Evaluation of Air Quality in Buildings Located Above TCE and Chloroform Contaminated Plume – A Field Study

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ABSTRACT

Vapor intrusion (VI) has been recognized since the 1990s as a potential pathway of concern at contaminated sites. VI is the migration of volatile organic compounds (VOCs) from the subsurface soils into overlying buildings. The major sources of organic vapors are waste disposal sites (landfills), contaminated old industrial sites, contaminated subsurface soils, and contaminated groundwater. The volatile organic compounds of concern in vapor intrusion are usually divided into two categories: chlorinated VOCs and petroleum hydrocarbons.

Several residential and commercial buildings were built on a closed old industrial site in the 1990s. Due to the presence of TCE and chloroform in a groundwater plume located under the site, VI investigation was conducted at the commercial and residential buildings located on and around the site. Sub-slab soil gas and indoor air samples were collected to determine the indoor air quality in these buildings using Summa canisters equipped with flow controls. All samples were analyzed for volatile organic compounds using the USEPA Method TO-15. The analytical data were compared with background ambient air data and the New Jersey Department of Environmental Protection (NJDEP) soil gas and indoor air screening levels.

The results indicated that chlorinated volatile organic compound including TCE and chloroform were present above the NJDEP screening levels in the sub-slab soil gas and indoor air samples collected from several buildings. To remediate the existing condition, a sub-slab depressurization system (SDS) was installed under the slab of each building with elevated levels of TCE and chloroform. After installation of the SDS, indoor air sampling was performed to determine the indoor air quality in these buildings. It was recommended that yearly inspection of the SDS and indoor air sampling be conducted.

Key Words: Vapor intrusion, indoor air, soil gas, PCE, TCE, CVOC

INTRODUCTION

The migration of volatile organic compounds from the contaminated groundwater into the indoor of overlying buildings through subsurface soils or preferential pathways (such as underground utilities) is known as vapor intrusion. VOCs of concern are usually divided into two categories: chlorinated volatile organic compounds and petroleum hydrocarbons (Tillman and Weaver, 2005)

Adults living in North America spend an estimated 80-90% of their time indoors (Orwell et al., 2004; Dales et al., 2008). Some of the VOCs identified in indoor air are considered suspected or confirmed carcinogens by the World Health Organization (WHO), an International Agency for Research on Cancer (IARC).

Vapor intrusion has been recognized since the 1990s as a potential pathway of concern at contaminated sites. It attracted national attention when news revealed human exposures to 1,1-dichloroethene (1,1-DCE) vapors from the contamination at Denver's Ridgefield rifle scope factory in 2002 (Obmascik, 2002). A number of vapor intrusion investigations have been conducted since the 1990s to determine the source of contamination in soil and groundwater, the migration of VOCs from the source into buildings, the factors affecting vapor intrusion, and how to remediate vapor intrusion (Erdogan and Hsieh, 2013; Fisher et al., 1996; Folkes and Kurtz, 2002; McDonald and Wertz, 2007; McHugh et al., 2007; Moseley and Meyer, 1992, and Sanders and Hers, 2006).

Some investigators have suggested using models with site-specific data to evaluate the VI pathway (McHugh et al., 2006; Yao et al., 2011, and McAlary et al., 2014, Diallo, et al., 2015). Models have their own additional challenges, often being either simplified and not accounting for all fate and transport processes, or complex and containing unmeasurable parameters. For screening level purposes, a simplified model may be appropriate, if it can be shown to produce a worst case prediction of current and future exposure in all cases. An example of the screening level model is the widely used Johnson and Ettinger vapor intrusion model (Johnson and Ettinger, 1991). One dimensional diffusion through the unsaturated zone and advection and diffusion through building slab are incorporated into the model, but biodegradation of organic vapors is not included (Tillman and Weaver, 2005).

