Health Consultation

BRIDGER CREEK COMMUNITY VAPOR INTRUSION

BOZEMAN, GALLATIN COUNTY, MONTANA

NOVEMBER 30, 2015

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

A health consultation is a verbal or written response from ATSDR or ATSDR's Cooperative Agreement Partners to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. In order to prevent or mitigate exposures, a consultation may lead to specific actions, such as restricting use of or replacing water supplies; intensifying environmental sampling; restricting site access; or removing the contaminated material.

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR or ATSDR's Cooperative Agreement Partner which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

HEALTH CONSULTATION

BRIDGER CREEK COMMUNITY VAPOR INTRUSION

BOZEMAN, GALLATIN COUNTY, MONTANA

Prepared By:

Agency for Toxic Substances and Disease Registry
Division of Community Health Investigations
Western Branch

Summary

Introduction	The Agency for Toxic Substances and Disease Registry (ATSDR) was petitioned by homeowners in the Bridger Community to evaluate past, present and future potential exposures to indoor air contaminants in their homes. ATSDR understands that people who live in the Bridger Community may need information about exposures to vapors that might have migrated from the former Bozeman Landfill site into buildings on and near the site. ATSDR has a responsibility to perform a public health assessment at all sites that have approved petitions from the public. Our objective in this health consultation is to evaluate existing data and information and give community members and the City of Bozeman information needed to protect public health.
Background	The City of Bozeman operated a sanitary landfill north of the City Center from 1970 until 2008. After the landfill was in operation, two residential developments, known as Bridger Creek Phase 2 and Bridger Creek Phase 3 ("Bridger Creek Community") were developed near the landfill. In 2012, volatile organic compounds (VOCs) were discovered in off-site soil gas (also called soil vapor). Several investigations have been conducted since the initial discovery including evaluations of volatile organic compounds in the landfill, soil vapor, groundwater, ambient air at the landfill and in the community, and indoor air in the Bridger Creek Community residences. The City of Bozeman installed vapor mitigation systems in the form of subslab depressurization equipment in 27 houses to reduce potential VOC exposures indoors (via vapor intrusion) while the situation is being analyzed. Questions arose from community members regarding the potential for health effects and property value impacts from vapor (soil gas) intrusion into residences. Specifically questions have been raised about whether or not VOCs migrating into homes from vapor intrusion could cause public health impacts to past, current and/or future residents of the Bridger Creek Community. Standard ATSDR soil vapor intrusion evaluation methods were utilized to evaluate the health risks associated with the soil vapor intrusion originating from the Bozeman Landfill (ATSDR 2008). The data considered in this document describe air concentrations *before* subslab depressurization (SSD) was installed in houses. ATSDR's Health Consultation follows ATSDR methods and has a few specific parameters: only exposures to indoor air contaminants are considered by ATSDR; each house is evaluated individually and not in aggregate; and maximum indoor air concentration is used for health hazard evaluation because there were too few samples collected in each house to generate a reliable central tendency estimate. Contaminants are evaluated regardless of source. Other reports provide extensive detail

	about the characterization of potential sources of contamination, and the relative contribution of sub-slab sources compared with other sources of contaminants; this information is not duplicated here.
Conclusion 1	ATSDR concludes that pre-mitigation levels of naturally-occurring radon gas posed the greatest health hazard by several orders of magnitude compared to other detected chemicals at all 18 houses where radon was sampled. All homes tested were above 4 pCi/L before sub-slab depressurization (SSD) was installed. This standard has been adopted by the governments of many counties and cities throughout the US in places where radon is a known problem.
Conclusion 1 Basis	Lung cancer risk rises 16% per 2.7 pCi/L increase in radon exposure. WHO has an action level of 2.7 pCi/L at which remediation is advised (WHO 2009). EPA considers exposures to non-smokers (never smoked) above 1.25 pCi/L to be above the EPA reference range for cancer risk. Smokers and past smokers have a greater potential risk. EPA has an action level of 4.0 pCi/L at which remediation is advised (EPA 2003). Radon is a potent lung carcinogen when inhaled. Any detectable amount of radon has the potential to increase the risk of developing lung cancer in residents who live in a house for anywhere from a few years to a lifetime. Higher radon levels and longer exposure periods increase the likelihood of a person getting lung cancer from inhaling radon.
Next steps for Conclusion 1	ATSDR recommends the following: • City's contractors collect additional concurrent subslab gas, indoor air, and outdoor air samples during winter. This is to ensure that radon levels do not rise any higher than the EPA action level of 4.0 pCi/L or the World Health Organization (WHO) action level of 2.7 pCi/L. Ideally, radon will be kept as low a technically feasible. Multiple sampling events during different seasons are necessary to evaluate the variation in vapor migration potential over time. Cold weather could cause greater pressure differentials between the subsurface and indoor air and, thus, greater vapor intrusion. • Encourage homeowners who have not yet tested for radon to do so.

	• Remediation system owner/operators continue proper operation and maintenance of the sub-slab depressurization (SSD) system for the duration of house occupancy. If the SSD system is discontinued or altered in the future, follow-up sampling is recommended to ensure that the changes do not allow vapor intrusion above acceptable levels. • Remediation system owner/operators inspect individual home characteristics periodically. Changes to site characteristics, such as heating, ventilation, and air condition (HVAC) systems, utility conduits, exhaust fans, slab integrity, and landscaping may affect vapor migration and warrant follow-up sampling.
Conclusion 2	ATSDR concludes that pre-mitigation levels of chemical contaminants (VOCs) in indoor air posed a past health hazard at 9 houses. Current SSD operation is reducing VOC levels below a level of concern.
Conclusion 2 Basis	Many of the VOCs detected in indoor air are potential carcinogens. Duration of exposure to pre-mitigation levels of VOCs was conservatively estimated to be 9 years. Cancer risk estimates assume a duration of 1 year or more. A one year exposure scenario is also presented for comparison. If SSD systems do not work properly, it is possible that a person could be exposed for a lifetime. Estimated excess lifetime cancer risk for blood, blood vessel, liver and kidney cancer ranged from slightly greater than 1 in 10,000 to 9 in 1,000 cases above background risk for these specific cancers *if a lifetime of exposure had occurred*. If pre-mitigation exposures were 9-years (the estimated maximum time between home construction and SSD installation), estimated excess lifetime cancer risk for blood, blood vessel, liver and kidney cancer ranged from 9 in a million to 1 in 1,000 cases above background risk. Only blood vessel cancer risk was above the EPA target cancer risk range, at House 20 only; this was due to 1,2-Dichloroethane exposure. If pre-mitigation exposures were 1 year, cancer risk for these same cancers ranged from 1 in a million to 1 in 10,000, which is within EPA's target risk range. If pre-mitigation exposures were longer than 1 year, cancer risk would exceed the target risk range at some of these houses.
Next steps for Conclusion 2	ATSDR recommends the following: • Collecting additional concurrent subslab gas, indoor air, and outdoor air samples during winter. This is to ensure that TCE levels do not rise above a level that can increase cancer risk above the EPA Reference Range. Multiple sampling events during

	different seasons are necessary to evaluate the variation in vapor migration potential over time. Cold weather could cause greater pressure differentials between the subsurface and indoor air and, thus, greater vapor intrusion. • Continuing proper operation and maintenance of the sub-slab depressurization (SSD) system for the duration of house occupancy. If the SSD system is discontinued or altered in the future, follow-up sampling is recommended to ensure that the changes do not allow vapor intrusion above acceptable levels. • Inspecting home characteristics periodically. Changes to home characteristics, such as heating, ventilation, and air condition (HVAC) systems, utility conduits, exhaust fans, slab integrity, and landscaping may affect vapor migration and warrant follow-up sampling. Monitoring the formation of biodegradation products in soil gas and air samples periodically on-site until contaminants are below levels of health concern.
Conclusion 3	Based on the data available, ATSDR cannot conclude whether or not pre-SSD exposures to TCE at House 31 could have harmed a first trimester fetus exposed during the period the heart is developing based on the data provided. ATSDR concludes that the most sensitive receptor, a fetus during the weeks the heart is developing during the first trimester of pregnancy, could be harmed by the mother breathing indoor air at House 31 *if levels fluctuate higher because SSD was not working properly*. TCE exposure may also increase the risk of immunological effects, as indicated by studies reporting decreased thymus weight and increased antibody production in animals. Finally, the detected pre-SSD levels of TCE at House 31 could also present a slight increase in lifetime cancer risk (15 in a million excess cases above background).
Conclusion 3 Basis	If SSD is not working properly and TCE in indoor air increases, exposure to TCE during the 3 week period of critical heart formation in the first trimester of pregnancy could result in an increased risk of a heart defect in the baby. Several animal and epidemiological studies have shown evidence that exposure to low concentrations of TCE may increase the risk of gestational or early postnatal development of cardiac malformations. TCE was measured in indoor air above the health screening value. Temporal variability of the vapor intrusion pathway for on-site buildings was not evaluated, and levels may change over time especially from season to season. Current SSD is adequately reducing TCE.

Next steps for Conclusion 3	ATSDR recommends the following: • Collecting additional concurrent subslab gas, indoor air, and outdoor air samples during winter. This is to ensure that TCE levels do not rise above a level that can cause fetal heart malformation. Multiple sampling events during different seasons are necessary to evaluate the variation in vapor migration potential over time. Cold weather could cause greater pressure differentials between the subsurface and indoor air and, thus, greater vapor intrusion. • Continuing proper operation and maintenance of the sub-slab depressurization (SSD) system for the duration of house occupancy. If the SSD system is discontinued or altered in the future, follow-up sampling is recommended to ensure that the changes do not allow vapor intrusion above acceptable levels. • Inspecting site characteristics periodically. Changes to home characteristics, such as heating, ventilation, and air condition (HVAC) systems, utility conduits, exhaust fans, slab integrity, and landscaping may affect vapor migration and warrant follow-up sampling. • Monitoring the formation of biodegradation products in soil gas and air samples periodically on-site until contaminants are below levels of health concern.
For more information	If you have questions or comments, you can call ATSDR toll-free at 1-800-CDC-INFO and ask for information on the Garvey Elevator site.

Introduction

The City of Bozeman operated a sanitary landfill under a Montana Department of Quality (MDEQ) permit from 1970 until 2008. After the landfill began operation, two residential developments, known as the Bridger Creek Phase 2 and Phase 3 subdivisions, were developed near the landfill. Many of these homes were built in 2004 and most were occupied soon after construction. In 2012, volatile organic compounds (VOCs) were discovered in off-site soil gas. Several investigations have been conducted since the initial discovery including evaluations of VOCs in the landfill, soil vapor, groundwater, ambient air and the Bridger Creek residences. Vapor intrusion from the soil into houses was recorded at this time.[1] Mitigation systems have been installed in many houses and monitoring and other activities are continuing. Many of the mitigation systems were installed in 2013. All data analyzed in this Health Consultation represent 'pre-mitigation' levels of chemicals in air. A human health risk assessment (HHRA) of the community was recently performed by CPF Associates, Inc., Takoma Park, MD, under contract to the City of Bozeman (March 4, 2015).

