

Letter Health Consultation

ANNANDALE PCE SITE

ANNANDALE, VIRGINIA

**Prepared by
Virginia Department of Health**

JULY 1, 2014

Prepared under a Cooperative Agreement with the
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Division of Community Health Investigations
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

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LETTER HEALTH CONSULTATION

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Dear Mr. Charles Fitzsimmons,

This letter is in response to your request for the Virginia Department of Health (VDH) to examine potential health risks associated with the indoor air in residential homes located in Annandale, Virginia. Through a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR), we have completed an evaluation of the air sampling information you provided to VDH on September 10, 2012. Potential public health implications from exposure to contaminants found in the indoor air are provided in this letter.

BACKGROUND

Site Description and History

The site is a single-family residence located near Little River Turnpike in Annandale, Fairfax County, Virginia 22003. The residential property was developed prior to 1966 and is in a mixed residential/commercial neighborhood. The property which will be referred to as “the site” for the remainder of the document uses a private well for potable water. The majority of businesses and residential properties in the area are connected to a public waterworks. There are two petroleum tanks located on the site: an inactive underground storage tank is located in the front; and an active above ground storage tank is behind the house (Weston 2011).

The site owner reported to Virginia Department of Environmental Quality (DEQ) that their drinking water had a bad taste. Because the site owner used a private well for drinking water and has an underground petroleum storage tank, DEQ hired a private environmental contractor in May 2010 to assess the well water quality. The assessment confirmed the presence of volatile organic compounds (VOCs) in the supply well and a carbon filtration unit (CFU) was installed. In July 2010, subsequent sampling showed VOCs in the well water (untreated water) but none

were detected in the post-CFU filtered water. In February 2012, the site was connected to the public water supply (J. Glassman, personal communication September 24, 2012).

The DEQ hired an environmental contractor Marshal Miller and Associates (MM&A) to determine the extent of contamination in soil and groundwater in the vicinity of the site. The results showed that the soil was impacted with petroleum products and the groundwater was impacted with VOCs. Because of the presence of VOCs in shallow groundwater (5 to 10 feet below the ground surface) on site, indoor air and ambient air samples from the site and two other residences were collected in November 2010 (Weston 2011). VOCs were detected in the indoor air at the site and the two residences which will be referred to as residence 2 and residence 3.

Currently the area of contamination is not fully defined and the source of contamination has not been directly linked to any physical property or chemical release at this time.

Land Use

The site is in Fairfax County which is 12 miles southwest of Washington DC. To the north and west of the site are various commercial properties such as a restaurant and an L-shaped shopping center that runs along Little River Turnpike. There is an undeveloped lot and residential property to the east and south. All the other residences in the area are connected to a public water works with some of them using well water for irrigation according to records obtained from Fairfax County Water Authority (Weston 2011).

Environmental Sampling

This letter of health consultation addresses the public health implications from exposure to VOCs in indoor air on site and at two neighboring residences. Additional findings are provided in this section for historical purposes and to put the extent of environmental contamination into perspective. In addition, no one is currently drinking the groundwater at the site or at the homes near the site; therefore, the groundwater ingestion pathway is eliminated. In the past, only the site was found to have contaminated well water; however, a CFU was installed immediately and tested for effectiveness, thereby limiting drinking water exposure.

DEQ contracted with Culligan of Hagerstown, MD to test the supply well water on site. VOCs and fuel oxygenates detected included: benzene, *cis*-1,2-dichloroethene (*cis*-1,2-DCE), methyl *tert*-butyl ether (MTBE), tetrachloroethylene (PCE), and trichloroethylene (TCE). The well water was negative for semi-volatile organic compounds (Weston 2011).

DEQ obtained records from Fairfax County Water Authority to identify other nearby residences with private wells. Eleven private wells were identified in the immediate vicinity of the site. These wells were tested in June 2010 and no contaminants were identified. The untreated well water and treated water at the site were tested roughly every six months between May 2010 and February 2011 (J. Glassman, personal communication September 24, 2012). Because contaminants continued to be present in the raw well water, in February 2012 the site was connected to a public waterworks.

