Health Consultation

Public Health Implications of Exposures to Indoor Air Contaminants

NORTH BRUNSWICK TOWNSHIP HIGH SCHOOL
NORTH BRUNSWICK, MIDDLESEX COUNTY, NEW JERSEY

EPA FACILITY ID: NJD103805370

Prepared by:
New Jersey Department of Health

MARCH 24, 2017

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

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.

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Summary

Introduction	Under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR), the New Jersey Department of Health (NJDOH) prepared this health consultation to evaluate the public health implications of indoor air data collected at the North Brunswick Township High School (NBTHS) site on Raider Road in North Brunswick, Middlesex County. NJDOH's and ATSDR's top priority at this site is to ensure that the occupants of the high school and surrounding community have the best information possible to safeguard their health. The NJDOH previously completed a public health assessment and three health consultations for this site. This health consultation evaluates indoor air data collected at the high school and nearby residences between April 2004 and June 2015. In addition, this health consultation was prepared to include the recently updated toxicity information for trichloroethylene (TCE), the primary contaminant of concern at this site.
Conclusions	After evaluating environmental data associated with the vapor intrusion investigation between April 2004 and June 2015, the NJDOH and ATSDR reached three conclusions regarding exposures to residents, students, and staff at the North Brunswick Township High School Site:
Conclusion 1	*The NJDOH and ATSDR conclude that past exposures to TCE in seven homes might have harmed people's health.*
Basis for Conclusion 1	Past exposure to elevated levels of TCE in seven homes were approaching levels of health concern for fetal heart malformations, kidney, and immune system damage to residents of these homes. Residents in three of these homes (residences G, H, and K) also were found to have an increased risk for cancer, based on the cumulative risk for site-related and non-site–related indoor air contaminants. Mitigation measures have been taken in six of these homes (residents A, C, D, G, H, and I) to eliminate current and future exposures to sub-surface contaminants. Post-mitigation levels of TCE in residences C and D were elevated during one sampling event. These elevated levels were attributed to an indoor source. Residents of one home (residence K) have refused mitigation measures.
Conclusion 2	*The NJDOH and ATSDR conclude that current and future exposures to TCE in one home might harm people's health.*

Basis for Conclusion 2	Of the seven homes with elevated TCE levels, residents of one home (residence K) have refused mitigation measures and therefore might currently be exposed to TCE and other contaminants through vapor intrusion. The most recent data for this home from June 2015 indicate that at that time, adverse non-cancer health effects would be unlikely. However, no current data are available to determine whether TCE levels have increased since the last sampling event. The most recent sampling event indicates TCE levels are approaching levels of health concern.
Recommended Next Steps	The NJDOH and ATSDR recommend that the Township of North Brunswick encourage residence K to have mitigation measures put in place to prevent current and future exposures to site contaminants through vapor intrusion.
Conclusion 3	*The NJDOH and ATSDR conclude that past exposure to volatile organic chemicals at North Brunswick Township High School and four nearby residences was not likely to harm people's health.*
Basis for Conclusion 3	Based on the data reviewed by the NJDOH, the levels of indoor air contaminants at the high school were below health-based comparison values for non-cancer health effects and cancer risks were determined to be low for students and faculty. One residence (residence E) had TCE levels slightly above its non-cancer health-based comparison value. Two residences (residences B and J) had benzene levels above its non-cancer health-based comparison value. Residence J also had toluene above its non-cancer health-based comparison value. However, non-cancer health effects are not likely, based on available toxicological literature, and the cancer risks for these homes were determined to be low. Levels at the remaining home (residence F) did not exceed health based comparison values for non-cancer health effects and the cancer risk for this home was also determined to be low.
Recommended Next Steps	The NJDOH and ATSDR recommend that the Township of North Brunswick • continue to monitor and evaluate the extent of groundwater contamination, • conduct indoor air sampling as appropriate to ensure that additional homes have not been affected by vapor intrusion from the site, and • ensure that mitigation measures taken at the school and nearby residences continue to prevent vapor intrusion of TCE and other sub-surface contaminants.
For more Information	Copies of this health consultation will be provided to North Brunswick Township and to affected residents. It will be available at the township library and on the Internet. Questions about this health consultation should be directed to the NJDOH at (609) 826-4984.