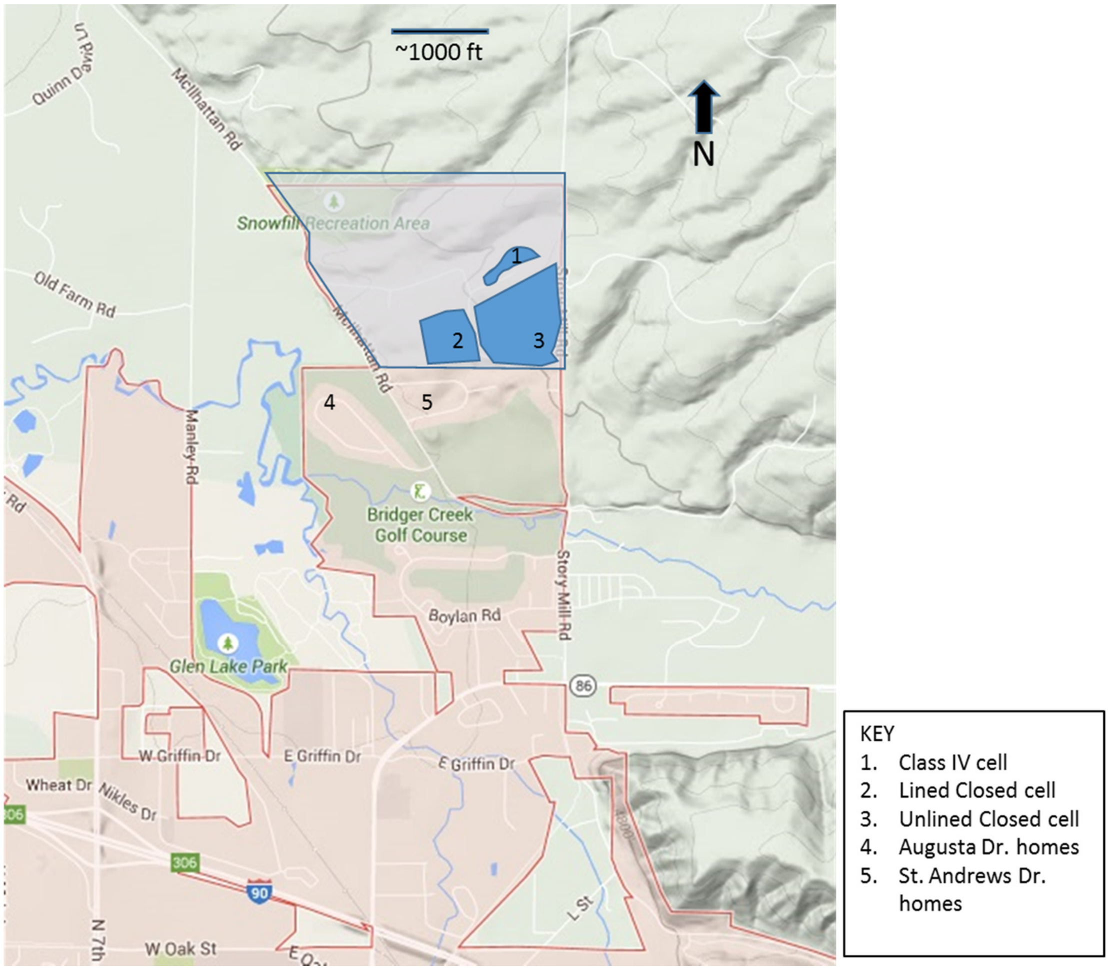
In 2014, Bridger Community residents petitioned ATSDR to evaluate data collected in their home. ATSDR evaluated data and made a health call for each residence. To protect confidentiality of results for individual homeowners, ATSDR assigned random identifiers to each home and is sending each resident their home-specific results and interpretation. The background information and underlying data used in this Health Consultation are the same as those used in the HHRA. Standard ATSDR soil vapor intrusion evaluation methods were utilized to evaluate the health risks associated with the soil vapor intrusion originating from the Bozeman Landfill (ATSDR 2008). ATSDR's Health Consultation considers:

- Only indoor air samples are considered by ATSDR
- Each house is evaluated individually and not in aggregate with other homes
- Maximum indoor air concentration is used for health hazard evaluation because there were too few samples collected in each house to generate a reliable central tendency estimate
- ATSDR comparison values are used when available and when they are more protective than Environmental Protection Agency (EPA) values; and
- Contaminants are evaluated for hazards regardless of source.

Figure 1 shows the City of Bozeman and the closed landfills in relation to the city and the affected Bridger Community. The shaded pink areas are within the City limits.

[1] Vapor intrusion is the process where volatile organic compounds (VOCs) or solvents from the subsurface, i.e. soil gas or groundwater off-gas, rise into indoor air [ITRC 2007, USEPA 2008a, USEPA 2015]. People can be harmed only when they breathe high enough concentrations of VOCs in indoor air for sufficient lengths of time. Many VOCs are typically present in indoor air from off-gassing buildings materials and commercial products. It can be difficult to differentiate indoor air contamination that comes from vapor intrusion versus what comes from indoor and outside sources. Therefore, ATSDR looks at VOC levels in the subsurface soil and groundwater to help determine the source of indoor air contaminants as well as other lines of evidence [ATSDR 2008].

Figure 1. Area Map



The exact location of each house is not identified in text or on a map to protect the privacy of property owners. Each house/property is assigned an arbitrary number in this report and all results are displayed in reference to these arbitrary numbers. Property owners will be sent their individual results directly via mail, and will not be informed of the identity of fellow community members' property numbers by ATSDR.

The landfill is situated on a 200 acre tract between Story Mill Road and McIlhattan Road approximately 2 miles northeast of downtown Bozeman (Figure 1). A groundwater monitoring program has been in operation at the landfill since 1981. In 1995, a corrective measures assessment (CMA) was performed (Maxim 1995) that evaluated the nature and extent of contamination of groundwater and landfill gas and recommended mitigation measures. As a result, a landfill gas extraction system was installed in the unlined closed cell in 1997. It is important to note that homes have been on city water since constructed and city water meets EPA standards.

VOC production tends to peak around 5 to 7 years after materials are placed in landfills and can result in pressure-driven gas flow through soil (ITRC 2007). VOCs in off-site soil gas were discovered in late 2012. For more information on all vapor intrusion studies and mitigation related to this site, see:
http://www.bozeman.net/Projects/BozemanLandfillSoilGasStudy/Home.aspx

Environmental Data Evaluation

Nature and Extent of Contamination

At the Bridger Creek Community, indoor air, crawl space, and subslab soil gas samples were analyzed for over 60 VOCs in 31 homes. In most cases, these are anthropogenic VOCs or breakdown products of anthropogenic compounds that have been found in other studies to be associated with municipal solid waste landfills. Many of these chemicals were not detected, were detected only infrequently, or were detected indoors at levels significantly higher than in soil gas.

Thirty seven VOCs were detected in subslab soil gas and 35 VOCs were detected in indoor air. Of the detected VOCs, 30% are associated with petroleum products, particularly gasoline and diesel or heating fuel. As of this writing, mitigation systems have been installed in all houses described in this Health Consultation, monitoring is continuing, and the City of Bozeman is in the process of developing a landfill remediation system.

In addition to VOCs, radon gas was found in indoor air at every residence tested. Radon concentrations ranged from 0.5 pCi/L to 34 pCi/L. Many of the concentrations exceed the current EPA guideline (action level) of 4 pCi/L and the current WHO guideline (action level) of 2.7 pCi/L. No detectable amount of radon is without some risk.

Buildings Construction

In the Bridger Creek community, the residences are built on concrete slabs with or without crawl spaces or basements. Individual slabs range from 2.5 inches to 16 inches in thickness with a typical slab being 3-4 inches thick. Most residences have basements or crawl spaces, have garages, are 1-3 stories in height and use forced-air heating. Since these homes are relatively new and are well maintained, the slabs are more likely to be a barrier to vapor intrusion than those in older houses. A few cracks or floor drains were noted by TetraTech during the house sampling, but otherwise the slabs seem to be intact. Most of the indoor air measurements were taken during winter months when the amount of ventilation is assumed to be low. The indoor air concentrations are anticipated to be reduced during other seasons when there is probably more ventilation. However, samples were not taken when the water table was at its highest during the spring. This is when upward pressure on soil gas from groundwater can be greatest.

Many of the Bridger Creek Community houses have crawl spaces that were sampled as part of site investigations. It was decided not to include these data. None of the crawl space samples were markedly higher than indoor air samples. Crawl space data are not directly applicable to exposure within the home’s livable space. Crawl space ventilation and porosity of flooring above are extremely variable. Also, people may use crawl spaces as storage and they may contain sources of VOCs such as paint, solvents, cleaners or related materials. Some examples of this were noted during TetraTech's field investigations at the Bridger Creek community residences.

Substantial variation in vapor intrusion rates can occur due to changes in factors such as temperature, barometric pressure, heating and ventilation [USEPA 2012b]. ATSDR will discuss the results of the available data, the limitations of the data, and the recommendations for filling data gaps.

Sample Collection and Analysis

Air samples were collected into SUMMA® canisters over a 24-hour period. The canisters are under vacuum at the start of the test and are calibrated to draw in air at a constant flow rate.

The chemical analytical data were obtained from samples collected by TetraTech between 2012 and 2014. Sampling methods and data management were generally consistent with EPA methodologies. VOCs were analyzed using EPA Method TO-15 by two independent laboratories -- Eurofins Air Toxics, Inc., Folsom California and AccuStar, Medford, MA. Eurofins maintains an accredited lab and participates in EPA's performance evaluation program as well as several state and federal certifications, validations and approvals. In addition to the air samples, field duplicates, blanks, surrogate recoveries, laboratory control samples and laboratory control sample duplicates were analyzed. Data were validated by TetraTech using EPA National Functional Guidelines and qualified as appropriate.

Radon testing was conducted as a measure of performance of the mitigation systems installed by the City. TetraTech used real-time scintillation measurement methods to obtain short-term (less than one day) near-continuous measurements of radon in indoor air.

Data Review

Quantitative concentrations were not provided by TetraTech for those samples flagged with an ND for non-detect, reflecting a result that was less than the detection or reporting limit. In these cases, TetraTech left the sample concentration cell in the table blank. For the purposes of selecting COPCs, only detectable concentrations with values reported by TetraTech were considered. All detection/reporting limits were lower than the health screening values for the VOCs present, so the ND reporting did not have an effect on the analyses presented in this document.