DEQ hired environmental contractor MM&A to assess the level of contaminants in the soil and groundwater on and near the site. The soil around the site was described primarily as having a sandy and silt texture. Seven monitoring wells were installed. Total petroleum hydrocarbons-diesel range organics (194 mg/kg) was measured in the soil in the front yard. The depth of the groundwater below the surface was between 5 to 10 feet as measured in the monitoring wells. Contaminants found in the groundwater on site included benzene (28.9 µg/L), xylenes (3.8 µg/L), MTBE (112 µg/L), and diisopropyl ether (DIPE) (13.5 µg/L) in the front of the house. Halogenated hydrocarbons were found in the monitoring wells in the back and side of the house. The side of the house had the highest concentrations of halogenated hydrocarbons in groundwater: PCE (148 µg/L), TCE (48 µg/L), and *cis*-1,2-DCE (27.5 µg/L).

Air Sampling

The Environmental Protection Agency (EPA) was asked by DEQ to test the air at the site. EPA contracted with Weston to collect the samples which were analyzed by Test America Laboratory (South Burlington, VT). In November 2010, samples were collected in 6-L SUMMA canisters over a 24-hour period. Air samples were collected from the basements and main levels of the site and the two residences; outdoors at the site; and from the sub slab at the site and residence 3. In January 2011, sub-slab soil gas and indoor air samples were collected. Benzene, PCE, TCE, chloroform, and xylenes were the only contaminants identified in samples collected November 2010 and January 2011 (see Table 1).

Benzene was detected in samples collected in November 2010 and January 2011. The concentration of benzene exceeded one or more health-based comparison values (CVs) (Table 2). Comparing environmental concentrations of contaminants to CVs allows VDH to determine if a public health hazard may exist; this is discussed in more detail in the Discussion section. Chloroform was present at concentrations exceeding at least one CV at the site and residence 2 in November 2010 and January 2011. Chloroform was only detected in the indoor air at residence 3 in November 2010 and in the sub slab in 2011. Xylenes were detected in the ambient air at the site, and in the basement and main level of residences 2 and 3. The concentrations of xylenes measured were below CVs. PCE was detected in the indoor air of residence 3 in November 2010. In January 2011, PCE was detected in the sub slab at the site and at residence 3. PCE was also detected in the indoor air at residences 2 and 3 in 2011. The concentrations of PCE exceed one or more CVs. TCE was detected in the ambient air and in residence 3 in November 2010. It was only found in the sub slab at residence 3 in 2011. The concentration of TCE exceeded one or more CVs.

EPA asked VDH to evaluate the results of these two rounds of air sampling to determine if vapor intrusion at these homes could harm people's health. Exposure to vapor intrusion will be evaluated further and is the main subject of this document.

Table 1: 2010 & 2011 Indoor air, ambient air and sub slab sampling results*

Chemical	Indoor						Ambient		Sub Slab	
	Site		Res2		Res3		Site		Site	Res3
	2010	2011	2010	2011	2010	2011	2010	2011	2011	2011
Benzene	1.0	5.2	3.6	4.2	1.3	1.7	1.1	1.1	5.5	0.97
Chloroform	0.79	2.5	5.4	6.5	1.9	ND	ND	ND	ND	8.2
Xylenes (total)	ND	ND	14	ND	31	ND	3.8	ND	ND	ND
Tetrachloroethylene	ND	ND	ND	12.7	26	4.4	ND	ND	2.5	2.4
Trichloroethylene	ND	ND	ND	ND	1.4	ND	0.91	ND	ND	1.4

(Source: EPA) *All units in $\mu\text{g}/\text{m}^3$. Results are the highest detected value from samples collected in November 2010 & January 2011. **Res2** = Residence 2. **Res3** = Residence 3. **ND** = Chemical not detected or qualified as not detected due to detection of chemical in “trip blank.”