Statement of Issues

In June 2004, North Brunswick Township officials and the New Jersey Department of Environmental Protection (NJDEP) asked the New Jersey Department of Health (NJDOH) for help in the interpretation and public health evaluation of site-related contamination detected during ongoing investigations for the North Brunswick Township High School site. Through a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR), the NJDOH reviewed indoor air data to determine the public health implications associated with contamination found at the high school and for the surrounding residential area and prepared this health consultation.

Previous documents prepared by the NJDOH have evaluated contaminants found in various media (i.e. soil, indoor air, groundwater) [NJDOH 2009]. This health consultation evaluates indoor air data collected at the high school and surrounding residential area between April 2004 and June 2015. The primary contaminant of concern at this site is trichloroethylene (TCE). Therefore, this document was prepared to evaluate indoor air data in comparison with the updated toxicity information for TCE [EPA 2011a].

Background and Site History

North Brunswick Township High School (NBTHS) is a public school located on Raider Road in North Brunswick Township, Middlesex County, New Jersey (**Figure 1**). The high school is bordered by residential areas to the north and south, undeveloped woodland to the east, and Veteran's Park to the west (**Figure 2**). The January 2009 public health assessment and the September 2009 health consultation for this site [NJDOH 2009] include background information and details about past remedial investigations and actions.

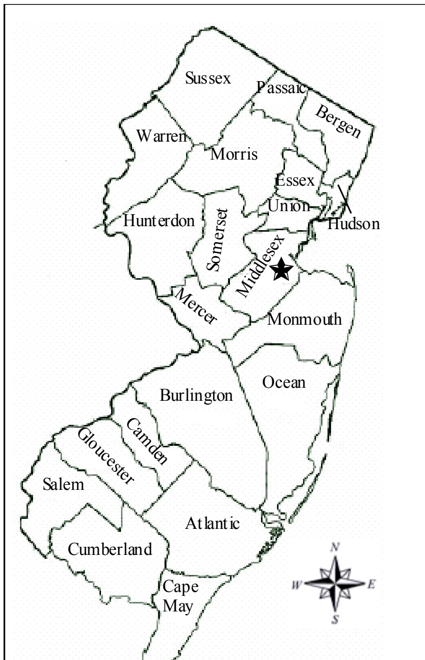

Figure 1: Location of North Brunswick High School

During a July 2003 excavation for a major renovation and expansion project at NBTHS, debris and fill material, including hazardous waste, were discovered in the soil. Construction activities at the school were suspended and NJDEP was notified. An engineering services firm hired on behalf of the North Brunswick Township Board of Education and the Township of North Brunswick began a site investigation in the fall of 2003. Findings indicated the presence of arsenic in the surface soil of three nearby residential properties above the NJDEP residential direct contact soil cleanup criteria [NJDOH 2005]. At each of those three residences, water samples from basement sumps were collected and analyzed for volatile organic compounds. Indoor air samples were collected and analyzed for volatile organic compounds. TCE was detected in the sumps of two residences, and one residence had elevated TCE in the indoor air. After remediation at all three residences, indoor air sampling indicated no detectable TCE in the indoor air.

Groundwater Investigation

Groundwater samples were collected from 2004 through 2016 from a total of 22 groundwater monitoring wells on the NBTHS property, the Public Service Electric and Gas easement, Veteran's Park, and the nearby residential area south of the site (**Figure 2**). Samples were collected quarterly from 2004 through 2010, biannually in 2011, and annually since 2012. Based on the most recent sampling data, concentrations of contaminants in excess of NJDEP's groundwater quality standards [Kleinfelder 2016] have been detected in samples from the 24 monitoring well network for the site. These contaminants include TCE, 1,2-dichloroethane, vinyl chloride, 1,1-dichloroethene, and cis-1,2-dichloroethene.