Screening

ATSDR compared results to ATSDR Minimal Risk Levels (MRLs) or EPA residential indoor air regional screening levels (RSLs) were used. ATSDR comparison values are used when available and when they are more protective than Environmental Protection Agency (EPA) values. Please refer to Table 1.

MRLs and RSLs represent conservative levels of safety; they are not thresholds of toxicity. Although concentrations at or below an MRL may reasonably be considered safe, concentrations above an MRL will not necessarily be harmful. The action on the part of ATSDR is to either 'screen in' or 'screen out' contaminants of concern that are then fully evaluated for their health hazard potential in this document.

Exposure Evaluation

An important part of determining if people will become sick from chemicals is determining how much of the chemicals they come into contact with. For places like Bridger Community, which is a residential community, we assume the worst-case scenario that people are home all the time and thus potentially exposed to the highest levels of contaminants in indoor air.

Seventeen of the 38 chemicals that were above their detection limits were above their respective screening values (Table 1). The chemical most frequently detected above its screening level was 1,2,4-Trimethylbenzene. The column 'Generic Indoor Air' presents the findings of an EPA study that describes typical levels of these contaminants in U.S. homes (EPA 2011a).

Table 1. Comparison of Maximum Indoor Air, Adjusted Maximum Indoor Air, Screening Value, and Generic Indoor Air Concentrations for 32 houses *

Chemical	**Maximum Detected Indoor Air**[†] (µg/m^3)	**# Houses Above CV**		**Inhalation Screening Values** (µg/m^3)	**Generic Indoor Air**[¥] (µg/m^3)
1,2,4-Trimethylbenzene	52	30		0.73 (RSL NC)	NA
1,2-Dichloroethane	350	28		0.038 (CREG), 2400 (cEMEG)	<RL-0.2
trans 1,2-Dichloroethene	26	1		6.3 (PPRT) 790 (i/aEMEG)	<RL-0.2
1,4-Dioxane	1.8	20		0.2 (CREG), 110 (cEMEG)	NA
2-Propanol	910	1		730 (RSL NC)	NA
Benzene	34	29		0.13 (CREG), 9.6 (cEMEG)	9.9-29
Carbon tetrachloride	0.84	20		0.17 (CREG), 190 (cEMEG)	<Reporting Limit – 1.1
Chloroform	18	24		0.043 (CREG) 98 (cEMEG)	4.1-7.5
Chloromethane	11	1		9.0 (RSL NC) 100 (cEMEG)	NA
Ethylbenzene	30	23		1.1 (RSL C) 260 (cEMEG)	12-17
Freon 12	50	2		10 (RSL NC)	NA
Hexane	110	1		73 (NC) 2100 (cEMEG)	NA
Radon	34 *pCi/L*	18		2.7 (WHO action level)^ 4.0 (EPA action level)^	1.3 *pCi/L*
Tetrachloroethylene	15	3		3.8(CREG), 270 (cEMEG)	4.1-9.5
Trichloroethylene	3.1	17		0.21 (RSL NC) 0.24 (CREG),	0.56-3.3

				2 (cEMEG)	
Vinyl chloride	0.25	1		0.11 (CREG), 77 (iEMEG)	<RL-0.09
Xylene (m, p)	140	10		10 (RSL NC) 220 (cEMEG)	21-63.5
Xylene (o)	40	6		10 (RSL NC) 220 (cEMEG)	13-20

[*]Samples collected 2012-2014.

RSL--EPA Regional Screening Level; NC--non-cancer; C--cancer; PPRT—EPA Provisional Peer Reviewed Toxicity value; CREG--ATSDR Cancer Risk Evaluation Guideline; EMEG--ATSDR Environmental Media Evaluation Guideline; c--chronic; i--intermediate; a--acute.

Regional Screening Levels (RSLs) used when more protective than other CVs. Source: EPA Mid-Atlantic RSL Table.

EPA Provisional Peer Reviewed Toxicity Value (PPRT) used when no other CV is available. Source: EPA Superfund.

† Environmental concentrations not time adjusted, residential scenario assumes constant potential exposure.

¥*Background Indoor Air Concentrations of Volatile Organic Compounds in North American Residences (1990-2005)*^Note: Radon action levels are not analogous to VOC screening values, action levels allow for a much higher level of inhalation risk and are partly based on technical feasibility of remediation.

Public Health Implications

Cancer

ATSDR estimated cancer risks (see Appendix A for calculations and Appendix B for formulae) were based on the maximum indoor air measurements for each individual house and are presented below (**Table 2**). Note again that there are *lifetime cancer risk, 9-year and 1-year exposure cancer risk estimates* presented here. The EPA target risk range for cancer is 10^{-4} to 10^{-6}. This is also written as E-4 to E-6 and can be expressed as 'one in ten thousand to one in a million' cancers for exposed people *in excess* of what would normally appear in the population. Cancer is common, with one in two men and one in three women developing some form of cancer in their lifetimes in the U.S.

Conservative assumptions about the magnitude and frequency of exposure are made for all scenarios considered. Nine-year exposure is an estimate of time between construction of homes and installation of SSD. Note that radon excess cancer risk is not calculated in the same manner as excess risk for VOCs; rather, the detected radon concentration is compared to threshold and guidance values generated by EPA and WHO. EPA considers exposures to non-smokers (never smoked) above 1.25 pCi/L to be above the EPA reference range for cancer risk. Smokers and past smokers have a greater potential risk than non-smokers at this threshold value.

Pre-mitigation levels of naturally-occurring radon gas posed the greatest health hazard by several orders of magnitude compared to other detected chemicals at all 18 houses where radon was sampled. Lung cancer risk rises 16% per 2.7 pCi/L increase in radon exposure. WHO has an action level of 2.7 pCi/L at which remediation is advised (WHO 2009). EPA considers exposures to non-smokers (never smoked) above 1.25 pCi/L to be above the EPA reference range for cancer risk. Smokers and past smokers have a greater potential risk. EPA has an action level of 4.0 pCi/L at which remediation is advised (EPA 2003). All homes tested were above 4 pCi/L before sub-slab depressurization (SSD) was installed.

Pre-mitigation levels of chemical contaminants (VOCs) in indoor air posed a health hazard at 9 houses. Estimated excess lifetime cancer risk for blood, blood vessel, liver and kidney cancer ranged from slightly greater than 1 in 10,000 to 9 in 1,000 cases above background risk for these specific cancers *if a lifetime of exposure had occurred*. If pre-mitigation exposures were 9-years (the estimated maximum time between home construction and SSD installation), estimated excess lifetime cancer risk for blood, blood vessel, liver and kidney cancer ranged from 9 in a million to 1 in 1,000 cases above background risk. Only blood vessel cancer risk was above the EPA target cancer risk range, at House 20 only; this was due to 1,2-Dichloroethane exposure. If pre-mitigation exposures were 1 year, cancer risk for these same cancers ranged from 1 in a million to 1 in 10,000, which is within EPA's target risk range. If pre-mitigation exposures were longer than 1 year, cancer risk would exceed the target risk range at some of these houses.

Table 2. Estimated Contaminant-Specific Cancer Risks Where 1-year Exposure Risk is Above EPA Reference Range Based on Indoor Air Measurements. (Lifetime Potential Risk is Above EPA Reference Range for All Houses Sampled).

House #	Contaminant	Max-imum Indoor Air	Excess Lifetime Cancer Risk	Excess 9-year Exposure Cancer Risk	Excess 1-year Exposure Cancer Risk	Most Sensitive Cancer Site
1	Total (excluding Radon)	-	9.3E-5	1.1E-5	1.2E-6	Multiple
3	Total (excluding Radon)	-	1.0E-4	1.2E-5	1.3E-6	Multiple
5	Benzene	34 $\mu g/m^3$	2.7E-4	3.1E-5	3.5E-6	Blood
	Chloroform	18 $\mu g/m^3$	4.1E-4	4.7E-5	5.3E-6	Liver
	Total (excluding Radon)	-	7.7E-4	8.9E-5	9.9E-6	Multiple
8	Radon^	10.1 *pCi/L*	>EPA action level	> EPA action level	> EPA action level	Lung
	Total (excluding Radon)	-	9.7E-5	1.1E-5	1.2E-6	Multiple
9	Total (excluding Radon)	-	8.9E-5	1.0E-5	1.1E-6	Multiple
10	Radon^	8.0 *pCi/L*	> EPA action level	> EPA action level	> EPA action level	Lung
11	Radon^	9.3 *pCi/L*	> EPA action level	> EPA action level	> EPA action level	Lung
12	1,2-Dichloroethane	5.3 $\mu g/m^3$	1.4E-4	1.6E-5	1.8E-6	Blood vessels
	Total (excluding Radon)	-	1.7E-4	2.0E-5	2.2E-6	Multiple
13	Radon^	11 *pCi/L*	> EPA action level	> EPA action level	> EPA action level	Lung
14	Benzene	26 $\mu g/m^3$	2.0E-4	2.3E-5	2.6E-6	Blood

	Total (excluding Radon)	-	2.8E-4	3.2E-5	3.6E-6	Multiple
16	Chloroform	12 µg/m^3	2.8E-4	3.23E-5	3.59E-6	Liver
	Total (excluding Radon)	-	3.2E-4	3.7E-5	4.1E-6	Multiple
17	Radon^	17.2 *pCi/L*	> EPA action level	> EPA action level	> EPA action level	Lungs
18	Radon^	20 *pCi/L*	> EPA action level	> EPA action level	> EPA action level	Lungs
19	Radon^	34 *pCi/L*	> EPA action level	> EPA action level	> EPA action level	Lungs
20	1,2-Dichloroethane	350 µg/m^3	9.1E-3	1.1E-3	1.2E-4	Blood vessels
	Total (excluding Radon)	-	9.2E-3	1.1E-3	1.2E-4	Multiple
21	Radon^	9.3 *pCi/L*	> EPA action level	> EPA action level	> EPA action level	Lungs
23	Radon^	9 *pCi/L*	> EPA action level	> EPA action level	> EPA action level	Lungs
24	1,2-Dichloroethane	6.2 µg/m^3	1.6E-4	1.85E-05	2.05E-06	Blood vessels
	Benzene	18 µg/m^3	1.4E-4	1.61E-05	1.79E-06	Blood
	Radon^	30 *pCi/L*	> EPA action level	> EPA action level	> EPA action level	Lungs
	Total (excluding Radon)	-	3.6E-4	4.2E-5	4.6E-6	Multiple
25	Benzene	13 µg/m^3	1.1E-4	1.3E-5	1.4E-6	Blood
	Radon^	3.5 *pCi/L*	between EPA and WHO action level	between EPA and WHO action level	between EPA and WHO action level	Lungs

	Total (excluding Radon)	-	2.4E-4	2.8E-5	3.1E-6	Multiple
26	Radon^	10.3 *pCi/L*	> EPA action level	> EPA action level	> EPA action level	Lungs
27	Radon^	19.7 *pCi/L*	> EPA action level	> EPA action level	> EPA action level	Lungs
29	Radon^	7.8 *pCi/L*	> EPA action level	> EPA action level	> EPA action level	Lungs
30	Radon^	15.5 *pCi/L*	> EPA action level	> EPA action level	> EPA action level	Lungs
31	1,2-Dichloroethane	7.3 $\mu g/m^3$	1.9E-4	2.2E-5	2.4E-6	Blood vessels
33	Benzene	16 $\mu g/m^3$	1.2E-4	1.4E-5	1.5E-6	Blood
	Radon^	8.8 *pCi/L*	> EPA action level	> EPA action level	> EPA action level	Lungs
	Total (excluding Radon)	-	1.9E-4	2.2E-5	2.6E-6	

Notes:

-1-year exposure is chosen to highlight houses with highest risk. It is assumed most occupants have lived in their homes for at least 1 year. Please see Appendix A for complete cancer risk calculations.
-Total risk represents summation of risk contributed by all chemicals present, including those which do not individually pose a risk above the EPA reference range. Radon is evaluated separately because there is not a widely-accepted cancer slope factor for radon.