DISCUSSION

Contaminants in the environment can only impact individual’s health if they are exposed to them at sufficient concentrations. Therefore, VDH examines exposure pathways (how individuals come into contact with contaminants) and whether the concentration of a contaminant in the environment is of concern. These two pieces of information can be used to decide if further evaluation at a site is needed.

An exposure pathway can be defined as having five key elements: a source of contamination (e.g., hazardous waste site, underground storage tank); an environmental transport medium (e.g., groundwater, air, and soil); a point of exposure (e.g., indoor air at residences); route of exposure (e.g., drinking water, or breathing air); an exposed population (e.g., people living at the site and residences). These elements determine to what extent exposures may have occurred, may be occurring, or may occur in the future.

A complete exposure pathway exists when there is evidence or an overwhelming likelihood that contact with contaminants on site has occurred or is presently occurring.

A potential exposure pathway exists when one or more of the five elements in a pathway are missing or unclear and exposure to site contaminants could have occurred in the past, could be occurring currently, or could occur in the future.

An eliminated exposure pathway exists when due to site characteristics or site use, one or more of the five elements is very unlikely to be present at the site in the past, present, or future.

VDH has determined vapor intrusion of VOCs from contaminated groundwater into the indoor air of residences is a completed pathway. There are no other current exposure pathways at this site.

Federal, state, and private organizations develop screening levels that are used to determine if a concentration of chemical in a particular medium such as air, water, or soil has the potential to be a health risk when an individual comes into contact (inhalation, ingestion, or dermal contact)

with it. ATSDR has developed CVs that VDH used for screening contaminants at this site. Contaminants below CVs do not need to be evaluated further, and contaminants above their CV are evaluated further in the Public Health Implications section of this document.

Comparison values used to screen contaminants in indoor air at this site include ATSDR’s: environmental media evaluation guides (EMEGs); minimal risk levels (MRLs); and cancer risk evaluation guides (CREGs) for carcinogenic effects.

EMEGs are CVs, which are media specific (soil, air, and water), developed from conservative health guidelines after applying standard exposure assumptions. They are used to determine if concentrations are below levels that may cause non-cancerous health effects. CREGs are media specific CVs that are used to identify contaminants at concentrations not expected to result in an increase in the number of additional cancers for the exposed population. CREGs are based on theoretical estimates of cancer risk and do not necessarily indicate or predict that cancer is expected for an exposed population. CREGs are calculated from EPA’s cancer slope factor for oral exposure and inhalation unit risk (IUR) for inhalation exposures. EPA’s derivation of these values is based on the assumptions about cancer risks at low levels of exposure. When a contaminant exceeds its CREG, VDH calculates the increase in additional cancers using EPA’s IUR factor for contaminants in the air.

Table 2: Indoor Air Concentrations and Comparison Values*

Chemical	Indoor Air			Ambient Air	Comparison Values	
	Site	Res2	Res3		EMEG	CREG
Benzene	5.2	4.2	1.7	1.1	9.6	0.13
Chloroform	2.5	6.5	1.9	ND	98	0.043
Xylenes (total)	ND	14	31	3.8	220	NA
Tetrachloroethylene	ND	12.7	26	ND	40 [†]	3.8
Trichloroethylene	ND	ND	1.4	0.91	2.0	0.24

(Source: EPA) *All units in $\mu\text{g}/\text{m}^3$. Results are the highest detected value from samples collected in 2010 and 2011. **Res2** = Residence 2. **Res3** = Residence 3. **EMEG** = environmental media evaluation guide (chronic). **CREG**= cancer risk evaluation guide. [†]EPA’s inhalation reference concentration. **Bold** = Comparison value that was exceeded. **ND** = Chemical not detected or qualified as not detected due to detection of chemical in “trip blank.”

