.265E+03
Top 2 Left	F	1/3/2008	<MDL	<MDL	5.035E+03
Top 2 Right	F	1/3/2008	<MDL	<MDL	5.581E+03
Pre Control Left	F	1/3/2008	1.579E+02	<MDL	<MDL
Pre Control Left	B	1/3/2008	<MDL	<MDL	<MDL
Pre Control Right	F	1/3/2008	9.408E+01	<MDL	<MDL
Pre Control Right	B	1/3/2008	<MDL	<MDL	<MDL
Top 1 Left	B	1/3/2008	<MDL	<MDL	<MDL
Top 1 Right	B	1/3/2008	<MDL	<MDL	<MDL
Top 2 Left	B	1/3/2008	<MDL	<MDL	<MDL
Top 2 Right	B	1/3/2008	<MDL	<MDL	<MDL
Post Control Left	B	1/3/2008	<MDL	<MDL	<MDL
Post Control Right	B	1/3/2008	<MDL	<MDL	<MDL

MDLs for each sample varied based on air flow rate and time sampled, average values were: TCE = 0.005-0.051 pg/min, 1,2 DCA = 0.004-0.036 pg/min, PCE = 0.001-0.014 pg/min

Table H 2 (cont).

Top 3 Left	F	1/8/2008	<MDL	1.282E+02	3.064E+03
Top 3 Right	F	1/8/2008	<MDL	<MDL	3.214E+03
Top 4 Right	F	1/8/2008	3.381E+02	<MDL	3.969E+03
Top 6 Left	F	1/8/2008	<MDL	<MDL	4.007E+03
Top 6 Right	F	1/8/2008	<MDL	<MDL	4.045E+03
Top 7 Left	F	1/8/2008	<MDL	<MDL	4.134E+03
Top 4 Left	F	1/8/2008	<MDL	<MDL	4.144E+03
Top 7 Right	F	1/8/2008	<MDL	<MDL	4.161E+03
Top 5 Right	F	1/8/2008	3.536E+02	<MDL	4.543E+03
Top 5 Left	F	1/8/2008	<MDL	<MDL	4.604E+03
Top 1 Left	F	1/8/2008	<MDL	<MDL	4.674E+03
Top 1 Right	F	1/8/2008	<MDL	<MDL	4.714E+03
Top 2 Right	F	1/8/2008	<MDL	<MDL	5.055E+03
Pre Control Left	F	1/8/2008	<MDL	<MDL	<MDL
Pre Control Left	B	1/8/2008	<MDL	<MDL	<MDL
Pre Control Right	F	1/8/2008	<MDL	<MDL	<MDL
Pre Control Right	B	1/8/2008	<MDL	<MDL	<MDL
Top 1 Left	B	1/8/2008	<MDL	<MDL	<MDL
Top 1 Right	B	1/8/2008	<MDL	<MDL	<MDL
Top 2 Left	F	1/8/2008	Computer Crash Lost Sample		
Top 2 Left	B	1/8/2008	<MDL	<MDL	<MDL
Top 2 Right	B	1/8/2008	<MDL	<MDL	<MDL
Top 3 Left	B	1/8/2008	<MDL	<MDL	<MDL
Top 3 Right	B	1/8/2008	<MDL	<MDL	<MDL
Top 4 Left	B	1/8/2008	<MDL	<MDL	<MDL
Top 4 Right	B	1/8/2008	<MDL	<MDL	<MDL
Top 5 Left	B	1/8/2008	<MDL	<MDL	<MDL
Top 5 Right	B	1/8/2008	<MDL	<MDL	<MDL
Top 6 Left	B	1/8/2008	<MDL	<MDL	<MDL
Top 6 Right	B	1/8/2008	<MDL	<MDL	<MDL
Top 7 Left	B	1/8/2008	<MDL	<MDL	<MDL
Top 7 Right	B	1/8/2008	<MDL	<MDL	<MDL
Post Control Left	F	1/8/2008	5.652E+02	<MDL	<MDL
Post Control Left	B	1/8/2008	<MDL	<MDL	<MDL
Post Control Right	F	1/8/2008	<MDL	<MDL	<MDL
Post Control Right	B	1/8/2008	3.976E+02	<MDL	<MDL
Dress 1 Right	F	2/8/2008	<MDL	<MDL	4.869E+03
Dress 1 Left	F	2/8/2008	<MDL	<MDL	4.984E+03
Pre Control Left	F	2/8/2008	<MDL	<MDL	<MDL
Pre Control Left	B	2/8/2008	<MDL	<MDL	<MDL
Pre Control Right	F	2/8/2008	<MDL	<MDL	<MDL
Pre Control Right	B	2/8/2008	<MDL	<MDL	<MDL
Dress 1 Left	B	2/8/2008	<MDL	<MDL	<MDL
Dress 1 Right	B	2/8/2008	<MDL	<MDL	<MDL
Dress 1 Right	F	2/16/2008	<MDL	<MDL	3.898E+03
Dress 1 Left	F	2/16/2008	<MDL	<MDL	3.976E+03
Pre Control Left	F	2/16/2008	<MDL	<MDL	<MDL
Pre Control Left	B	2/16/2008	<MDL	<MDL	<MDL
Pre Control Right	F	2/16/2008	<MDL	<MDL	<MDL