Predicting whether or not vapor intrusion will occur at rates sufficient to cause health risk is extremely difficult and depends on many factors (Yao et al., 2011). Major factors to be considered during a vapor intrusion investigation include the presence and concentrations of the pollutants, distance to the contamination source, groundwater flow direction, soil type, depth to groundwater below the foundation, type of foundation, geology of the site, preferred pathways (utility lines), occupied levels, the presence of a clean water lens on top of the groundwater aquifer, weather conditions, and ventilation (Erdogan and Hsieh, 2013)

Indoor air sampling and analysis is a fairly routine procedure, yet the interpretation of the results is often difficult (Sanders and Hers, 2006). Many household building supplies and products such as household cleaners, sealants, gules, adhesives, paints, lubricants, and personal care products contain organic compounds identical to common contaminants in soil or groundwater (Sanders and Hers, 2001). The quality of the outside air may also be important because some of these

contaminants may be present in the outside air. Additionally, VOCs may be emitted from wall board, ceiling, tile, carpet, and upholstery during high concentration periods (Sanders and Hers, 2006).

New Jersey Department of Environmental Protection (NJDEP) has developed a technical guidance document based on a phased approach for investigating the VI pathway (NJDEP, 2012) The NJDEP technical guidance follows the basic provisions of the USEPA VI guidance (USEPA, 2002). NJDEP's VI investigation procedure involves four stages: receptor evaluation, site investigation, mitigation, and maintenance and monitoring. It begins with evaluation of the VI receptor and assessment of the potential for VI. The second stage involves site investigation and evaluation of the analytical data. At the third stage, appropriate mitigation technologies are identified and implemented. The fourth stage is a long-term maintenance and monitoring of the mitigation system.

NJDEP has developed groundwater screening levels (GWSLs), soil gas screening levels (SGSLs), and indoor air screening levels (IASLs) to be used in the third stage. Exceedances of these screening levels will require further evaluation of VI and possible mitigation of the VI pathway (NJDEP, 2012).

The purpose of this study was to investigate VI of chlorinated volatile organic compounds (CVOC) including tetrachloroethene (PCE), trichloroethene (TCE), and chloroform at several houses located above the CVOC plume and adjacent to the contaminated site.

BACKGROUND

The contaminated site investigated in this study is located in northern New Jersey. In 1956, Ronson Metals, Inc. (RM) built a manufacturing facility at the site to produce thorium-containing metal discs and coating strips referred as getters. Discs were produced using michmetal, a mixture of rare earth elements in the lanthanide series. The facility consisted of several buildings and associated paved parking areas. The facility ceased operation in 1989 and underwent remedial investigation and remediation under the NJDEP Industrial Site Recovery Act (ISRA) formerly known as ECRA (Environmental Cleanup Responsibility Act).

The facility had a hazardous waste disposal operation (i.e., incinerator) on site. Hazardous waste was stored in 55 gallon drums. At one time, there were between 2,000 and 3,000 drums stored in one of the buildings. On October 2, 1985, NJDEP conducted a site inspection and observed that some of the drums were leaking. Record showed that the facility filed the Part B Resource Conservation and Recovery Act (RCRA) application for obtaining a hazardous waste disposal permit in 1984.

The site is situated in the Triassic lowlands of the piedmont physiographic province of New Jersey. Based on the New Jersey Geologic Survey, the near surface soil of this region is Passaic formation consisting of sandstone, siltstone, shale and conglomerates (NJGS, 2003). Soil boring and testing conducted during the study revealed the presence of 1-3 feet of fill material at the site. The fill material was underlain by brown, yellow brown and red brown silt, sandy silt and clayey silt to a depth of at least 3 feet.

In addition, the site investigation has revealed the presence of a 550 gallon underground storage tank (UST) at the site. The UST was removed on March 17, 1992 and three soil samples (T1, T2, and T3) were collected from the excavation and analyzed for total petroleum hydrocarbons (PHC), priority pollutant volatile organic compounds (PP VOCs), and lead. Lead was detected in soil samples at concentrations of 35 ppm, 630 ppm and 16 ppm. TCE was also detected above NJDEP soil remediation standards in these samples. Figure 1 shows contaminated areas that were remediated during the investigation.