Public Health Implications

None of the contaminants found in indoor air in 2010 or 2011 from the three residences exceeded the non-cancer environmental guidelines. The maximum air concentration of benzene, chloroform, PCE, and TCE did exceed cancer comparison values (CREGs). VDH calculated excess cancers from exposure to the concentration of these chemicals in air by multiplying them by their IUR.

$$\text{Cancer Risk} = IUR \times C$$

Where **IUR** is the inhalation unit risk in $[\mu\text{g}/\text{m}^3]^{-1}$ and **C** is the concentration of the contaminant in air expressed as $\mu\text{g}/\text{m}^3$. An example cancer risk calculation using the maximum concentration of benzene measured in indoor air at the site is below.

$$\text{Cancer Risk from benzene} = 7.8 \times 10^{-5} [\mu\text{g}/\text{m}^3]^{-1} \times 5.2 \mu\text{g}/\text{m}^3 = 4.06 \times 10^{-5}$$

This means that if a population of 100,000 was to be exposed to benzene in air at this concentration for a lifetime (70 years), 4 additional cancers is possible.

Based on 2008-2010 data, the lifetime risk of developing cancer in the United States for men and women is approximately 41 percent (Cancer 2014). The sum of the additional cancer risks from exposure to the higher of the two benzene, chloroform, PCE, and TCE sampling events at the site (10 in 100,000), residence 2 (2 in 10,000), and residence 3 (7 in 100,000) are low compared to the 2008-2010 cancer rates. However, characterization of the temporal variability of indoor air levels is limited to 2 sampling events collected during the same season. Additional cancer risk estimates for benzene, chloroform, PCE, and TCE are included in the Attachment in Table 3.

Chemicals

Benzene

The additional cancer risk from exposure to benzene in indoor air at the site and three residences is very low. The highest additional cancer risk (4 in 100,000) was on site. The Department of Health and Human Services (DHHS) categorizes the carcinogenicity of benzene as follows: *known to be a human carcinogen* based on sufficient evidence from human studies. Human studies have shown that people exposed to benzene can develop leukemia, total lymphatic, and hematopoietic cancer (ATSDR 2007).

Benzene is an aromatic compound that is a clear, colorless liquid at room temperature. It is slightly miscible in water, flammable, and boils at 80 °C. It is used in the chemical and pharmaceutical industry as a solvent, and as a gasoline additive (also naturally occurring in gasoline as a by-product of the oil-refining processes). The sources of benzene in the atmosphere include forest fires, automobile exhaust, industrial emissions, and fuel evaporation from gasoline stations. Humans are primarily exposed to benzene in the air they breathe. The highest exposure to benzene in the general public is in areas of heavy motor vehicle traffic and at gasoline stations. Air concentrations measured throughout the U.S. range from 0.06 $\mu\text{g}/\text{m}^3$ in rural areas to 356 $\mu\text{g}/\text{m}^3$ in urban areas. Additional exposure to benzene includes tobacco smoke, contaminated drinking water, paints, glue, furniture wax, and detergents (ATSDR 2007 & 2011, NTP 2011). Indoor air concentrations measured from 1990 to 2005 in North American homes ranged from 9.9 to 29 $\mu\text{g}/\text{m}^3$ (95th %) (EPA 2011).

Chloroform

The additional cancer risk from exposure to chloroform in indoor air at the site, residence 2 and residence 3 is low. The highest additional cancer risk for chloroform (2 in 10,000) was at residence 2. The DHHS categorizes the carcinogenicity of chloroform as follows: *reasonably anticipated to be a human carcinogen* based on sufficient evidence from studies in experimental animals. Rodents that were exposed to chloroform orally developed tumors at more than one tissue site. Mice exposed to chloroform via inhalation developed kidney tumors (ATSDR 1997a).