-Some houses were not tested for Radon or the data were not provided. Radon risk likely exists at most houses above the EPA Reference Range of 1E-4 to 1E-6.
- No additive risks (1-year exposure) for the same cancer site due to multiple chemical exposure were above the EPA Reference Range. See Appendix A for full analysis.

^Risk to non-smokers. Current or ever smokers are at much greater risk for lung cancer if exposed to radon.

Non-cancer

Non-cancer risks from VOC exposure are presented below (**Table 3**).

TCE
In October 2014, ATSDR published a chronic EMEG of 2.1 µg/m^3 for chronic (more than 365 days) and intermediate (2 weeks to 365 days) inhalation exposure to trichloroethylene (TCE) [ATSDR 2014]. The most sensitive endpoint of the cEMEG is an increase in fetal cardiac malformations in rats, with an uncertainty (safety) factor built in. The effect level for fetal cardiac malformations, based on a human equivalent concentration (HEC) derived from rat studies, is 21 µg/m^3 for the critical exposure period during pregnancy. With an uncertainty factor of only 10 applied to the effect level for fetal heart impacts, concentrations of TCE of about three times greater than the cEMEG may become a concern for health effects. The most sensitive receptor, a fetus during the period the heart is developing during the first trimester of pregnancy, could be harmed by breathing indoor air at House 31 *if levels were to fluctuate higher because SSD was not working properly*. ATSDR could not conclude whether or not pre-SSD exposures to TCE at House 31 could have harmed a first trimester fetus during the period the heart is developing based on the data provided.

Other Contaminants
Benzene, 1,2,4-trimethylbenzene, and xylenes were detected at levels above their health based non-cancer risk values. An MRL is an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse non-cancer health effects over a specified duration of exposure. For chronic, this means exposure greater than one year; intermediate, two weeks up to one year; and acute, one day to two weeks. MRLs are generally based on the most sensitive substance-induced end point considered to be of relevance to humans which, in the case of benzene, is a decrease in white blood cells. The highest measured benzene level was at House #5 and was the only location where benzene exceeded an MRL. At this location it exceeded the acute, intermediate and chronic MRLs. The acute MRL is the highest value of the three, and the measured concentration in House #5 fell just above the acute MRL but well below a known health effect level. In other words, benzene did not come close to exceeding an air concentration that has been demonstrated to cause health effects. To explain it in terms of the benzene chronic MRL (the lowest value of the three MRLs), the chronic MRL has an uncertainty factor of 10 for human variability, and is based on the Lowest Observable Adverse Effect Level (LOAEL) that is modified by a 300-fold uncertainty factor. The highest measured benzene level in air, at House #5, was only 13% higher than the chronic MRL but several hundred times below the LOAEL, thus we do not anticipate any non-cancer health effects from exposure to this air concentration, even with chronic exposure.

1,2,4-trimethylbenzene and xylenes exceeded their respective EPA chronic reference concentrations (RfCs). Note that the RfC for 1,2,4-trimethylbenzene is a Provisional Peer Reviewed Toxicity Value for Superfund, not an official EPA IRIS value (USEPA 2007b). RfCs are an estimate of continuous inhalation exposure of a chemical to the human population (including sensitive subpopulations) that is likely to be without risk of deleterious non-cancer effects during a lifetime. RfCs are also generally based on the most sensitive substance-induced end point considered to be of relevance to humans: for 1,2,4-trimethylbenzene this end point is decreased clotting time in blood, while for xylenes this end point is reduced motor coordination. The 1,2,4-trimethylbenzene RfC is based on a No Observable Adverse Effect Level (NOAEL);

that concentration is then modified by a 3000-fold uncertainty factor. The highest measured 1,2,4-trimethylbenzene concentration was detected in House #14 and was approximately seven and a half times higher than the Provisional RfC but was 400 times lower than the NOAEL concentration, thus we do not anticipate and health effects from exposure to this air concentration. The xylenes RfC is based on a (NOAEL) that is modified by a 300-fold uncertainty factor. The highest measured concentration of xylenes, at House #14, was 1.8 times higher than the RfC but was more than 150 times lower than the NOAEL, thus we do not anticipate and health effects from exposure to this air concentration.

Table 3. Contaminant-Specific Non-Cancer Risk Values Compared to Indoor Air Measurements

House #	Contaminant	Max Indoor Air (µg/m³)	MRL or RfC (µg/m³)	Target Organ/Effect
5	Benzene	**34**	30 (acute MRL)	Immune system (decrease in white blood cells)
	1,2,4-Trimethylbenzene	**21**	7* (provisional chronic RfC)	Blood (decreased clotting time)
14	1,2,4-Trimethylbenzene	**52**	7* (provisional chronic RfC)	Blood (decreased clotting time)
	Xylenes (total)	**180**	100 (chronic RfC)	Blood (decreased clotting time)
24	1,2,4-Trimethylbenzene	**21**	7* (provisional chronic RfC)	Blood (decreased clotting time)
25	1,2,4-Trimethylbenzene	**23**	7* (provisional chronic RfC)	Blood (decreased clotting time)
31	Trichloroethylene ~	**3.1**	2.1 (chronic and intermediate EMEG)	Fetal heart (malformation)
33	1,2,4-Trimethylbenzene	**28**	7* (provisional chronic RfC)	Blood (decreased clotting time)

Notes:

-Chronic effects usually depend on long-term average exposures, though some chemicals, like trichloroethylene, can cause health effects within shorter exposure windows at relatively low concentrations. If the indoor levels were to increase due to increased background source emission, vapor intrusion, or installation of new buildings without preemptive mitigation systems, those health effects increase.

~ While this TCE sample is not approaching the health effect concentration (HEC), the HEC is very low and the necessary exposure window is relatively short compared to other contaminants. It is plausible that TCE levels could fluctuate. Thus TCE should be closely monitored at this house.

*The provisional RfC for 1,2,4-trimethylbenzene comes from EPA PPRT Values for Superfund. On 9/29/2015, the Science Advisory Board for EPA IRIS decided upon an RfC of 20 µg/m³ which is approximately 3x less protective than the EPA PPRT value used here, and has decided to use the original

IRIS health endpoint of decreased pain sensitivity. This proposed change in IRIS does not affect the conclusions of this report.
http://yosemite.epa.gov/sab/sabproduct.nsf/fedrgstr_activites/D929A3B7F0E6FB7585257ECF00640AEF/$File/EPA-SAB-15-013+unsigned.pdf

Uncertainties and Data Limitations

Indoor air variability – Indoor air VOC and radon levels can vary greatly, i.e. samples represent exposure levels for a snapshot in time. Actual average and peak levels could be considerably higher or lower than those found in the indoor samples. Fluctuations that result in higher short-term average exposures to VOCs, for example, could result in exposures of concern to sensitive individuals, especially fetuses in the first trimester of development.

Meteorological effects - Vapor intrusion rates tend to vary spatially and temporally on an hourly, daily, and monthly basis [Hers 2001]. Temporal variability could be caused by variation in temperature, barometric pressure, precipitation, ground cover by snow and ice, and changes in groundwater levels [USEPA 2012b]. Vapor intrusion rates may be substantially different during winter conditions.

Other indoor air contributions - Indoor air exposures to contaminants can be a combination of breathing VOCs from vapor intrusion and indoor sources. Other indoor VOC sources in residential homes include building materials, carpets, adhesives, concrete sealers, cabinet finishes, maintenance supplies, chemicals, commercial products or cigarette smoke [USEPA 2011a].

Improving Indoor Air Quality - Actions that can reduce indoor VOC exposure include providing for maximum ventilation while using VOC-containing products indoors, storing VOC-containing products in a well-ventilated area, and appropriately discarding VOC-containing products that are no longer needed [USEPA 2011b]. Avoid allowing vehicles to idle in attached garages and ensure proper ventilation for fuel oil heaters.

If future buildings are constructed on the sites, preemptive vapor mitigation systems are recommended for any buildings constructed in the vicinity of areas with soil gas contamination [USEPA 2008b, c]. New houses in this area should be built using appropriate vapor barriers to reduce both VOCs and radon. This radon standard for construction has been adopted by the governments of many counties and cities throughout the west in places where radon is a known problem.

Conclusions

1. ATSDR concludes that pre-mitigation levels of naturally-occurring radon gas posed the greatest health hazard by several orders of magnitude compared to other detected chemicals at all 18 houses where radon was sampled. Lung cancer risk rises 16% per 2.7 pCi/L increase in radon exposure. WHO has an action level of 2.7 pCi/L at which remediation is advised (WHO 2009). EPA considers exposures to non-smokers (never smoked) above 1.25 pCi/L to be above the EPA reference range for cancer risk. Smokers and past smokers have a greater potential risk. EPA has an action level of 4.0 pCi/L at

which remediation is advised (EPA 2003). All homes tested were above 4 pCi/L before sub-slab depressurization (SSD) was installed.