MDLs for each sample varied based on air flow rate and time sampled, average values were: TCE = 0.005-0.051 pg/min, 1,2 DCA = 0.004-0.036 pg/min, PCE = 0.001-0.014 pg/min

Table H 2 (cont.)

Pre Control Right	B	2/16/2008	<MDL	<MDL	<MDL
Dress 1 Left	B	2/16/2008	<MDL	<MDL	<MDL
Dress 1 Right	B	2/16/2008	<MDL	<MDL	<MDL
Dress 1 Right	F	2/21/2008	<MDL	<MDL	3.149E+03
Dress 1 Left	F	2/21/2008	<MDL	<MDL	3.294E+03
Pre Control Left	F	2/21/2008	<MDL	<MDL	<MDL
Pre Control Left	B	2/21/2008	<MDL	<MDL	<MDL
Pre Control Right	F	2/21/2008	<MDL	<MDL	<MDL
Pre Control Right	B	2/21/2008	<MDL	<MDL	<MDL
Dress 1 Left	B	2/21/2008	<MDL	<MDL	<MDL
Dress 1 Right	B	2/21/2008	<MDL	<MDL	<MDL
Dress 1 Right	F	3/11/2008	<MDL	<MDL	3.772E+03
Dress 1 Left	F	3/11/2008	<MDL	<MDL	3.821E+03
Pre Control Left	F	3/11/2008	<MDL	<MDL	<MDL
Pre Control Left	B	3/11/2008	<MDL	<MDL	<MDL
Pre Control Right	F	3/11/2008	<MDL	<MDL	<MDL
Pre Control Right	B	3/11/2008	<MDL	<MDL	<MDL
Dress 1 Left	B	3/11/2008	<MDL	<MDL	<MDL
Dress 1 Right	B	3/11/2008	<MDL	<MDL	<MDL
Pre Control Right	F	4/17/2008	<MDL	<MDL	4.978E+01
Pre Control Left	F	4/17/2008	<MDL	<MDL	1.266E+02
Dress Bottom Left	F	4/17/2008	<MDL	<MDL	2.607E+03
Dress Bottom Right	F	4/17/2008	<MDL	<MDL	2.670E+03
Dress Top Right	F	4/17/2008	<MDL	<MDL	6.131E+03
Dress Top Left	F	4/17/2008	<MDL	<MDL	6.158E+03
Pre Control Left	B	4/17/2008	<MDL	<MDL	<MDL
Pre Control Right	B	4/17/2008	<MDL	<MDL	<MDL
Dress Bottom Left	B	4/17/2008	<MDL	<MDL	<MDL
Dress Bottom Right	B	4/17/2008	<MDL	<MDL	<MDL
Dress Top Left	B	4/17/2008	<MDL	<MDL	<MDL
Dress Top Right	B	4/17/2008	<MDL	<MDL	<MDL
Post Control Left	B	4/17/2008	<MDL	<MDL	<MDL
Post Control Right	B	4/17/2008	<MDL	<MDL	<MDL
Post Control Left	F	4/17/2008	<MDL	<MDL	ND
Post Control Right	F	4/17/2008	<MDL	<MDL	ND

MDLs for each sample varied based on air flow rate and time sampled, average values were: TCE = 0.005-0.051 pg/min, 1,2 DCA = 0.004-0.036 pg/min, PCE = 0.001-0.014 pg/min