Chloroform is a trihalomethane that is a clear, colorless liquid with a pleasant odor at room temperature. It is slightly soluble in water and miscible with ether, benzene, alcohol and boils at 63 °C. Chloroform is used as an extraction solvent in floor polish, resins, fat, gum, oils and rubber and in dry-cleaning to remove spots. In the U.S. chloroform was used in the manufacture of chlorodifluoromethane which was used as a refrigerant. Chloroform is used in medicine as a local anesthetic. Chloroform is present in household products like bleaches, household cleaning products and air deodorizers.

Exposure to chloroform occurs mainly through chlorinated water because public water supplies contain trihalomethanes, which are the by-products of water treatment. Reported air concentrations of chloroform in urban area in the U.S. are between 0.10 to 10 $\mu\text{g}/\text{m}^3$, and 0.17 to 43.9 $\mu\text{g}/\text{m}^3$ in indoor air (ATSDR 1997a, NTP 2011). The maximum concentrations found at the site (2.5 $\mu\text{g}/\text{m}^3$), residence 2 (6.5 $\mu\text{g}/\text{m}^3$), and residence 3 (1.9 $\mu\text{g}/\text{m}^3$) are within this range.

Tetrachloroethylene (PCE)

The additional cancer risk from exposure to PCE in indoor air at the site, residence 2 and residence 3 is extremely low. The highest additional cancer risk for PCE (7 in 1,000,000) was at residence 3. The DHHS categorizes the carcinogenicity of PCE as follows: *reasonably anticipated to be a human carcinogen* based on sufficient evidence from studies in experimental animals. Rodents exposed to PCE via inhalation developed benign and malignant liver tumors. Mice administered PCE through a stomach tube developed liver tumors. There is no sufficient data to prove the relation between human cancer and exposure to PCE. International Agency for Research on Cancer (IARC) concluded that exposure to PCE can cause esophageal cancer and cervical cancer (ATSDR 1997b).

PCE is a halogenated alkene, a colorless liquid with a mild sweet odor at room temperature. It is slightly soluble in water and miscible with alcohol, chloroform, benzene, ether and boils at 122 °C. PCE is widely used as a dry-cleaning solvent. Other uses of PCE are as an insulating fluid and cooling gas in transformers. Consumer products that contain PCE are sealants, polishes, lubricants, rug and fabric cleaners, stain spot removers and rust removers.

PCE comes into the environment from consumer products and industrial processes. Indoor air concentrations of PCE are high in buildings adjacent to dry-cleaning facilities. Studies have shown that PCE in indoor air is 2 to 30 times higher in homes that have freshly dry cleaned clothes in the closet. Background concentrations of PCE in air are usually less than 7 $\mu\text{g}/\text{m}^3$

(ATSDR 1997b, NTP 2011). The concentration of PCE in the indoor air at residence 3 (26 $\mu\text{g}/\text{m}^3$) was higher than typical background concentrations.

Trichloroethylene (TCE)

TCE was detected in residence 3 only and the additional cancer risk to TCE in indoor air is 6 in 1,000,000 which is extremely low. The DHHS categorizes the carcinogenicity of TCE as follows: *reasonably anticipated to be a human carcinogen* based on limited evidence from human studies and sufficient evidence from animal studies. Human studies have shown that people exposed to TCE can develop lymphoma, kidney, liver, and cervical cancer. When rodents were exposed to TCE via inhalation or via stomach tube mice developed benign and malignant liver tumors; whereas, rats developed kidney cancer and testicular tumors. Inhalation exposure caused lung tumors in both sexes of mice and lymphoma in females (ATSDR 1997c, NTP 2011).

TCE is a halogenated alkene and a clear, colorless liquid with an ethereal odor at room temperature. It is slightly soluble in water, soluble in chloroform, acetone, ethanol, miscible in oil and boils at 88 °C. TCE is used as a degreaser, in furniture production, fabricated metal products, electrical equipment and transport equipment (ATSDR 1997c).