Pursuant to ISRA rules and requirements, a cleanup plan was developed to investigate and remediate the site in 1992. Groundwater investigations conducted in April 1992 and May 1992 revealed the presence of CVOC beneath the site and nearby residential and commercial areas. Groundwater sampling identified a large plume of VOCs including trichloroethene, tetrachloroethene, 1,1-dichloroethene, vinyl chloride, ethylbenzene, and xylenes under the site. VOCs detected in the groundwater samples are given in Table 1.

During the investigation, soil sampling was also conducted to determine the environmental impact of facility operations on the surrounding soils and subsurface soils. The analytical data revealed the elevated levels of heavy metals including arsenic, barium, lead, and radioactive metals such as cerium and samarium, and chlorinated volatile organic compounds, specifically, trichloroethene, tetrachloroethene, and chloroform in surface and subsurface soils.

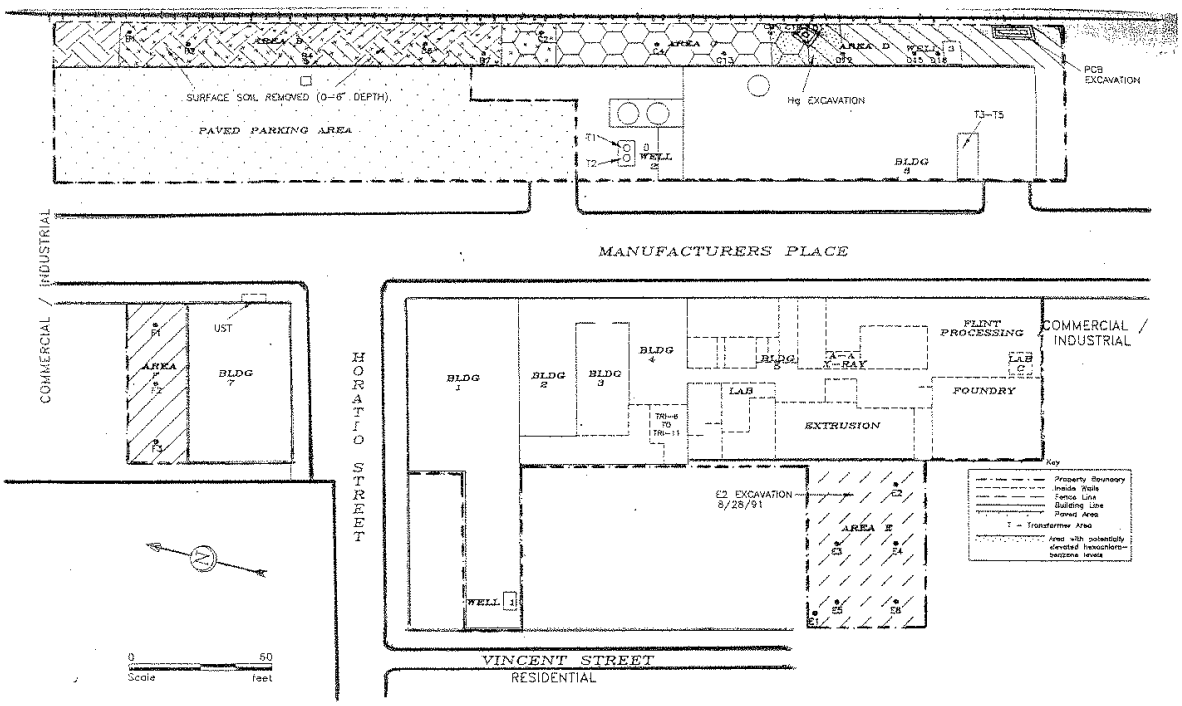

Figure 1. Contaminated and remediated areas identified at the former RM site

The site cleanup began in 1998. Hot spots containing heavy metals and radioactive materials were excavated and removed. After completion of the remediation activities, lead and TCE were

the only contaminants remaining at the site above NJDEP soil cleanup standards. In order to remediate the remaining contaminated areas, engineering controls (capping) and institutional controls (Deed Note) were implemented at the site on February 19, 2002.