2. ATSDR concludes that pre-mitigation levels of chemical contaminants (VOCs) in indoor air posed a past health hazard at 9 houses. Estimated excess lifetime cancer risk for blood, blood vessel, liver and kidney cancer ranged from slightly greater than 1 in 10,000 to 9 in 1,000 cases above background risk for these specific cancers *if a lifetime of exposure had occurred*. If pre-mitigation exposures were 9-years (the estimated maximum time between home construction and SSD installation), estimated excess lifetime cancer risk for blood, blood vessel, liver and kidney cancer ranged from 9 in a million to 1 in 1,000 cases above background risk. Only blood vessel cancer risk was above the EPA target cancer risk range, at House 20 only; this was due to 1,2-Dichloroethane exposure. If pre-mitigation exposures were 1 year, cancer risk for these same cancers ranged from 1 in a million to 1 in 10,000, which is within EPA's target risk range. If pre-mitigation exposures were longer than 1 year, cancer risk would exceed the target risk range at some of these houses.

3. Based on the data provided, ATSDR cannot conclude whether or not pre-SSD exposures to TCE at House 31 could have harmed a first trimester fetus during the period the heart is developing. ATSDR concludes that the most sensitive receptor, a fetus during the period the heart is developing during the first trimester of pregnancy, could be harmed in the future by the mother breathing indoor air at House 31 *if level fluctuates higher because SSD was not working properly*. TCE was measured in indoor air pre-mitigation above the health screening value. TCE exposure may also increase the risk of immunological effects, as indicated by studies reporting decreased thymus weight and increased antibody production in animals.

   Finally, the detected pre-SSD levels of TCE at House 31 could also present a slight increase in lifetime cancer risk (15 in a million excess cases above background). Temporal variability of the vapor intrusion pathway for on-site buildings was not fully evaluated, and levels may change over time especially from season to season. Current SSD is adequately reducing TCE concentration in air at this and other houses.

Recommendations

ATSDR recommends the following:

- Continuing proper operation and maintenance of the sub-slab depressurization (SSD) systems for the duration of building occupancy. SSD systems should have an audible failure alarm. If an SSD system is shut down or altered in the future, follow-up sampling is needed to ensure that the changes do not allow vapor intrusion above acceptable levels.
- Encouraging homeowners who have not yet tested for radon to do so.
- Inspecting site characteristics periodically. Changes to site characteristics, such as heating, ventilation, and air condition (HVAC) systems, utility conduits, exhaust fans, slab integrity, and landscaping may affect vapor migration and warrant follow-up sampling.
- Taking actions that can reduce VOC exposure include providing for maximum ventilation while using VOC-containing products indoors, storing VOC-containing products that will not be used immediately in a designated chemical safety cabinet, and appropriately discarding VOC-containing products that are no longer needed.

- Considering that new houses in this area be built using appropriate radon barriers. This standard has been adopted by the governments of many counties and cities throughout the west in places where radon is a known problem.

Public Health Action Plan

The public health action plan for the site contains a description of actions ATSDR and other stakeholders have taken and will take. This plan provides action items designed to mitigate and to prevent harmful human health effects resulting from contact with hazardous substances in the environment.

Completed public health actions:

-ATSDR reviewed

- Available historical information on site activities and information from environmental investigations including
    - Groundwater, soil gas, sub-slab gas and indoor air sampling
    - Remediation activities (SSD systems)

-ATSDR authored this document to summarize potential health hazards posed by pre-mitigation air concentrations of radon and VOCs.

Planned public health actions:

ATSDR is available to assist in addressing health concerns upon request by

- continuing to dialogue with the community, the City of Bozeman, and the City's consultants to address health and exposure concerns
- reviewing additional sampling data and making recommendations to protect public health

Authors

LCDR Kai Elgethun, PhD, MPH
Associate Director for Science
Western Branch
Division of Community Health Investigations
Agency for Toxic Substances and Disease Registry

References

[ACGIH] American Conference of Governmental Industrial Hygienists. 2015. TLV for Isopropyl alcohol (2-propanol).

[ATSDR] Agency for Toxic Substances and Disease Registry. 2007. ToxProfile for Benzene. http://www.atsdr.cdc.gov/toxprofiles/tp.asp?id=40&tid=14

[ATSDR] Agency for Toxic Substances and Disease Registry. 2005. *Public health assessment guidance manual*. Atlanta: US Department of Health and Human Services. Available at: http://www.atsdr.cdc.gov/HAC/PHAManual/. Accessed Jul 2009.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2008. *Evaluating vapor intrusion pathways at hazardous waste sites*. Atlanta: US Department of Health and Human Services. Available at: http://www.atsdr.cdc.gov/document/evaluating_vapor_intrusion.pdf. Accessed Sep 2011.

[ATSDR] Agency for Toxic Substances and Disease Registry. October 2014. *Draft toxicological profile for trichloroethylene*. Atlanta: US Department of Health and Human Services. Available at: http://www.atsdr.cdc.gov/ToxProfiles/tp19.pdf. Accessed Apr 30, 2015. [ATSDR] Agency for Toxic Substances and Disease Registry. In clearance-2015. *Public health assessment: Garvey Elevator Groundwater Contamination Site, Hastings, NE*. Atlanta: US Department of Health and Human Services.

City of Bozeman. Website documenting actions for remediation from old landfill: http://www.bozeman.net/Projects/BozemanLandfillSoilGasStudy/Home.aspx

CPF Associates, Inc. Bridger Creek Community Vapor Intrusion Human Health Risk Assessment. Takoma Park, MD. March 4, 2015.

Eurofins. 2014. Laboratory reported dated 1/15/2014.

Hers I, Reider Z-G, Li L, et al. 2001. *The use of indoor air measurement to evaluate intrusion of subsurface volatile organic chemical vapors into buildings*. J Air Waste Manage Assoc 51:1318–31.

[ITRC] Interstate Technology & Regulatory Council. 2007. *Vapor intrusion pathway: A practical guideline*. Available at: http://www.itrcweb.org/Documents/VI-1.pdf. Accessed Aug 2014.

Maxim Technologies 1995. Corrective Measures Assessment: City of Bozeman Sanitary Landfill. Prepared for City of Bozeman.

[NLM] National Library of Medicine. 2010. *Household products database: Health & safety information on household products*. Washington DC: US Department of Health & Human Services. Available at: http://householdproducts.nlm.nih.gov/ [updated Jun 2010; accessed Sept 15, 2011].

TetraTech. 2007. Landfill gas extraction system evaluation. Bozeman Sanitary Landfill. Prepared for City of Bozeman.

TetraTech. 2014. Revised Corrective Measures Assessment, Bozeman Landfill, Gallatin County, Montana. August 17, 2014.

[USEPA] US Environmental Protection Agency. 2003. *EPA Assessment of Risk from Radon in Homes*. Available at: http://www.epa.gov/radiation/docs/assessment/402-r-03-003.pdf

[USEPA] US Environmental Protection Agency. 2004. *User's guide for evaluating subsurface vapor intrusion into buildings.* Feb 22, 2004. Available at: http://www.epa.gov/oswer/riskassessment/airmodel/pdf/2004_0222_3phase_users_guide.pdf

[USEPA] US Environmental Protection Agency. 2007a. *ORNL Provisional Peer Reviewed Toxicity Values for Superfund.* Available at: http://hhpprtv.ornl.gov/quickview/pprtv.php

[USEPA] US Environmental Protection Agency. 2007b. Provisional Peer Reviewed Toxicity Values for 1,2,4-Trimethylbenzene (CASRN 95-63-6). U.S. Environmental Protection Agency, Superfund Technical Support Center, National Center for Environmental Assessment, Cincinnati, OH.

[USEPA] US Environmental Protection Agency. 2008a. DRAFT: *U.S. EPA's vapor intrusion database: Preliminary evaluation of attenuation factors*. Washington DC; Mar 4.

[USEPA] US Environmental Protection Agency. 2008b. *Engineering issue: Indoor air vapor intrusion mitigation approaches*. Washington DC; Oct. Available at: http://www.epa.gov/nrmrl/pubs/600r08115/600r08115.pdf. Accessed Dec 16, 2011.

[USEPA] US Environmental Protection Agency. 2008c. *Brownfields technology primer: Vapor intrusion considerations for redevelopment*. Washington DC; March.

[USEPA] US Environmental Protection Agency. 2011a. *Background indoor air concentrations of volatile organic compounds in North American residences (1990–2005): A compilation of statistics for assessing vapor intrusion*. Washington DC; Jun. Available at: http://www.epa.gov/oswer/vaporintrusion/documents/oswer-vapor-intrusion-background-Report-062411.pdf Accessed Nov 2011.

[USEPA] US Environmental Protection Agency. 2011b. *An introduction to indoor air quality*. Washington DC. Available at: http://www.epa.gov/iaq/voc.html#content. [Updated Aug 25, 2011; Accessed September 2011].

[USEPA] US Environmental Protection Agency. 2011c. *ADAF sample calculator for TCE.* Available at: http://hero.epa.gov/index.cfm/reference/details/reference_id/758648

[USEPA] US Environmental Protection Agency. 2012a. *Superfund vapor intrusion FAQs*. 2012. Washington DC; Feb. Available at: http://www.epa.gov/superfund/sites/npl/Vapor_Intrusion_FAQs_Feb2012.pdf. Accessed Aug 2012

[USEPA] US Environmental Protection Agency. 2012b. IRIS Toxicological Review of Trimethylbenzenes (External Review Draft). June 2012. http://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=237915

[USEPA] US Environmental Protection Agency. 2015. *OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air.* Washington DC; Jun. Available at:

http://www.epa.gov/oswer/vaporintrusion/documents/OSWER-Vapor-Intrusion-Technical-Guide-Final.pdf

[USEPA] US Environmental Protection Agency. 2015. *Mid-Atlantic Risk Assessment Screening Tables.* Washington DC; Jun. Available at: http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/

[WHO] World Health Organization. 2009. *WHO handbook on indoor radon: a public health perspective.* Available at: http://whqlibdoc.who.int/publications/2009/9789241547673_eng.pdf

Appendix A. House-by-House Cancer Risk Estimation by Contaminant and Cancer Site (prior to installation of SSD abatement systems)

Lifetime cancer risk assumes 78 year lifetime and are shown below. Nine year and 1 year estimates are derived from lifetime estimates and are shown in Table 2 TCE calculations include Age Dependent Adjustment Factors (ADAFs) for kidney cancer only; TCE calculations are additive for kidney, liver and non-Hodgkin's lymphoma (NHL). Radon risk is qualitative, all radon inhalation contributes to lung cancer risk. *Multiple chemicals that cause liver cancer were detected, thus total additive liver cancer excess risk is reported.