The predominant contaminant in groundwater at this site is TCE, which ranged in concentrations from non-detect to 4,100 micrograms of TCE per liter of water (µg/L) in groundwater samples from March 2016. Concentrations of other contaminants included the following:

- 1,2-dichloroethane — non-detect to 20 µg/L
- vinyl chloride — non-detect to 9.6 µg/L
- 1,1-dichloroethene — non-detect to 2.1 µg/L
- cis-1,2-dichloroethene — non-detect to 230 µg/L

The groundwater plume containing the highest TCE concentrations is located in the area between the new high school building addition (southwest perimeter) and the residential area to the south of the high school [Kleinfelder 2016]. Groundwater flow is generally toward the east-southeast in the direction of the residential area. Concentrations of TCE in monitoring wells in the residential area on Plains Gap Road range from non-detect to 280 µg/L (**Figure 3**). All homes within and immediately surrounding the area of the groundwater plume were sampled. According to the most recent groundwater monitoring report from March 2016, the groundwater plume is relatively stable [Kleinfelder 2016].

In addition to the monitoring wells, groundwater was sampled from a sump near the orchestra pit within the auditorium of the new building addition of NBTHS. A granular activated carbon bed treatment system has been installed to treat low concentrations of TCE in water within the sump. Sump water is sampled monthly with the treated effluent discharged to the sewer system by permit with the Middlesex County Utilities Authority [G. Hunsberger, Kleinfelder, personal communication, May 2007]. The maximum daily permitted discharge level is 2,130 µg/L [G. Hunsberger, Kleinfelder, email correspondence, August 2016].

Vapor Intrusion Investigation

This health consultation evaluates all indoor air samples collected at NBTHS from April 2004 through December 2010. It also evaluates all indoor air data collected from the residential area south of the site from April 2004 through June 2015. Sampling data previously collected from April 2004 through April 2009 were evaluated in the January 2009 public health assessment and the September 2009 health consultation prepared by the NJDOH [NJDOH 2009].

The U.S. Environmental Protection Agency (EPA) released updated toxicity information on TCE in September 2011 [EPA 2011a]. Consequently, this health consultation evaluated additional TCE sampling data from September 2009 through June 2015, along with historical indoor air data (2004–2010).

Between April 2004 and December 2010, indoor air samples were collected in several areas of the high school. These areas included

- the student's common area,
- student and faculty cafeterias,
- the guidance office,
- classrooms,
- the auditorium of the new addition,
- the groundwater treatment room (also known as the scene shop), and
- the orchestra pit sump area.

In 2004, a vapor intrusion investigation was initiated with three residences within the area of known groundwater contamination. This was later expanded to 11 residences (identified as residences A through K) in 2010. The most recent indoor air samples for the residences were collected in June 2015.

Remedial and Cleanup Actions

Groundwater Remediation Efforts

Groundwater will be remediated through modern technology methods after further investigation. A groundwater classification exception area will be established through NJDEP to address remaining TCE concentrations in groundwater and reduce those to levels that are considered low enough not to cause a threat to public health. A classification exception area notifies the public that there is ground water pollution in a specific area from a contaminated site.

NBTHS Property

TCE was detected at the NJDEP residential indoor air screening level of 3 micrograms of TCE per cubic meter of air ($\mu g/m^3$) in June 2007 at the orchestra sump pit. A blower was installed in July 2007 to the existing passive radon mitigation system to help remove TCE vapors below the concrete slab of the auditorium. TCE has not been detected in indoor air samples since the blower was installed, including the last round of sampling in December 2010. A remediation system was installed to treat sump water within the orchestra pit before discharge to the county sewer system [G. Hunsberger, Kleinfelder, personal communication, April 2009]. During construction of the new building addition, a vapor suppression system also was installed to help prevent the migration of subsurface contaminant vapors into the building [G. Hunsberger, Kleinfelder, personal communication, May 2007]. Specifically, a vapor retarder and a passive radon mitigation system were installed during construction. After construction, a blower was added to the radon mitigation system. In addition, the heating, ventilation, and air conditioning

(HVAC) system was adjusted to maintain positive air pressure in the building to limit vapors from entering the orchestra pit [G. Hunsberger, Kleinfelder, email correspondence, August 2016].