The cap designed for the impacted areas included six (6) inches of a clay layer, geotextile fabric and six (6) inches of a gravel layer. Clay layer was placed over the TCE impacted area and geotextile was placed over the clay layer. Six (6) inches of ¾ inch gravel was then placed on the top of the geotextile. A Deed Notice restricting use of the site was filed with township for the impacted areas.

After remediation of the impacted areas, several residential units were built at the site. This investigation was conducted to determine whether there is a potential VI into the residential and commercial buildings built at the site. Figure 2 shows the site and residential and commercial units built at the site.

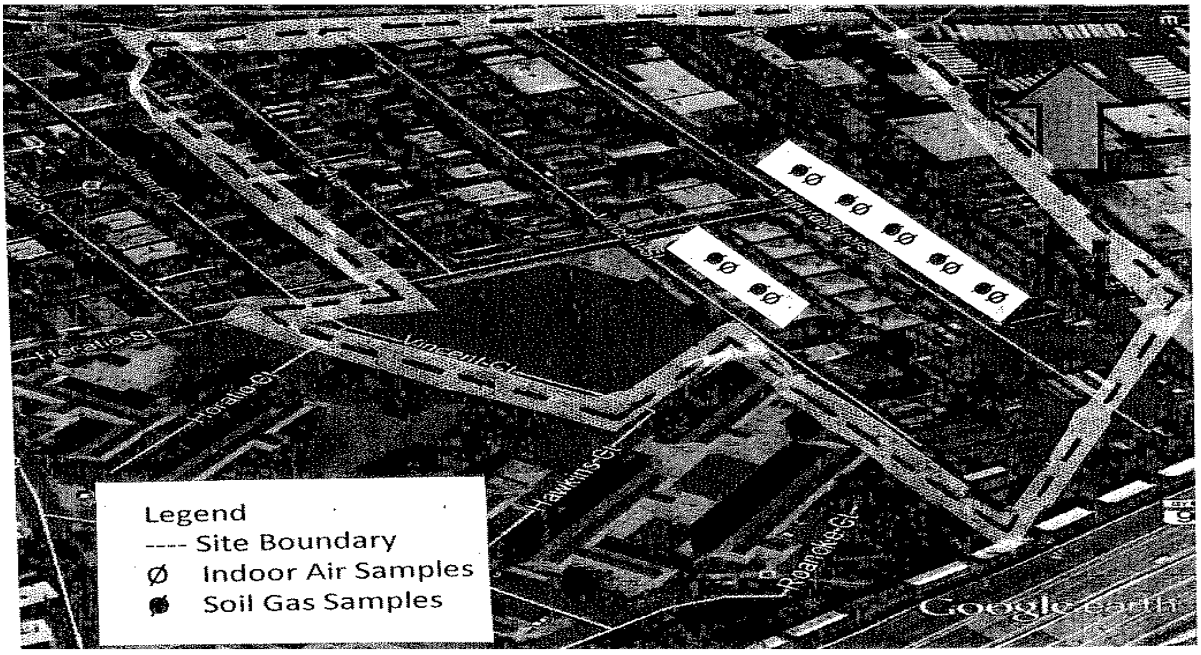

Figure 2. Former RM site and residential and commercial buildings surrounding the site

APROACH

Sub-slab soil gas, and indoor air and outdoor air samples were collected during VI investigation from the residential buildings located above the VOC plume.

To determine whether there is a potential for vapor intrusion into the nearby buildings, groundwater samples, sub-slab soil gas samples, and indoor air samples were collected from the affected buildings.

The first step was to collect groundwater samples at the site to determine the concentration of VOCs and the flow direction. On March 19, 1992, a groundwater monitoring well was installed at the site and the well was sampled on April 7 and May 14, 1992. Groundwater samples were analyzed for volatile organic compounds. Concentrations of VOC detected in groundwater are presented in Table 1.