QA/QC

Table H 3. Data for emission chamber QA/QC samples

Sample Name	Sample Date	TCE on tube (pg)	1,2-DCA on tube (pg)	PCE on tube (pg)
CCV 1980	6/4/2008	2064.84	2038.82	2020.80
Blank	6/4/2008	<MDL	<MDL	<MDL
CCV 1980	6/5/2008	1792.53	1851.13	1814.43
Blank	6/5/2008	<MDL	<MDL	<MDL
CCV 1980	6/5/2008	1808.45	1834.36	1810.02
Blank	6/5/2008	<MDL	<MDL	<MDL
CCV 1980	6/2/2008	1739.62	1839.62	1774.47
Blank	6/2/2008	<MDL	<MDL	<MDL
CCV 1980	6/2/2008	1760.45	1839.16	1788.20
Blank	6/2/2008	<MDL	<MDL	<MDL
CCV 1980	6/2/2008	1742.49	1986.67	1726.11
Blank	6/2/2008	<MDL	<MDL	<MDL
CCV 1980	5/30/2008	1623.88	1709.09	1667.45
Blank	5/30/2008	<MDL	<MDL	<MDL
CCV 1980	5/30/2008	1647.74	1705.92	1684.24
Blank	5/30/2008	<MDL	<MDL	<MDL
CCV 1980	5/30/2008	1724.18	1935.29	1649.52
Blank	5/30/2008	<MDL	<MDL	<MDL
CCV 1980	5/30/2008	1708.80	1687.81	1654.74
Blank	5/30/2008	<MDL	<MDL	<MDL
CCV 1980	6/17/2008	2488.00	2479.11	2491.42
Blank	6/17/2008	<MDL	<MDL	<MDL
CCV 1980	6/18/2008	1612.94	1796.51	1582.75
Blank	6/18/2008	<MDL	<MDL	<MDL
CCV 1980	6/18/2008	1479.81	1619.26	1286.00
Blank	6/18/2008	<MDL	<MDL	<MDL
CCV 1980	6/12/2008	1792.29	1822.01	1461.17
Blank	6/12/2008	<MDL	<MDL	<MDL
CCV 1980	6/13/2008	1635.52	1739.89	1477.77
Blank	6/13/2008	<MDL	<MDL	<MDL
CCV 1980	6/13/2008	1557.44	1515.35	1431.75
Blank	6/13/2008	<MDL	<MDL	<MDL
CCV 1980	6/13/2008	1421.44	1524.01	1483.39
Blank	6/13/2008	<MDL	<MDL	<MDL
CCV 1980	7/7/2008	1792.37	1987.02	1943.42
Blank	7/7/2008	<MDL	<MDL	<MDL
CCV 1980	7/7/2008	1799.02	2042.52	1964.78
Blank	7/7/2008	<MDL	<MDL	<MDL
CCV 1980	7/7/2008	1891.43	2097.98	2017.93
Blank	7/7/2008	<MDL	<MDL	<MDL
Blank	7/8/2008	<MDL	<MDL	<MDL
CCV 1980	7/8/2008	2260.50	2488.95	2366.99
Blank	7/8/2008	<MDL	<MDL	<MDL

MDLs for each sample varied based on air flow rate and time sampled, average values were: TCE = 0.005-0.051 pg/min, 1,2 DCA = 0.004-0.036 pg/min, PCE = 0.001-0.014 pg/min

Table H 3 (cont.)

CCV 1980	7/9/2008	2367.91	2691.90	2444.24
Blank	7/9/2008	<MDL	<MDL	<MDL
CCV 1980	7/9/2008	753.30	1878.80	<MDL
Blank	7/9/2008	<MDL	<MDL	<MDL
CCV	7/16/2008	523.05	359.39	575.74
Blank	7/16/2008	<MDL	<MDL	<MDL
Blank	7/25/2008	151.16	<MDL	333.34
CCV 1980	7/25/2008	2156.00	1903.93	2226.83
Blank	7/25/2008	146.14	<MDL	300.05
CCV 1980	7/25/2008	2290.28	1979.22	2266.63
Blank	7/25/2008	137.69	<MDL	<MDL
CCV 1980	7/26/2008	2243.93	1906.68	2230.10
Blank	7/26/2008	<MDL	<MDL	<MDL
CCV 1980	8/1/2008	2040.71	1903.46	2052.85
Blank	8/1/2008	<MDL	<MDL	<MDL
CCV 1980	8/2/2008	1887.46	1899.04	1993.26
Blank	8/2/2008	<MDL	<MDL	<MDL
CCV 1980	8/2/2008	1631.57	1832.52	1966.33
Blank	8/2/2008	<MDL	<MDL	<MDL
CCV 1980	7/29/2008	2013.86	1671.99	1987.37
Blank	7/29/2008	<MDL	<MDL	<MDL
CCV 1980	7/29/2008	1946.59	1606.25	1894.29
Blank	7/29/2008	<MDL	<MDL	<MDL
CCV 1980	8/11/2008	1721.13	1686.11	1821.19
Blank	8/11/2008	<MDL	186.53	<MDL
CCV 1980	8/11/2008	1771.48	1728.97	1905.12
Blank	8/11/2008	<MDL	<MDL	<MDL
CCV 1980	8/13/2008	1733.82	1667.35	1866.53
Blank	8/13/2008	<MDL	<MDL	<MDL
CCV 1980	8/13/2008	1703.69	1701.84	1860.43
Blank	8/13/2008	<MDL	<MDL	<MDL
CCV 1980	7/16/2008	1456.32	1065.44	1343.22
Blank	7/16/2008	<MDL	<MDL	<MDL
CCV 1980	7/16/2008	1631.57	1404.40	1400.01
Blank	7/16/2008	<MDL	<MDL	<MDL
CCV 1980	8/5/2008	1782.70	1835.41	4588.01
Blank	8/5/2008	<MDL	<MDL	880.77
CCV 1980	8/5/2008	1800.37	1775.44	1875.74
Blank	8/5/2008	<MDL	<MDL	<MDL
CCV 1980	8/12/2008	1690.05	1638.22	1898.37
Blank	8/12/2008	<MDL	<MDL	<MDL
CCV 1980	8/12/2008	1784.42	1682.08	1924.09
Blank	8/12/2008	<MDL	<MDL	59.54
Lab Blank	12/21/2007	<MDL	<MDL	<MDL
995 pg	12/21/2007	1003.99	1068.79	1058.9975
Lab Blank	12/21/2007	<MDL	<MDL	<MDL
Lab Blank	12/21/2007	<MDL	<MDL	<MDL
995 pg	12/21/2007	1019.32	1077.89	1049.8975
Lab Blank	12/21/2007	<MDL	<MDL	<MDL