Residential Area

Indoor air samples were collected from 11 residential properties between April 2004 and June 2015. Samples were collected from the basement and first floor of residences A through K. With the exception of residence K, mitigation measures at these homes included covering and sealing the basement sump pump and installing an exhaust fan on the existing radon mitigation system. After these remediation activities, additional air sampling was conducted at the residences. The results indicated that TCE was either not detected or detected below the NJDEP residential indoor air screening level of 3 $\mu g/m^3$.

Table 1 lists the TCE levels before and after remedial measures were taken at the residences. Mitigation measures were completed at the residences between April 2004 and September 2009. Four of the homes had mitigation measures completed as a precaution due to the presence of indoor air impacts from vapor intrusion at nearby homes. Residences C and D had TCE detected in post-remediation samples above the NJDEP residential indoor air screening level. These exceedances were due to indoor sources within these homes [G. Hunsberger, email correspondence, August 2016]. These homes were re-sampled within 60 days and TCE was not detected. Subsequent samples collected at residence C did not detect any TCE. However, TCE levels increased to 0.59 $\mu g/m^3$ in residence D during subsequent sampling events. Post mitigation samples were obtained for six homes (A, B, C, D, E, and H) to account for seasonal variability.

Occupants of one residence (residence K) have refused mitigation measures. For this residence, indoor air samples were collected five times between June 2009 and June 2015. Levels of TCE in this home ranged from 1.6 $\mu g/m^3$ to 13 $\mu g/m^3$. The TCE level during the most recent sampling event at this property in June 2015 was 4.7 $\mu g/m^3$.

Table 1. Pre-Mitigation and Post-Mitigation TCE Summary (April 2004–June 2015)

Residence	Pre-Mitigation			Post-Mitigation			Mitigation completed
	Sample date	Number of samples	TCE concentration range ($\mu g/m^3$)	Sample date	Number of samples	TCE concentration range ($\mu g/m^3$)	
A	April 2004	2	5.4–12	June 2004 – June 2015	8	ND–1.6	
B*	NA	0	NA	June 2004 – June 2010	7	ND–0.42	April 2004
C*	NA	0	NA	June 2004 – March 2015†	9	ND–9.7	
D	December 2006	1	2.2	June 2007 – March 2015†	7	ND–6.5	
E	December 2006	1	2.4	June 2007 – March 2015	5	ND–2.0	June 2007
F*	December 2006	1	ND	NA	0	NA	
G	March 2009 – June 2009	2	3.5–13	September 2009 – August 2013	3	ND	
H	March 2009 – June 2009	2	7.0–21	September 2009 – June 2015	4	0.31–1.8	September 2009
I	March 2009 – June 2009	2	4.8–10	September 2009 – June 2015	4	0.23–1.2	
J*	April 2009	1	ND	NA	0	NA	
K‡	June 2009 – June 2015	5	1.6–13	NA	0	NA	NA

NA = not analyzed; ND = not detected; TCE = trichloroethylene

***** Mitigation done as a precaution because nearby properties had TCE in indoor air from vapor intrusion.

† When TCE post-mitigation concentrations were above the New Jersey Department of Environmental Protection's residential indoor air screening level (3 $\mu g/m^3$), additional sampling was conducted within 60 days to confirm the readings. Confirmatory sampling indicated TCE concentrations were reduced from 9.7 $\mu g/m^3$ to ND at residence C and from 6.5 $\mu g/m^3$ to ND at residence D. Post-mitigation TCE levels that exceeded the screening levels resulted from indoor sources within these homes.