Table 1 shows trichloroethene, tetrachloroethene, and total xylenes exceeded the NJDEP groundwater quality standards (GWQS). Concentrations of TCE exceeded the NJDEP groundwater screening levels (GWSLs) as well as the NJDEP GWQS.

Elevated levels of chlorinated volatile organic compounds and petroleum hydrocarbons in groundwater triggered a vapor intrusion investigation. The NJDEP Vapor Intrusion Technical Guidance requires that a VI investigation be conducted at structures located above or/and within 100 feet of a shallow VOC plume containing contaminants above the NJDEP GWQS or/and GWSLs. It also requires benzene, toluene, ethylbenzene, and xylenes (B TEX) sampling within 30 feet of the BTEX plume.

Table 1. Concentrations of VOC detected in groundwater

Volatile Organic Compounds (VOCs)	**NJDEP Groundwater Quality Standards (GWQS)**	**NJDEP Groundwater Screening levels (GWSLs)**	**Concentration of CVOC µg/L**	**Concentration of CVOC µg/L**
	µg/L	**µg/L**	**April 7, 1992**	**May 14, 1992**
Trichloroethene (TCE)	1	2	37	27
Tetrachloroethene (PCE)	1	31	24	12
Ethylbenzene	700	700	30	160
Xylenes (total)	40	8,600	100	215
1,1-Dichloroethene	2	260	U[5][a]	U[5]
Vinyl chloride	5	1	U[10]	10[b]

Notes:
All concentrations are in microgram per liter (µg/L)
a: U = Undetected; method detection limit [MDL]
b: Detected at levels below the MDL; estimated value

In order to determine the extent of indoor air pollution resulting from contaminated subsurface soils and groundwater, it is important to determine the background sources first. To identify potential background sources, Building Indoor Air Survey and Sampling Forms developed by the NJDEP were distributed to the residences prior to conducting sub-slab soil gas and indoor air sampling.

Sub-slab soil gas samples were collected using stainless steel 1 liter Summa canisters equipped with flow controllers. The maximum flow rate into each Summa canister was 200 millimeter per minute, which corresponds to a sample time of 5 minutes for 1 liter canisters. The canister's pressure was set at approximately -30 inches of mercury at the laboratory prior to shipment.

A minimum of one sample per 1,500 square feet of residential or commercial space was collected for indoor air. Indoor air samples were collected from the breathing zone (3-5 feet above the floor basement) using 6 liter stainless steel Summa canisters over a 24 hour period. All samples were analyzed for VOCs using the USEPA Method TO-15.

RESULTS AND DISCUSSION

Sub Slab Soil Gas Sampling

Based on the results of the groundwater investigation, site inspection was conducted to determine sampling locations, and numbers of sub-slab soil gas samples and indoor air samples.

During the period of February 23 to 25, 2013, the investigation team collected sub-slab soil gas samples at six (6) residential buildings (Building #1, #2, #3, #4, #5, and #6) located above the CVOC contaminated plume. A total of six (6) sub-slab soil gas samples, SS-1, SS-2, SS-3, SS-4, SS-5, and SS-6 (one sample from each building) were collected and analyzed for VOCs. All samples were collected using Summa canisters equipped with flow controls. Samples were sent to TestAmerica Burlington Laboratory, Inc. for the VOC analysis using USEPA TO-15 method.

The results of sub-slab soil gas samples and indoor air and outdoor air samples were compared with the NJDEP residential soil gas screening levels and indoor air screening levels. The results of sub-slab soil gas samples are presented in Table 2. Chloroform exceeded the SGSLs in four samples and TCE exceeded the SGSLs in all five samples.