Exposure to TCE comes mainly from consumer products. It is listed as a major ingredient in many consumer products such as wood stains, finishes, varnishes, adhesives, typewriter correction fluid, and paint removers. The mean air concentration of TCE in rural areas is 0.16 $\mu\text{g}/\text{m}^3$ and 2.5 $\mu\text{g}/\text{m}^3$ in urban areas. Concentrations similar to these were reported at residence 3 (1.4 $\mu\text{g}/\text{m}^3$) and in the ambient air near the site (0.91 $\mu\text{g}/\text{m}^3$). TCE has been found to be a common contaminant in groundwater and drinking water (NTP 2011).

Child Health Considerations

VDH recognizes that health implications from being exposed to environmental contaminants differ between children and adults. Children are at a greater risk than adults to hazardous substances in the environment because of their rapidly growing body, size, and behavior. Children are more likely to be exposed to contaminants in the environment because they play outdoors, are more likely to put things in their mouth that may have been contaminated by the environment; and rely on adults to prevent exposure. Children breathe more air and consume more food and water per body weight than adults. Also, children are shorter than adults and as a result, they are more likely to be exposed to contaminated air that accumulates near the ground. If toxic exposures occur during critical growth stages, the developing body systems of children can sustain permanent damage. Health based CVs for children, when available, were compared with the concentration of contaminants detected in indoor air.

CONCLUSIONS AND RECOMMENDATIONS

The VOCs detected in indoor air at the site and two residences are low; therefore, non-cancer health effects are not expected. The sum of the additional cancer risks from exposure to VOCs in indoor air at the site and two residences are low and not considered a public health hazard. However, vapor intrusion can exhibit significant variability from a daily to seasonal basis. Multiple sampling events in multiple seasons are recommended to characterize variation in vapor intrusion over time.

Indoor air sampling information was collected in residences at this site in two different sampling events, but both occurred during the fall/winter season. Additional indoor air monitoring would provide useful information about seasonal fluctuations in indoor air concentrations. However, no additional agency monitoring activities are planned for this site at this time.

The source of the groundwater contamination at this site is unknown. The VOCs detected may be present from vapor intrusion, household products, or both. Chloroform was not detected in the groundwater; therefore, the source is likely to be attributed to consumer products used in the home.

VDH or the local health department will provide information on chloroform to residents about ways to reduce exposure to this household contaminant.

VDH will review new groundwater and indoor air monitoring data as they become available.

REPORT PREPARATION

This Letter Health Consultation for the Annandale PCE Site was prepared by the Virginia Department of Health under a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with the approved agency methods, policies, procedures existing at the date of publication. Editorial review was completed by the cooperative agreement partner. ATSDR has reviewed this document and concurs with its findings based on the information presented. ATSDR's approval of this document has been captured in an electronic database, and the approving agency reviewers are listed below.

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REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR) (March 2011).

[ToxGuide Profile for Benzene.](#) Accessed December 05, 2012.

Agency for Toxic Substances and Disease Registry (2007). Toxicological Profile for Benzene. U.S. Department of Health and Human Services, Atlanta, GA.

Agency for Toxic Substances and Disease Registry (1997a). Toxicological Profile for Chloroform. U.S. Department of Health and Human Services, Atlanta, GA.

Agency for Toxic Substances and Disease Registry (1997b). Toxicological profile for Tetrachloroethylene. U.S. Department of Health and Human Services, Atlanta, GA.

Agency for Toxic Substances and Disease Registry (1997c). Toxicological Profile for Trichloroethylene. U.S. Department of Health and Human Services, Atlanta, GA.

Cancer (2014). SEER Stat Fact Sheets: All Cancer Sites.

<http://seer.cancer.gov/statfacts/html/all.html>. Accessed June 2014.

National Toxicology Program (2011). Benzene. Report on Carcinogens, Twelfth Edition.

Department of Health and Human Services. <http://ntp.niehs.nih.gov/go/roc12> Accessed February 2013.

National Toxicology Program (2011). Chloroform. Report on Carcinogens, Twelfth Edition.