‡ Residence K refused mitigation measures.

Community Health Concerns

In September 2009, the ATSDR and NJDOH released a health consultation evaluating cancer incidence data to address cancer concerns expressed by the community [NJDOH 2009]. Public meetings were held in December 2008 and May 2009 to inform residents of environmental investigation data. Residents also learned about future remedial actions to address TCE contamination found in indoor air within residences and TCE contamination within groundwater. The NJDOH provided information to address health concerns regarding exposure to TCE contamination in indoor air detected at the residences at that time. The NJDOH is not aware of any current community concerns since these public meetings were held.

Prior NJDOH/ATSDR Involvement

The NJDOH has previously evaluated the public health implications from exposures at the North Brunswick Township site. These reports include a public health assessment released in January 2009 and three health consultations, one released in August 2005 and two in September 2009. These documents evaluate the public health implications from exposures to various environmental media, including soil and indoor air on the school property and surrounding properties. One of the two health consultations released in September 2009 specifically evaluated cancer incidence for the area in response to community concerns [NJDOH 2009].

Demographics

According to the 2010 U.S. census data, about 14,730 people live within 1 mile of the NBTHS site (**see Appendix A** for demographic information).

Environmental Contamination

An evaluation of site-related environmental contamination follows a two-tiered approach:

1) a screening analysis and
2) an in-depth analysis to determine public health implications of site-specific exposures.

First, maximum concentrations of detected substances are compared with environmental media–specific health-based guideline comparison values. If concentrations exceed the environmental comparison value, these substances, referred to as contaminants of concern, are selected for further evaluation. Contaminant levels above environmental comparison values do not mean that adverse health effects are likely, but that further evaluation is needed. After exposure doses are estimated, they are further evaluated to determine the likelihood of adverse health effects.

Environmental Comparison Value Guidelines

A number of environmental comparison values are available for screening environmental contaminants to identify contaminants of concern. These include the ATSDR environmental media evaluation guides (EMEGs) and reference media evaluation guides (RMEGs). EMEGs are estimated contaminant concentrations that are not expected to result in adverse non-carcinogenic health effects. RMEGs represent the concentration in water or soil at which daily human exposure is unlikely to result in adverse non-carcinogenic effects. If the substance is a known or a probable carcinogen, ATSDR's cancer risk evaluation guides (CREGs) are also considered as comparison values. CREGs are estimated contaminant concentrations that would be expected to cause no more than one excess cancer in a million (10^{-6}) persons exposed over their lifetime (78 years). If ATSDR comparison values are not available, NJDEP or EPA values are used.

Substances exceeding applicable environmental comparison values are identified as contaminants of concern. These are evaluated further to determine whether these contaminants pose a health threat to exposed or potentially exposed populations. If environmental comparison values are unavailable, these contaminants are selected for further evaluation.

Indoor Air – North Brunswick Township High School

In December 2010, indoor air samples were collected over a 24-hour period using SUMMA® canisters. Samples from three locations at the school were analyzed for volatile organic compounds (VOCs) using EPA Method TO-15 [EPA 1999]. One canister was placed in the orchestra pit and another canister was placed in the room that houses the sump water treatment units (the scene shop). One other canister was placed outside near the loading dock to measure contaminant levels in the surrounding air.

In addition to TCE, benzene was also detected above its comparison value in the high school indoor air samples. However, benzene has not been detected in the groundwater above its vapor intrusion groundwater screening level. Therefore, the source of benzene in air samples is likely background sources within the school rather than vapor intrusion. Typical background sources of benzene include gasoline-powered equipment, cigarette smoke, scented candles, scatter rugs, and carpet glue. **Table 2** summarizes the compounds detected in the indoor air of the high school throughout the sampling period (April 2004 through December 2010).