House 1 N=5	Maximum Indoor Air ($\mu g/m^3$)	Excess Lifetime Cancer Risk	Most Sensitive Cancer Site
1,2-Dichloroethane	0.66	1.7E-5	Blood vessels
1,4-Dioxane	BSL		Multiple
Benzene	3.10	2.4E-5	Blood
Carbon tetrachloride	0.66	4.0E-6	Adrenal gland
Chloroform	1.70	3.9E-5	Liver
Ethylbenzene	3.40	8.5E-6	Multiple
Radon	No data		Lung
Tetrachloroethylene	BSL		Liver
TCE ages 0-<2 years	BSL		Multiple
TCE ages 2-<16 years	BSL		Multiple
TCE ages 16 years & older	BSL		Multiple
Vinyl chloride	BSL		Liver
		*Liver Cancer Total =3.9E-5	
Total Risk (any cancer, not including Radon)		**9.3E-5**	

House 2 N=7	Maximum Indoor Air ($\mu g/m^3$)	Excess Lifetime Cancer Risk	Most Sensitive Cancer Site
1,2-Dichloroethane	1.2	3.1E-5	Blood vessels
1,4-Dioxane	BSL		Multiple
Benzene	0.74	5.8E-6	Blood
Carbon tetrachloride	0.57	3.4E-6	Adrenal gland
Chloroform	0.58	1.3E-5	Liver

Ethylbenzene	BSL		Multiple
Radon	No data		Lung
Tetrachloroethylene	BSL		Liver
TCE ages 0-<2 years	0.4	1.5E-7	Multiple
TCE ages 2-<16 years	0.4	4.9E-7	Multiple
TCE ages 16 years & older	0.4	1.3E-6	Multiple
Vinyl chloride	BSL		Liver
		Liver Cancer Total =1.3E-5	
Total Risk (any cancer, not including Radon)		**5.5E-5**	

House 3 N=6	**Maximum Indoor Air (μg/m^3)**	**Excess Lifetime Cancer Risk**	**Most Sensitive Cancer Site**
1,2-Dichloroethane	2.00	5.2E-5	Blood vessels
1,4-Dioxane	BSL		Multiple
Benzene	2.20	1.7E-5	Blood
Carbon tetrachloride	0.58	3.5E-6	Adrenal gland
Chloroform	0.73	1.7E-5	Liver
Ethylbenzene	5.1	1.3E-5	Multiple
Radon	No data		Lung
Tetrachloroethylene	BSL		Liver
TCE ages 0-<2 years	BSL		Multiple
TCE ages 2-<16 years	BSL		Multiple
TCE ages 16 years & older	BSL		Multiple
Vinyl chloride	BSL		Liver
		Liver Cancer Total = 1.7E-5	
Total Risk (any cancer, not including Radon)		**1.0E-4**	

House 4 N=5	**Maximum Indoor Air (μg/m^3)**	**Excess Lifetime Cancer Risk**	**Most Sensitive Cancer Site**
1,2-Dichloroethane	0.62	1.6E-5	Blood vessels
1,4-Dioxane	BSL		Multiple
Benzene	2.60	2.0E-5	Blood
Carbon tetrachloride	0.70	4.2E-6	Adrenal gland

Chloroform	0.93	2.1E-5	Liver
Ethylbenzene	2.80	7.0E-6	Multiple
Radon	No data		Lung
Tetrachloroethylene	BSL		Liver
TCE ages 0-<2 years	0.23	8.6E-8	Multiple
TCE ages 2-<16 years	0.23	2.8E-7	Multiple
TCE ages 16 years & older	0.23	7.3E-7	Multiple
Vinyl chloride			Liver
		Liver Cancer Total = 2.1E-5	
Total Risk (any cancer, not including Radon)		**6.9E-5**	

House 5 N=3	**Maximum Indoor Air (µg/m^3)**	**Excess Lifetime Cancer Risk**	**Most Sensitive Cancer Site**
1,2-Dichloroethane	0.85	2.2E-5	Blood vessels
1,4-Dioxane	1.2	6.0E-6	Multiple
Benzene	34	2.7E-4	Blood
Carbon tetrachloride	0.50	3.0E-6	Adrenal gland
Chloroform	18	4.1E-4	Liver
Ethylbenzene	21	5.3E-5	Multiple
Radon	No Data		Lung
Tetrachloroethylene	4.70	1.2E-6	Liver
TCE ages 0-<2 years	0.51	1.9E-7	Multiple
TCE ages 2-<16 years	0.51	6.2E-7	Multiple
TCE ages 16 years & older	0.51	1.6E-6	Multiple
Vinyl chloride	0.25	1.1E-6	Liver
		Liver Cancer Total = 4.1E-4	
Total Risk (any cancer, not including Radon)		**7.7E-4**	

House 6 N=2	**Maximum Indoor Air (µg/m^3)**	**Excess Lifetime Cancer Risk**	**Most Sensitive Cancer Site**
1,2-Dichloroethane	0.53	1.4E-5	Blood vessels

1,4-Dioxane	0.36	1.8E-6	Multiple
Benzene	2.30	1.8E-5	Blood
Carbon tetrachloride	0.55	3.3E-6	Adrenal gland
Chloroform	0.66	1.5E-5	Liver
Ethylbenzene	1.70	4.3E-6	Multiple
Radon	No data		Lung
Tetrachloroethylene	BSL		Liver
TCE ages 0-<2 years	0.046	1.7E-8	Multiple
TCE ages 2-<16 years	0.046	5.6E-8	Multiple
TCE ages 16 years & older	0.046	1.5E-7	Multiple
Vinyl chloride	BSL		Liver
		Liver Cancer Total = 1.5E-5	
Total Risk (any cancer, not including Radon)		**5.7E-5**	

House 7 N=2	**Maximum Indoor Air (µg/m³)**	**Excess Lifetime Cancer Risk**	**Most Sensitive Cancer Site**
1,2-Dichloroethane	BSL		Blood vessels
1,4-Dioxane	BSL		Multiple
Benzene	6.0	4.7E-5	Blood
Carbon tetrachloride	0.68	4.1E-6	Adrenal gland
Chloroform	0.49	1.1E-5	Liver
Ethylbenzene	2.0	5.0E-6	Multiple
Radon	No data		Lung
Tetrachloroethylene	BSL		Liver
TCE ages 0-<2 years	BSL		Multiple
TCE ages 2-<16 years	BSL		Multiple
TCE ages 16 years & older	BSL		Multiple
Vinyl chloride	BSL		Liver
		Liver Cancer Total = 1.1E-5	
Total Risk (any cancer, not including Radon)		**6.7E-5**	

House 8 N=4	Maximum Indoor Air (µg/m^3)	Excess Lifetime Cancer Risk	Most Sensitive Cancer Site
1,2-Dichloroethane	0.52	1.3E-5	Blood vessels
1,4-Dioxane	0.66	3.3E-6	Multiple
Benzene	4.8	3.7E-5	Blood
Carbon tetrachloride	0.84	5.0E-6	Adrenal gland
Chloroform	1.3	3.0E-5	Liver
Ethylbenzene	3.4	8.5E-6	Multiple
Radon	10.1	>1E-4	Lung
Tetrachloroethylene	BSL		Liver
TCE ages 0-<2 years	0.11	4.1E-8	Multiple
TCE ages 2-<16 years	0.11	1.3E-7	Multiple
TCE ages 16 years & older	0.11	3.5E-7	Multiple
Vinyl chloride	BSL		Liver
		Liver Cancer Total =3.0E-5	
Total Risk (any cancer, not including Radon)		**9.7E-5**	

House 9 N=2	Maximum Indoor Air (µg/m^3)	Excess Lifetime Cancer Risk	Most Sensitive Cancer Site
1,2-Dichloroethane	0.23	6.0E-6	Blood vessels
1,4-Dioxane	0.64	3.2E-6	Multiple
Benzene	3.2	2.5E-5	Blood
Carbon tetrachloride	BSL		Adrenal gland
Chloroform	1.6	3.7E-5	Liver
Ethylbenzene	7.1	1.8E-5	Multiple
Radon	No data		Lung
Tetrachloroethylene	BSL		Liver
TCE ages 0-<2 years	0.015	5.6E-9	Multiple
TCE ages 2-<16 years	0.015	1.8E-8	Multiple
TCE ages 16 years & older	0.015	4.7E-8	Multiple
Vinyl chloride	BSL		Liver
		Liver Cancer Total = 3.7E-5	
Total Risk (any cancer, not including Radon)		**8.9E-5**	

House 10 N=3	**Maximum Indoor Air ($\mu g/m^3$)**	**Excess Lifetime Cancer Risk**	**Most Sensitive Cancer Site**
1,2-Dichloroethane	0.11	2.9E-6	Blood vessels
1,4-Dioxane	1.4	7.0E-6	Multiple
Benzene	0.38	3.0E-6	Blood
Carbon tetrachloride	BSL		Adrenal gland
Chloroform	0.27	6.2E-6	Liver
Ethylbenzene	2.7	6.8E-6	Multiple
Radon	8.0	>1E-4	Lung
Tetrachloroethylene	BSL		Liver
TCE ages 0-<2 years	0.052	1.9E-8	Multiple
TCE ages 2-<16 years	0.052	6.3E-8	Multiple
TCE ages 16 years & older	0.052	1.6E-7	Multiple
Vinyl chloride	BSL		Liver
		Liver Cancer Total = 6.2E-6	
Total Risk (any cancer, not including Radon)		**2.6E-5**	

House 11 N=2	**Maximum Indoor Air ($\mu g/m^3$)**	**Excess Lifetime Cancer Risk**	**Most Sensitive Cancer Site**
1,2-Dichloroethane	0.41	1.1E-5	Blood vessels
1,4-Dioxane	BSL		Multiple
Benzene	0.42	3.3E-6	Blood
Carbon tetrachloride	BSL		Adrenal gland
Chloroform	BSL		Liver
Ethylbenzene	BSL		Multiple
Radon	9.3	>1E-4	Lung
Tetrachloroethylene	BSL		Liver
TCE ages 0-<2 years	BSL		Multiple
TCE ages 2-<16 years	BSL		Multiple
TCE ages 16 years & older	BSL		Multiple
Vinyl chloride	BSL		Liver
Total Risk (any cancer, not including Radon)		**1.4E-5**	

House 12 N=2	Maximum Indoor Air ($\mu g/m^3$)	Excess Lifetime Cancer Risk	Most Sensitive Cancer Site
1,2-Dichloroethane	5.3	1.4E-4	Blood vessels
1,4-Dioxane	BSL		Multiple
Benzene	2.5	1.9E-5	Blood
Carbon tetrachloride	0.49	2.9E-6	Adrenal gland
Chloroform	BSL		Liver
Ethylbenzene	2.8	7.0E-6	Multiple
Radon	0.5	<1E-4	Lung
Tetrachloroethylene	BSL		Liver
TCE ages 0-<2 years	1.2	4.5E-7	Multiple
TCE ages 2-<16 years	1.2	1.5E-6	Multiple
TCE ages 16 years & older	1.2	3.8E-6	Multiple
Vinyl chloride	BSL		Liver
Total Risk (any cancer, not including Radon)		**1.7E-4**	