Department of Health and Human Services. <http://ntp.niehs.nih.gov/go/roc12> Accessed February 2013.

National Toxicology Program (2011). Tetrachloroethylene. Report on Carcinogens, Twelfth Edition.

Department of Health and Human Services. <http://ntp.niehs.nih.gov/go/roc12> Accessed February 2013.

National Toxicology Program (2011). Trichloroethylene. Report on Carcinogens, Twelfth Edition.

Department of Health and Human Services. <http://ntp.niehs.nih.gov/go/roc12> Accessed February 2013.

U.S. Census Bureau (2010). Available at:

http://factfinder2.census.gov/faces/nav/jsf/pages/community_facts.xhtml. Accessed September 15, 2012.

US Environmental Protection Agency (EPA) (Dec 2001). [Draft Guidance for Evaluating the](#)

[Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils \(Subsurface Vapor Intrusion Guidance\)](#). Accessed September 17, 2012.

US Environmental Protection Agency (EPA) (Nov 2007a). [Technology Transfer Network Air](#)

[Toxics Web Site: Trichloroethylene](#). Assessed December 05, 2012.

US Environmental Protection Agency (EPA) (Nov 2007b). [Technology Transfer Network Air Toxics Web Site: Tetrachloroethylene](#). Assessed December 05, 2012.

US Environmental Protection Agency (EPA) (Jan 2000a). [Technology Transfer Network Air Toxics Web Site: Chloroform](#). Assessed February 01, 2012.

US Environmental Protection Agency (EPA) (Jan 2000b). [Technology Transfer Network Air Toxics Web Site: Xylenes](#). Assessed February 01, 2012.

US Environmental Protection Agency (EPA) (June 2011). [Background Indoor Air Concentrations of Volatile Organic Compounds in North American Residences \(1990–2005\): A Compilation of Statistics for Assessing Vapor Intrusion](#).

US Environmental Protection Agency (EPA) (July 2012). [EPA Risk Assessment Glossary](#). Accessed October 24, 2012.

Weston (January 2011). Trip Report for the Annandale PCE Site.

Available at:

http://www.epaos.org/sites/6450/files/Annandale_PCE_Trip_Report_Rev_per_CFcompressed.pdf Accessed September 17, 2012.

Weston (March 2011). Trip Report for the Annandale PCE Site.

Available at:

http://www.epaos.org/sites/6450/files/Annandale_PCE_Trip_Report_2011compressed.pdf Accessed September 17, 2012.

Weston (November 2010). Sampling and Analysis Plan for the Annandale PCE Site.

Available at:

http://www.epaos.org/sites/6450/files/START_AssessmentFSP_AnnandalePCE_DRAFT_Rev1.pdf. Accessed October 24, 2012.

ATTACHMENT

Table 3. Individual and total cancer risk from exposure to contaminants in indoor air.*

Contaminant	Inhalation Unit Risk ($\mu\text{g}/\text{m}^3$) ⁻¹	Site		Residence 2		Residence 3	
		Max ($\mu\text{g}/\text{m}^3$)	Risk	Max ($\mu\text{g}/\text{m}^3$)	Risk	Max ($\mu\text{g}/\text{m}^3$)	Risk
Benzene	7.80E-06	5.2	4 in 100,000	4.2	3 in 100,000	1.7	1 in 100,000
Chloroform	2.30E-05	2.5	6 in 100,000	6.5	2 in 10,000	1.9	4 in 100,000
Tetrachloroethylene	2.60E-07			12.7	3 in 1,000,000	26	7 in 1,000,000
Trichloroethylene	4.10E-06					1.4	6 in 1,000,000
Total Risk		10 in 100,000		2 in 10,000		7 in 100,000	

***Max** = maximum concentration of contaminant in air sampled in November 2010 and January 2011. **Shaded** = data not available. Values reported for Risk and Total Risk were rounded for simplicity.