Table 2. Compounds Detected in Indoor Air at North Brunswick Township High School

Contaminant	Number of samples	Number of detections	Concentration (μg/m^3)			Contaminant of concern
			Minimum	Maximum	Comparison value	
Benzene *	20	12	ND	2	0.13 (CREG)	**Yes**
Tetrachloroethylene	20	3	ND	3	3.8 (CREG)	No
Toluene	20	20	0.57	6	300 (EMEG)	No
Trichloroethylene	42	3	ND	3	0.24 (CREG)	**Yes**
Total xylenes	20	18	ND	57	220 (EMEG)	No

ND = not detected; CREG = ATSDR cancer risk evaluation guide; EMEG = ATSDR environmental media evaluation guide; * = Benzene detections are likely due to background sources and not vapor intrusion

Indoor Air – Residential Properties

Indoor air samples were collected over a 24-hour period using SUMMA® canisters in the basement and on the first floor of 11 residences between April 2004 and June 2015 and analyzed for VOCs using EPA Method TO-15. Each residence was sampled at least once. **Table 3** shows the compounds detected in the indoor air of these homes during that period. Two homes (residences F and J) were sampled once and had no TCE detected. These two homes had mitigation measures taken, but have not been re-sampled to evaluate the effectiveness of those measures and to account for seasonal variability.

Table 3. Compounds Detected in Indoor Air – Residential Properties

Contaminant	Number of samples	Number of detections	Concentration (µg/m³)			Number of residences above comparison value	Contaminant of concern
			Minimum	Maximum	Comparison value		
Benzene *	60	58	ND	35	0.13 (CREG)	11	**Yes**
1,2-Dichloroethane	59	14	ND	17	0.038 (CREG)	6	**Yes**
trans-1,2-Dichloroethylene	61	2	ND	0.67	63 (NJDEP)	0	No
cis-1,2-Dichloroethylene	60	2	ND	4.4	No value	2	**Yes**
Methyl tert butyl ether	54	9	ND	123	2,500 (EMEG)	0	No
Tetrachloroethylene (PCE) *	61	24	ND	13	3.8 (CREG)	1	**Yes**
Toluene *	59	56	ND	648	300 (EMEG)	1	**Yes**
Trichloroethylene (TCE)	64	40	ND	21	0.24 (CREG)	9	**Yes**
Total xylenes *	59	56	ND	244	220 (EMEG)	1	**Yes**

ND = not detected; CREG = ATSDR cancer reference evaluation guide; EMEG = ATSDR environmental media evaluation guide; NJDEP = New Jersey Department of Environmental Protection residential indoor air screening level; * = These contaminants are likely due to background sources and not vapor intrusion

In addition to TCE, the following compounds also exceeded their respective comparison values:

- benzene,
- 1,2-dichloroethane,
- tetrachloroethylene (PCE),
- toluene, and
- total xylenes.

Benzene, toluene, and xylenes were not detected in groundwater above their respective NJDEP vapor intrusion groundwater screening levels. They likely resulted from background sources within the home, not from vapor intrusion. These contaminants are typically associated with gasoline-powered equipment, automobile exhaust, scented candles, and cigarette smoke. PCE, cis-1,2-dichloroethylene, and 1,2-dichloroethane have been detected in past groundwater samples from site monitoring wells near the southwest corner of the NBTHS new addition.

According to the health consultation prepared by the NJDOH in September 2009, PCE is likely related to background sources within the home and not from vapor intrusion. This is based on data from sump water samples collected during 2004 through 2006. The samples showed no PCE detections and potential sources of PCE were identified in the homes during the sampling [NJDOH 2009]. We do not have enough information to conclude whether the presence of 1,2-dichloroethane and cis-1,2-dichloroethylene in the indoor air of some of the homes might be from background contamination or from vapor intrusion. These compounds have not been found consistently in groundwater and indoor air. It is important for residents to identify the sources of background contaminants to reduce indoor air levels of these substances as much as possible. **Appendix B** has information about typical sources of indoor air contaminants.