MDLs for each sample varied based on air flow rate and time sampled, average values were: TCE = 0.005-0.051 pg/min, 1,2 DCA = 0.004-0.036 pg/min, PCE = 0.001-0.014 pg/min

Table H 3 (cont.)

Lab Blank	12/21/2007	<MDL	<MDL	<MDL
995 pg	12/21/2007	1057.48	1062.16	1054.1875
Lab Blank	12/21/2007	<MDL	<MDL	<MDL
CCV 1980	4/17/2008	1840.8	1997.46	1863.52
Blank	4/17/2008	<MDL	<MDL	<MDL
CCV 1980	4/17/2008	1817.94	2023.2	1775.55
Blank	4/17/2008	<MDL	<MDL	<MDL
CCV 1980	4/17/2008	1838.38	2055.17	1783
Blank	4/17/2008	<MDL	<MDL	<MDL
CCV 995	2/8/2008	913.63	924.29	1065.32
Blank	2/8/2008	<MDL	<MDL	<MDL
CCV 995	2/16/2008	1907.54	1796.77	2106.13
Blank	2/16/2008	<MDL	<MDL	<MDL
CCV 995	2/16/2008	1886.67	1771.88	2087.18
Blank	2/16/2008	<MDL	<MDL	<MDL
CCV 995	2/21/2008	1995	1506.06	1774.46
Blank	2/21/2008	<MDL	<MDL	<MDL
995 pg	1/3/2008	971.52	983.2	983.0175
Lab Blank	1/3/2008	<MDL	<MDL	<MDL
995 pg	1/3/2008	922.38	1009.07	1005.3975
Lab Blank	1/3/2008	<MDL	<MDL	<MDL
995 pg	1/8/2008	1108.45	1056.69	1095.12
Lab Blank	1/8/2008	<MDL	<MDL	<MDL
995 pg	1/8/2008	1192.62	1051.95	1035.89
Lab Blank	1/8/2008	168.21	<MDL	<MDL
995 pg	1/8/2008	1246.01	1108.53	1093.1
Lab Blank	1/8/2008	276.73	<MDL	<MDL
995 pg	1/8/2008	1413.14	1110.74	1057.65
Lab Blank	1/8/2008	228	<MDL	<MDL
995 pg	1/8/2008	1556.32	1316.41	1036.32
Lab Blank	1/8/2008	<MDL	<MDL	<MDL
CCV 1980	3/11/2008	1936.39	1908.45	1908.3
Blank	3/11/2008	<MDL	<MDL	<MDL
CCV 1980	7/28/2008	2316.80	1555.97	2322.32
Blank	7/28/2008	183.17	<MDL	<MDL
CCV 1980	7/28/2008	2385.00	2024.81	2342.31
Blank	7/28/2008	<MDL	<MDL	<MDL
CCV 1980	7/28/2008	2446.29	2063.63	2365.04
Blank	7/28/2008	<MDL	<MDL	<MDL
Blank	8/18/2008	<MDL	<MDL	144.12
CCV 1980	8/18/2008	2316.16	2315.65	2424.26
Blank	8/18/2008	<MDL	<MDL	<MDL
CCV 1980	8/18/2008	2142.25	2092.63	2282.92
Blank	8/18/2008	<MDL	196.31	<MDL
CCV 1980	8/18/2008	2070.13	1995.76	2211.79
Blank	8/18/2008	<MDL	<MDL	<MDL

MDLs for each sample varied based on air flow rate and time sampled, average values were: TCE = 0.005-0.051 pg/min, 1,2 DCA = 0.004-0.036 pg/min, PCE = 0.001-0.014 pg/min