Table 2 reveal the presence of elevated levels of trichloroethene (TCE) and chloroform in the sub-slab soil gas samples collected from these buildings. TCE was detected in sub-slab soil gas samples SS-1, SS-2, SS-3, SS-4, SS-5, and SS-6 at concentrations of 25,000 $\mu g/m^3$, 13,000 $\mu g/m^3$, 5,000 $\mu g/m^3$, 1,700 $\mu g/m^3$, 4,500 $\mu g/m^3$, and 2,000 $\mu g/m^3$, respectively. These concentrations exceeded both the residential and non-residential soil gas screening levels. These concentrations also exceeded 10 times the residential SGSL of 27 $\mu g/m^3$ for TCE.

Several other contaminants were also detected in the sub-slab soil gas samples. However, concentrations of these contaminants were below the SGSLs with the exception of chloroform. Chloroform was detected in sub-slab soil gas samples SS-1, SS-2, SS-4, SS-5, and SS-6 at concentrations of 37 $\mu g/m^3$, 64 $\mu g/m^3$, 49 $\mu g/m^3$, 37 $\mu g/m^3$, and 30 $\mu g/m^3$, respectively. These concentrations exceeded the SGSL of 24 $\mu g/m^3$ for chloroform.

Indoor Air Sampling

On July 23, 2013, the investigation team collected indoor air samples at the same six (6) residential buildings located above the VOC plume. A total of six (6) indoor air samples IA-1, IA-2, IA-3, IA-4, IA-5, and IA-6 (one sample from each building) were collected. In addition, an ambient air sample, IA-7 was collected outside in front of the buildings. Indoor air samples were analyzed for VOCs using the USEPA Method TO-15. Concentrations of VOCs detected in the indoor air samples are presented in Table 3.

Table 2. Concentrations of VOCs detected in sub-slab soil gas samples

Chemical	NJDEP Residential Soil Gas Screening Levels ($\mu g/m^3$)	Sub-Slab Soil Gas Samples					
		SS-1	SS-2	SS-3	SS-4	SS-5	SS-6
Acetone	1,600,000	-	240	-	120	580	120
Chloroform	24	**37**	**64**	12	**49**	**37**	**30**
Carbon disulfide	36,000	-	-	-	20	25	-
1,1-Dichloroethane	76	24	-	-	-	-	-
1,1-Dichloroethene	10,000	31	-	-	-	-	-
1,2-Dichloroethene (cis)	NA	1,900	690	-	35	160	290
1,2-Dichloroethene (trans)	3,100	230	220	-	20	110	25
n-Heptane	NA	-	-	-	34	-	-
n-Hexane	36,000	-	-	-	55	-	-
Methyl ethyl ketone	260,000	49	-	-	-	-	17
Toluene	260,000	-	-	-	-	8	16
Tetrachloroethene (PCE)	470	46	-	-	-	-	-
1,1,1-Trichloroethane	260,000	47	-	-	-	-	-
Trichloroethene (TCE)	27	**25,000**	**13,000**	**5,000**	**1,700**	**4,500**	**2,000**

Notes:
Only compounds detected at one or more sample locations above the analytical reporting limits are listed in this table.
All results are in micrograms per cubic meter ($\mu g/m^3$).
NA – A Soil Gas Screening Level is currently unavailable for this chemical.
ND - Not Detected
Bolded and shaded results identify exceedances of the applicable NJDEP Soil Gas Screening Levels.

The indoor air analytical data were evaluated using the NJDEP residential indoor air screening levels. Table 3 revealed the presence of elevated levels of TCE in indoor air samples. TCE was detected in the indoor air samples IA-1, IA-2, IA-3, IA-4, IA-5, and IA-6 at concentrations of 5 $\mu g/m^3$, 32 $\mu g/m^3$, 16 $\mu g/m^3$, 23 $\mu g/m^3$, 22 $\mu g/m^3$, and 5 $\mu g/m^3$, respectively. These concentrations have exceeded the residential IASL of 3 $\mu g/m^3$ for TCE. Other VOCs including benzene, carbon tetrachloride, chloroform, 1,4-dichlorobenzene, and ethylbenzene were also detected above the residential IASLs in some of the indoor air samples.