Discussion

The NJDOH and ATSDR assess whether a health hazard exists by determining whether there is a completed exposure pathway from a contaminant source to people who could be exposed to that contaminant. It is then determined whether exposures to the contaminants are high enough to be of health concern. Site-specific exposure doses can be calculated and compared with health guideline comparison values.

Assessment Methodology

An exposure pathway is a series of steps starting with the release of a contaminant in environmental media and ending with contact with the human body. A completed exposure pathway consists of five elements:

1. Source of contamination
2. Environmental media and transport mechanisms
3. Point of exposure
4. Route of exposure
5. Receptor population (people who could come into contact with hazardous substances)

Generally, the ATSDR considers three exposure categories:

1. Completed exposure pathways — all five elements of a pathway are present
2. Potential exposure pathways — one or more of the elements might not be present, but information is insufficient to eliminate or exclude the element
3. Eliminated exposure pathways — a receptor population does not come into contact with contaminated media

Exposure pathways are used to evaluate specific ways in which people were, are, or will be exposed to environmental contamination in the past, present, and future. The exposed populations identified for this site include students and faculty of the high school and children and adults associated with the 11 nearby residences. **Table 4** shows the exposure pathways evaluated for site-related contaminants.

Table 4. Exposure Pathways Evaluated in North Brunswick Township, New Jersey

Pathway	Exposure Pathway Elements				Pathway classification
	Environmental medium	Route of exposure	Location	Exposed population	
Vapor intrusion	Indoor air	Inhalation	North Brunswick Township High School	Students/Faculty	• Past – Completed • Current & Future – Eliminated*
			8 homes	Residents (child/adult)	• Past – Completed • Current & Future – Eliminated†
			1 home	Residents (child/adult)	• Past, Current & Future - Completed‡
			2 homes	Residents (child/adult)	• Past – Potential • Current and Future – Eliminated§

* The June 2007 mitigation measures eliminated current, and future exposures to students and faculty from site contaminants.
† The April 2004, June 2007, and September 2009 mitigation measures eliminated current and future exposures to adults and children from site contaminants.
‡ Past, current, and future exposure pathways are considered completed for one residence, based on 2009–2015 sampling data. This residence (residence K) refuses mitigation.
§ The potential for current and future vapor intrusion has been interrupted by mitigation measures taken as precautions, even though trichloroethylene (TCE) was not found in the indoor air of these homes.

Completed Exposure Pathways

Inhalation of contaminants of concern in high school indoor air. Because students and staff at the high school might have breathed air contaminated with TCE that entered the building through vapor intrusion, that past exposure pathway is complete. The exposure pathway involves TCE vapors moving up through contaminated groundwater and entering the school building. Installation of a blower on the existing radon mitigation system in June 2007 and a vapor suppression system for the new building addition have eliminated current and future exposures.

Inhalation of contaminants of concern in residential indoor air. Of the 11 homes sampled, nine had a past completed exposure pathway for inhalation of indoor air contaminated with TCE, possibly resulting from vapor intrusion, based on groundwater data. The exposure pathway involves vapors moving up from contaminated groundwater and entering the interior of these residences. Mitigation measures were put in place between April 2004 and September 2009. Those have eliminated current and future exposures to site-related contaminants from vapor intrusion at eight of these residences. The occupants of one residence (residence K) refused mitigation measures. Therefore, for that residence, a completed pathway exists for past, current, and future exposures to TCE from contaminated groundwater.

Potential Exposure Pathways

Inhalation of contaminants of concern in indoor air at residential properties. Two homes had a past potential exposure pathway for vapor intrusion. Although the indoor air was not affected at the time of sampling, groundwater data indicate there was a potential for contaminants of concern to affect the indoor air of these homes. Remedial measures were taken at these homes as a precaution to prevent current and future vapor intrusion. Therefore, current and future exposure to subsurface contaminants of concern has been eliminated.