House 13 N=3	Maximum Indoor Air ($\mu g/m^3$)	Excess Lifetime Cancer Risk	Most Sensitive Cancer Site
1,2-Dichloroethane	0.19	4.9E-6	Blood vessels
1,4-Dioxane	1.3	6.5E-6	Multiple
Benzene	0.49	3.8E-6	Blood
Carbon tetrachloride	BSL		Adrenal gland
Chloroform	0.26	6.0E-6	Liver
Ethylbenzene	BSL		Multiple
Radon	11	>1E-4	Lung
Tetrachloroethylene	BSL		Liver
TCE ages 0-<2 years	0.016	6.0E-9	Multiple
TCE ages 2-<16 years	0.016	2.0E-8	Multiple
TCE ages 16 years & older	0.016	5.1E-8	Multiple
Vinyl chloride	BSL		Liver
		Liver Cancer Total = 6.0E-6	

Total Risk (any cancer, not including Radon)		**2.1E-5**	

House 14 N=2	Maximum Indoor Air (µg/m^3)	Excess Lifetime Cancer Risk	Most Sensitive Cancer Site
1,2-Dichloroethane	BSL		Blood vessels
1,4-Dioxane	1.6	8.0E-6	Multiple
Benzene	26	2.0E-4	Blood
Carbon tetrachloride	BSL		Adrenal gland
Chloroform	BSL		Liver
Ethylbenzene	30	7.5E-5	Multiple
Radon	No data		Lung
Tetrachloroethylene	BSL		Liver
TCE ages 0-<2 years	BSL		Multiple
TCE ages 2-<16 years	BSL		Multiple
TCE ages 16 years & older	BSL		Multiple
Vinyl chloride	BSL		Liver
Total Risk (any cancer, not including Radon)		**2.8E-4**	

House 15 N=3	Maximum Indoor Air (µg/m^3)	Excess Lifetime Cancer Risk	Most Sensitive Cancer Site
1,2-Dichloroethane	0.18	4.7E-6	Blood vessels
1,4-Dioxane	0.68	3.4E-6	Multiple
Benzene	1.7	1.3E-5	Blood
Carbon tetrachloride	0.60	3.6E-6	Adrenal gland
Chloroform	0.54	1.2E-5	Liver
Ethylbenzene	2.6	6.5E-6	Multiple
Radon	No data		Lung
Tetrachloroethylene	BSL		Liver
TCE ages 0-<2 years	BSL		Multiple
TCE ages 2-<16 years	BSL		Multiple
TCE ages 16 years & older	BSL		Multiple
Vinyl chloride	BSL		Liver
		Liver Cancer Total = 1.2E-5	

Total Risk (any cancer, not including Radon)		**4.3E-5**	

House 16 N=3	**Maximum Indoor Air (µg/m³)**	**Excess Lifetime Cancer Risk**	**Most Sensitive Cancer Site**
1,2-Dichloroethane	0.71	1.8E-5	Blood vessels
1,4-Dioxane	0.52	2.6E-6	Multiple
Benzene	1.40	1.1E-5	Blood
Carbon tetrachloride	BSL		Adrenal gland
Chloroform	12	2.8E-4	Liver
Ethylbenzene	2.4	6.0E-6	Multiple
Radon	No data		Lung
Tetrachloroethylene	BSL		Liver
TCE ages 0-<2 years	BSL		Multiple
TCE ages 2-<16 years	BSL		Multiple
TCE ages 16 years & older	BSL		Multiple
Vinyl chloride	BSL		Liver
		Liver Cancer Total = 2.8E-4	
Total Risk (any cancer, not including Radon)		**3.2E-4**	

House 17 N=2	**Maximum Indoor Air (µg/m³)**	**Excess Lifetime Cancer Risk**	**Most Sensitive Cancer Site**
1,2-Dichloroethane	0.17	4.4E-6	Blood vessels
1,4-Dioxane	0.26	1.3E-6	Multiple
Benzene	0.99	7.7E-6	Blood
Carbon tetrachloride	0.76	4.6E-6	Adrenal gland
Chloroform	0.36	8.3E-6	Liver
Ethylbenzene	BSL		Multiple
Radon	17.2	>1E-4	Lung
Tetrachloroethylene	BSL		Liver
TCE ages 0-<2 years	BSL		Multiple
TCE ages 2-<16 years	BSL		Multiple
TCE ages 16 years & older	BSL		Multiple
Vinyl chloride	BSL		Liver

		Liver Cancer Total = 8.3E-6	
Total Risk (any cancer, not including Radon)		**2.6E-5**	

House 18 N=3	**Maximum Indoor Air (µg/m^3)**	**Excess Lifetime Cancer Risk**	**Most Sensitive Cancer Site**
1,2-Dichloroethane	0.3	7.8E-6	Blood vessels
1,4-Dioxane	0.34	1.7E-6	Multiple
Benzene	0.34	2.7E-6	Blood
Carbon tetrachloride	0.6	3.6E-6	Adrenal gland
Chloroform	0.39	9.0E-6	Liver
Ethylbenzene	BSL		Multiple
Radon	20	>1E-4	Lung
Tetrachloroethylene	BSL		Liver
TCE ages 0-<2 years	BSL		Multiple
TCE ages 2-<16 years	BSL		Multiple
TCE ages 16 years & older	BSL		Multiple
Vinyl chloride	BSL		Liver
		Liver Cancer Total = 9.0E-6	
Total Risk (any cancer, not including Radon)		**2.5E-5**	

House 19 N=2	**Maximum Indoor Air (µg/m^3)**	**Excess Lifetime Cancer Risk**	**Most Sensitive Cancer Site**
1,2-Dichloroethane	0.42	1.1E-5	Blood vessels
1,4-Dioxane	0.26	1.3E-6	Multiple
Benzene	0.46	3.6E-6	Blood
Carbon tetrachloride	0.81	4.9E-6	Adrenal gland
Chloroform	0.34	7.8E-6	Liver
Ethylbenzene	1.4	3.5E-6	Multiple
Radon	34	>1E-4	Lung
Tetrachloroethylene	4.9	1.3E-6	Liver
TCE ages 0-<2 years	0.06	2.2E-8	Multiple
TCE ages 2-<16 years	0.06	7.3E-8	Multiple
TCE ages 16 years & older	0.06	1.9E-7	Multiple
Vinyl chloride	BSL		Liver

		Liver Cancer Total = 9.1E-6	
Total Risk (any cancer, not including Radon)		**3.4E-5**	

House 20 N=3	Maximum Indoor Air ($\mu g/m^3$)	Excess Lifetime Cancer Risk	Most Sensitive Cancer Site
1,2-Dichloroethane	350	9.1E-3	Blood vessels
1,4-Dioxane	0.62	3.1E-6	Multiple
Benzene	0.92	7.2E-6	Blood
Carbon tetrachloride	BSL		Adrenal gland
Chloroform	1.0	2.3E-5	Liver
Ethylbenzene	3.2	8.0E-6	Multiple
Radon	1.0	<1E-4	Lung
Tetrachloroethylene	BSL		Liver
TCE ages 0-<2 years	0.49	1.8E-7	Multiple
TCE ages 2-<16 years	0.49	6.0E-7	Multiple
TCE ages 16 years & older	0.49	1.5E-6	Multiple
Vinyl chloride	BSL		Liver
		Liver Cancer Total = 2.3E-5	
Total Risk (any cancer, not including Radon)		**9.2E-3**	

House 21 N=1	Maximum Indoor Air ($\mu g/m^3$)	Excess Lifetime Cancer Risk	Most Sensitive Cancer Site
1,2-Dichloroethane	1.5	3.9E-5	Blood vessels
1,4-Dioxane	BSL		Multiple
Benzene	0.94	7.3E-6	Blood
Carbon tetrachloride	0.64	3.8E-6	Adrenal gland
Chloroform	BSL		Liver
Ethylbenzene	1.3	3.3E-6	Multiple
Radon	9.3	>1E-4	Lung
Tetrachloroethylene	BSL		Liver
TCE ages 0-<2 years	BSL		Multiple
TCE ages 2-<16 years	BSL		Multiple

TCE ages 16 years & older	BSL		Multiple
Vinyl chloride	BSL		Liver
Total Risk (any cancer, not including Radon)		**5.3E-5**	

House 22 N=4	**Maximum Indoor Air ($\mu g/m^3$)**	**Excess Lifetime Cancer Risk**	**Most Sensitive Cancer Site**
1,2-Dichloroethane	0.26	6.8E-6	Blood vessels
1,4-Dioxane	0.71	3.6E-6	Multiple
Benzene	1.2	9.4E-6	Blood
Carbon tetrachloride	0.81	4.9E-6	Adrenal gland
Chloroform	0.72	1.6E-5	Liver
Ethylbenzene	BSL		Multiple
Radon	No data		Lung
Tetrachloroethylene	BSL		Liver
TCE ages 0-<2 years	0.5	1.9E-7	Multiple
TCE ages 2-<16 years	0.5	6.1E-7	Multiple
TCE ages 16 years & older	0.5	1.6E-6	Multiple
Vinyl chloride	BSL		Liver
		Liver Cancer Total = 1.6E-5	
Total Risk (any cancer, not including Radon)		**4.3E-5**	

House 23 N=2	**Maximum Indoor Air ($\mu g/m^3$)**	**Excess Lifetime Cancer Risk**	**Most Sensitive Cancer Site**
1,2-Dichloroethane	1.2	3.1E-5	Blood vessels
1,4-Dioxane	0.38	1.9E-6	Multiple
Benzene	0.88	6.9E-6	Blood
Carbon tetrachloride	0.78	4.7E-6	Adrenal gland
Chloroform	0.22	5.1E-6	Liver
Ethylbenzene	BSL		Multiple
Radon	9	>1E-4	Lung
Tetrachloroethylene	BSL		Liver
TCE ages 0-<2 years	0.13	4.9E-8	Multiple
TCE ages 2-<16 years	0.13	1.6E-7	Multiple

TCE ages 16 years & older	0.13	4.1E-7	Multiple
Vinyl chloride	BSL		Liver
		Liver Cancer Total = 5.1E-6	
Total Risk (any cancer, not including Radon)		**5.0E-5**	

House 24 N=2	Maximum Indoor Air (µg/m^3)	Excess Lifetime Cancer Risk	Most Sensitive Cancer Site
1,2-Dichloroethane	6.2	1.6E-4	Blood vessels
1,4-Dioxane	BSL		Multiple
Benzene	18	1.4E-4	Blood
Carbon tetrachloride	0.48	2.9E-6	Adrenal gland
Chloroform	BSL		Liver
Ethylbenzene	23	5.8E-5	Multiple
Radon	30	>1E-4	Lung
Tetrachloroethylene	BSL		Liver
TCE ages 0-<2 years	BSL		Multiple
TCE ages 2-<16 years	BSL		Multiple
TCE ages 16 years & older	BSL		Multiple
Vinyl chloride	BSL		Liver
Total Risk (any cancer, not including Radon)		**3.6E-4**	