Benzene was detected in the sample IA-5 at a concentration of 6 $\mu g/m^3$. Carbon tetrachloride was detected in the sample IA-3 at a concentration of 5 $\mu g/m^3$. Chloroform was detected in indoor air samples IA-2, IA-3, and IA-5 at concentrations of 72 $\mu g/m^3$, 15 $\mu g/m^3$, 8 $\mu g/m^3$, respectively. 1,4-dichlorobenzene was detected in the sample IA-2 at a concentration of 5 $\mu g/m^3$. Ethylbenzene was detected in the sample IA-3 and IA-5. Concentrations of these contaminants exceeded the residential IASLs.

Sub-slab soil gas and indoor air analytical data show that the main contaminants of concern in these buildings are TCE and chloroform. Concentrations of TCE detected in the sub-slab soil gas samples are more than 10 times the residential SGSL of 27 $\mu g/m^3$ and non-residential SGSL of 150 $\mu g/m^3$ for TCE. In addition, concentrations of TCE detected in indoor air samples also exceeded both the residential and non-residential IASL of 3 $\mu g/m^3$ for TCE.

Table 3. Concentrations of VOCs detected in indoor air samples

Chemical	NJDEP Residential Indoor Air Screening Levels ($\mu g/m^3$)	Indoor air Samples					
		IA-1	IA-2	IA-3	IA-4	IA-5	IA-6
Benzene	2	2	1	2	ND	**6**	2
Carbon tetrachloride	3	ND		**5**	ND	ND	ND
Chloroform	2	**ND**	**72**	**15**	**ND**	**8**	ND
1,4-Dichlorobenzene	3	**ND**	**5**	ND	**ND**	**ND**	**ND**
Ethylbenzene	2	2		**3**	ND	**8**	ND
Trichloroethene (TCE)	3	**5**	**32**	**16**	**23**	**22**	**5**

Notes:
Only compounds detected at one or more sample locations above the analytical reporting limits are listed in this table.
All results are in micrograms per cubic meter ($\mu g/m^3$).
ND – Not Detected
Bolded and shaded results identify exceedances of the applicable NJDEP Indoor Air Screening Levels.

Chloroform was detected above the residential and non-residential IASL of 2 $\mu g/m^3$ in three of the six indoor air samples collected. Concentrations of chloroform ranged from 8 $\mu g/m^3$ to 72 $\mu g/m^3$. Chloroform is often associated with chlorinated drinking water, the common use of bleach, and leaking sewer lines.

With the exception of chloroform, none of the other contaminants, including benzene, carbon tetrachloride, and 1,4-dichlorobenzene, and ethylbenzene present in the indoor air samples, were detected in the sub-slab soil gas samples. Therefore, these contaminants are not related to the previous operations conducted at the site. They may be due to the use of household products at these houses.

The results of indoor air samples were also compared to the NJDEP residential rapid action levels (RALs). The RALs are generic indoor air numbers developed by the NJDEP to determine whether further investigation or implementation of an interim remedial measure is needed (NJDEP, 2012). Any compound that exceeds the RALs triggers a call for prompt action.

The evaluation of the VI analytical data indicated that VI pathways exist at these residences for TCE and chloroform. TCE was detected above the residential and non-residential IASL of 3 $\mu g/m^3$ in all six indoor air samples. In addition, TCE was detected above the residential and non-residential SGSLs in all six sub-slab soil gas samples. Concentrations of TCE detected in the indoor air samples also have exceeded the RAL of 4 $\mu g/m^3$. The decision flow chart developed by the NJDEP and RALs indicated that implementation of interim remedial measures are necessary in these residences (NJDEP, 2012).
At the present time the most common method of remediating VI is installation of a subsurface depressurization system. A subsurface depressurization system was installed by the NJDEP at these six houses. The subsurface depressurization system works by intercepting soil gas prior to its entry across the building foundation and directing it aboveground to the outdoor air. Perforated pipes are placed under the basement to collect soil gas. An exhaust fan pulls air

through these pipes and vents it to the atmosphere. The cracks and penetrations in the building foundation have been sealed to prevent VI.