House 25 N=3	Maximum Indoor Air (µg/m^3)	Excess Lifetime Cancer Risk	Most Sensitive Cancer Site
1,2-Dichloroethane	3.2	8.3E-5	Blood vessels
1,4-Dioxane	BSL		Multiple
Benzene	13	1.1E-4	Blood
Carbon tetrachloride	0.78	4.7E-6	Adrenal gland
Chloroform	BSL		Liver
Ethylbenzene	18	4.5E-5	Multiple
Radon	3.5	>1E-4	Lung
Tetrachloroethylene	BSL		Liver
TCE ages 0-<2 years	BSL		Multiple
TCE ages 2-<16 years	BSL		Multiple

TCE ages 16 years & older	BSL		Multiple
Vinyl chloride	BSL		Liver
Total Risk (any cancer, not including Radon)		**2.4E-4**	

House 26 N=1	**Maximum Indoor Air (µg/m³)**	**Excess Lifetime Cancer Risk**	**Most Sensitive Cancer Site**
1,2-Dichloroethane	BSL		Blood vessels
1,4-Dioxane	BSL		Multiple
Benzene	BSL		Blood
Carbon tetrachloride	BSL		Adrenal gland
Chloroform	BSL		Liver
Ethylbenzene	5.9	1.5E-5	Multiple
Radon	10.3	>1E-4	Lung
Tetrachloroethylene	BSL		Liver
TCE ages 0-<2 years	BSL		Multiple
TCE ages 2-<16 years	BSL		Multiple
TCE ages 16 years & older	BSL		Multiple
Vinyl chloride	BSL		Liver
Total Risk (any cancer, not including Radon)		**1.5E-5**	

House 27 N=2	**Maximum Indoor Air (µg/m³)**	**Excess Lifetime Cancer Risk**	**Most Sensitive Cancer Site**
1,2-Dichloroethane	No data		Blood vessels
1,4-Dioxane	No data		Multiple
Benzene	No data		Blood
Carbon tetrachloride	No data		Adrenal gland
Chloroform	No data		Liver
Ethylbenzene	No data		Multiple
Radon	19.7	>1E-4	Lung
Tetrachloroethylene	No data		Liver
TCE ages 0-<2 years	No data		Multiple

TCE ages 2-<16 years	No data		Multiple
TCE ages 16 years & older	No data		Multiple
Vinyl chloride	No data		Liver
Total Risk (any cancer, not including Radon)			

House 28 N=3	**Maximum Indoor Air ($\mu g/m^3$)**	**Excess Lifetime Cancer Risk**	**Most Sensitive Cancer Site**
1,2-Dichloroethane	0.17	4.4E-6	Blood vessels
1,4-Dioxane	0.69	3.5E-6	Multiple
Benzene	0.65	5.1E-6	Blood
Carbon tetrachloride	0.48	2.9E-6	Adrenal gland
Chloroform	0.52	1.2E-5	Liver
Ethylbenzene	1.3	3.3E-6	Multiple
Radon	No data		Lung
Tetrachloroethylene	BSL		Liver
TCE ages 0-<2 years	0.063	2.4E-8	Multiple
TCE ages 2-<16 years	0.063	7.7E-8	Multiple
TCE ages 16 years & older	0.063	2.0E-7	Multiple
Vinyl chloride	BSL		Liver
		Liver Cancer Total = 1.2E-5	
Total Risk (any cancer, not including Radon)		**3.2E-5**	

House 29 N=5	**Maximum Indoor Air ($\mu g/m^3$)**	**Excess Lifetime Cancer Risk**	**Most Sensitive Cancer Site**
1,2-Dichloroethane	0.39	1.0E-5	Blood vessels
1,4-Dioxane	0.92	4.6E-6	Multiple
Benzene	1.7	1.3E-5	Blood
Carbon tetrachloride	0.54	3.2E-6	Adrenal gland
Chloroform	0.42	9.7E-6	Liver
Ethylbenzene	BSL		Multiple
Radon	7.8	>1E-4	Lung
Tetrachloroethylene	BSL		Liver
TCE ages 0-<2 years	0.57	2.1E-7	Multiple

TCE ages 2-<16 years	0.57	7.0E-7	Multiple
TCE ages 16 years & older	0.57	1.8E-6	Multiple
Vinyl chloride	BSL		Liver
		Liver Cancer Total = 9.7E-6	
Total Risk (any cancer, not including Radon)		**4.2E-5**	

House 30 N=3	Maximum Indoor Air (μg/m^3)	Excess Lifetime Cancer Risk	Most Sensitive Cancer Site
1,2-Dichloroethane	0.11	2.9E-6	Blood vessels
1,4-Dioxane	1.8	9.0E-6	Multiple
Benzene	BSL		Blood
Carbon tetrachloride	BSL		Adrenal gland
Chloroform	0.24	5.5E-6	Liver
Ethylbenzene	2.2	5.5E-6	Multiple
Radon	15.5	>1E-4	Lung
Tetrachloroethylene	BSL		Liver
TCE ages 0-<2 years	0.02	1.2E-9	Multiple
TCE ages 2-<16 years	0.02	3.8E-8	Multiple
TCE ages 16 years & older	0.02	9.8E-8	Multiple
Vinyl chloride	BSL		Liver
		Liver Cancer Total = 5.5E-6	
Total Risk (any cancer, not including Radon)		**2.4E-5**	

House 31 N=3	Maximum Indoor Air (μg/m^3)	Excess Lifetime Cancer Risk	Most Sensitive Cancer Site
1,2-Dichloroethane	7.3	1.9E-4	Blood vessels
1,4-Dioxane	0.87	4.4E-6	Multiple
Benzene	1.3	1.0E-5	Blood
Carbon tetrachloride	BSL		Adrenal gland
Chloroform	0.55	1.3E-5	Liver
Ethylbenzene	1.6	4.0E-6	Multiple
Radon	No data		Lung
Tetrachloroethylene	BSL		Liver
TCE ages 0-<2 years	3.1	1.2E-6	Multiple

TCE ages 2-<16 years	3.1	3.8E-6	Multiple
TCE ages 16 years & older	3.1	9.8E-6	Multiple
Vinyl chloride	BSL		Liver
		Liver Cancer Total = 1.3E-5	
Total Risk (any cancer, not including Radon)		**2.4E-5**	
House 32 N=3	**Maximum Indoor Air (µg/m^3)**	**Excess Lifetime Cancer Risk**	**Most Sensitive Cancer Site**
1,2-Dichloroethane	BSL		Blood vessels
1,4-Dioxane	0.81	4.1E-6	Multiple
Benzene	BSL		Blood
Carbon tetrachloride	BSL		Adrenal gland
Chloroform	1.4	3.2E-5	Liver
Ethylbenzene	BSL		Multiple
Radon	No data		Lung
Tetrachloroethylene	BSL		Liver
TCE ages 0-<2 years	BSL		Multiple
TCE ages 2-<16 years	BSL		Multiple
TCE ages 16 years & older	BSL		Multiple
Vinyl chloride	BSL		Liver
		Liver Cancer Total = 3.2E-5	
Total Risk (any cancer, not including Radon)		**3.6E-5**	

House 33 N=2	**Maximum Indoor Air (µg/m^3)**	**Excess Lifetime Cancer Risk**	**Most Sensitive Cancer Site**
1,2-Dichloroethane	0.35	9.1E-6	Blood vessels
1,4-Dioxane	BSL		Multiple
Benzene	16	1.2E-4	Blood
Carbon tetrachloride	BSL		Adrenal gland
Chloroform	BSL		Liver
Ethylbenzene	23	5.8E-5	Multiple
Radon	8.8	>1E-4	Lung
Tetrachloroethylene	15	3.9E-6	Liver
TCE ages 0-<2 years	BSL		Multiple
TCE ages 2-<16 years	BSL		Multiple

TCE ages 16 years & older	BSL		Multiple
Vinyl chloride	BSL		Liver
		Liver Cancer Total = 3.9E-6	
Total Risk (any cancer, not including Radon)		**1.9E-4**	

BSL: Below screening level. May also be below limit of detection / limit of quantitation LOD/LOQ.
No data: house was not sampled for this contaminant or sampling not reported.
N=number of samples taken at each house. Maximum air concentration is used to calculate excess cancer risk estimates since not enough samples taken at most houses to generate reliable central tendency for each house.

Appendix B. Cancer Calculations

Excess lifetime cancer risk (ELCR) was calculated by the following equation for **non-mutagenic carcinogens:**

$IUR * C_{air} = ELCR$

where IUR = Inhalation unit risk with units $(\mu g/m^3)^{-1}$

C_{air} = Maximum detected concentration or detection limit for non-detects in air with units $\mu g/m^3$

ELCR was calculated by the following equation for the **mutagenic carcinogen TCE**:

$IUR * C_{air} * ADAF = ELCR$

where ADAF = Age dependent adjustment factor for mutagenic carcinogens

Inhalation Unit Risk (IURs), $(\mu g/m^3)^{-1}$

1,2-Dichloroethane	2.6E-5
1,4-Dioxane	5.0E-6
Benzene	7.8E-6
Carbon tetrachloride	6.0E-6
Chloroform	2.3E-5
Ethylbenzene^	2.5E-6
Radon	NA
Tetrachloroethylene	2.6E-7
TCE ages 0-<2 years*	3.7E-7
TCE ages 2-<16 years*	1.2E-6
TCE ages 16 years & older*	3.2E-6
Vinyl chloride	4.4E-6

^Mid-Atlantic EPA value.

*Includes ADAF (0-2yrs=10, 2-16yrs=3, 16+=1). Covers additive risk of kidney, liver and NHL cancers. ADAF only applied to mutagenic mode of action for kidney cancer.

Greetings,

You are receiving a document from the Agency for Toxic Substances and Disease Registry (ATSDR). We are very interested in your opinions about the document you received. We ask that you please take a moment now to complete the following ten question survey. You can access the survey by clicking on the link below.

Completing the survey should take less than 5 minutes of your time. If possible, please provide your responses within the next two weeks. All information that you provide will remain confidential.

The responses to the survey will help ATSDR determine if we are providing useful and meaningful information to you. ATSDR greatly appreciates your assistance as it is vital to our ability to provide optimal public health information.

https://www.surveymonkey.com/r/ATSDRDocumentSatisfaction

LCDR Donna K. Chaney, MBAHCM
U.S. Public Health Service
4770 Buford Highway N.E. MS-F59
Atlanta, GA 30341-3717
(W) 770.488.0713
(F) 770.488.1542