In order to determine whether the implemented remedy is effective for preventing VI in these buildings, an indoor air sampling was conducted at these six residences on July 10, 2014. Post-remediation indoor air samples and outdoor air samples were collected and analyzed for VOCs using the USEPA Method TO-15. The data indicated that the implemented remedy is working very well and affectively removing the contaminated soil gas from beneath the basement slab of these houses. The post-remediation analytical data are presented in Table 4. As shown in Table 4, no VOCs including TCE and chloroform were detected above the IASLs in the post-remediation indoor air samples.

Table 4. Concentrations of VOC detected in the post-remediation indoor air samples

Chemical	NJDEP Residential Indoor Air Screening Levels ($\mu g/m^3$)	Indoor air Samples						Outdoor Air Sample
		IA-1	IA-2	IA-3	IA-4	IA-5	IA-6	
Acetone	32,000	20	96	110	18	31	130	ND
Benzene	2	**4**	2	2	1	2	2	1
Chloromethane	94	1	2	1	1	2	1	1
Chloroform	2	ND	ND	3	1	ND	ND	ND
Cyclohexane	6,300	0.7	0.9	1	ND	ND	1	ND
Dichlorodifluoromethane	100	ND	3	ND	3	3	3	ND
Ethylbenzene	2	4	1	ND	ND	2	1	1
n-Heptane	NA	2	1	1	ND	2	ND	ND
n-Hexane	730	5	2	4	1	3	2	2
Methylene chloride	94	3	3	ND	ND	3	3	4
Methyl ethyl ketone	5,200	2	11	7	2	8	3	4
Toluene	5,200	37	8	4	2	11	4	6
Trichlorofluoromethane	730	ND	1	1	1	1	1	1
Trichloroethene (TCE)	3	1	ND	ND	ND	ND	ND	ND
1,2,4-Trimethylbenzene	NA	2	3	ND	ND	2	ND	ND
2,2,4-Trimethylpentane	NA	7	ND	1	ND	4	1	2
Xylenes (total)	100	22	4	ND	ND	7	2	4

Notes:
Only compounds detected at one or more sample locations above the analytical reporting limits are listed in this table.
All results are in micrograms per cubic meter ($\mu g/m^3$).
NA – An Indoor Air Screening Level is currently unavailable for this chemical.
ND – Not Detected
Bolded and shaded results identify exceedances of the applicable NJDEP Indoor Air Screening Levels.

Benzene is the only compound that was detected above the IASL of 2 $\mu g/m^3$ in a post-remediation indoor air sample collected at building #2. The presence of benzene in this residence may be due to background. Paint and lawn mower were stored in the basement area of the house. Several other VOCs were also detected in the post-remediation indoor air samples at very low levels below the IASLs. Those may also be due to the background and outdoor air quality. The same compounds were also detected in the indoor air samples collected at these residences prior

to installation of subsurface depressurization systems. Concentrations of VOCs detected in the outdoor air are presented in the last column of Table 4.

CONCLUSION

Vapor intrusion investigation was conducted to evaluate the impact of chlorinated volatile organic compounds detected in subsurface soil and groundwater on the quality of air in the six residences located above a CVOC plume. Soil gas data and indoor air data clearly show that those six houses were impacted by VI despite the presence of a capping system at the site. The analytical data show that the capping system have been damaged or partially removed during the construction of these residential buildings.

The post-remediation indoor air sampling confirmed that the subsurface depressurization systems were effective at improving the quality of indoor air in these residences and no VOCs including TCE and chloroform were detected above the NJDEP indoor air screening levels at these buildings.

Investigation of the company's past history indicated that chloroform was not used in any of the previous operations conducted at the site. Chloroform could be a regional problem. It was also detected in groundwater samples collected from the up-gradient well located at the site. Chloroform has been attributed to the background condition.

Based on the results of VI investigation conducted in these homes, vapor intrusion study was expanded to include other residential and commercial buildings located on the site or adjacent to the site. This VI investigation has been completed at the site in June 2015.

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