Public Health Implications of Completed Exposure Pathways

After it has been determined that people have or are likely to come in contact with site-related contaminants (a completed exposure pathway), the next step in the public health assessment process is to calculate site-specific exposure doses. This is called a health guideline comparison. It involves looking more closely at site-specific exposure conditions, estimating exposure doses, and looking at health guideline comparison values. Health guideline comparison values are based on data drawn from epidemiologic and toxicological literature and often include uncertainty or safety factors to ensure that they are amply protective of human health.

Several factors determine whether a person exposed to site-related contaminants might be harmed. These factors include

- the amount of contaminant that enters the body,
- the duration and frequency that someone contacts the contaminant, and
- how the person comes in contact with it.

Additional considerations regarding potential adverse health effects from exposures to a contaminant include age, sex, diet, family traits, lifestyle, and state of health.

Non-Cancer Health Effects

To assess non-cancer health effects, ATSDR has developed minimal risk levels (MRLs) for contaminants commonly found at hazardous waste sites. An MRL is an estimate of the daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk for adverse, non-cancer health effects. MRLs are developed for a route of exposure, such as swallowing or breathing, over a specified period. Exposure periods are classified as

- acute (less than 14 days),
- intermediate (15–364 days), or
- chronic (365 days or more).

MRLs are based largely on toxicological studies in animals and on reports of human occupational (workplace) exposures. MRLs are usually extrapolated from observed effect levels reported in animal toxicological studies or occupational studies. They are adjusted by a series of uncertainty factors or through the use of statistical models. In toxicological literature, observations might be reported as

- no-observed-adverse-effect level (NOAEL) or
- lowest-observed-adverse-effect level (LOAEL).

A NOAEL is the highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals. A LOAEL is the lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals. To provide additional perspective on these health effects, the calculated exposure doses are then compared with the applicable NOAEL or LOAEL. As the exposure dose increases beyond the MRL to the level of the NOAEL or LOAEL, the likelihood of adverse health effects increases.

When MRLs for specific contaminants are unavailable, other health-based comparison values are used. These include EPA's reference concentration (RfC). An RfC is an estimate of a how much of a contaminant people (including sensitive subgroups) can breathe during a day without having an appreciable risk for harmful effects during a lifetime of exposure.

When assessing an exposure risk to a contaminant of concern, EPA recommends using the 95% upper confidence limit (95% UCL) of the arithmetic mean to determine the exposure point concentrations (EPC) for site-related contaminants [EPA 2013a]. The EPC is a conservative estimate of the average chemical concentration in an environmental medium, such as indoor air, soil, or water. The 95% UCL was used for samples collected at the high school for contaminants of concern other than TCE, as there was a relatively large dataset (greater than 10 samples) to obtain a reliable EPC. Because the number of samples collected in each home during the vapor intrusion investigation varied from one to 10, we could not accurately determine a 95% UCL. Therefore, the EPC for contaminants of concern detected at the residential properties was determined based on the maximum concentrations. In addition, because of recently updated toxicity information for TCE [EPA 2011a], the maximum concentration was used to calculate the EPC for the high school and the residential properties rather than the 95% UCL.

Exposure point concentrations for non-cancer health effects to indoor air contaminants were calculated using the following formula:

$$EPC_{\text{non-cancer}} = C \times ET \times EF$$

where
EPC = exposure point concentration of contaminant in air ($\mu g/m^3$),
C = 95% UCL or maximum concentration of contaminant in air ($\mu g/m^3$),
ET = exposure time (hours/24 hours), and
EF = exposure frequency (days/365 days).

Table 5 lists the site-specific exposure assumptions [EPA 2011b] used to calculate exposures doses to residents, high school students, and faculty.

Table 5. Exposure Assumptions – Non-Cancer Health Effects

Exposed population	Exposure assumptions	
	Hourly	Daily
Adult/Child residents	24 hours/day	365 days/365 days
Adult faculty and students	8 hours/day	180 days/365 days

Site-Related Contaminants

Because TCE was found in indoor air and groundwater at the site, it was determined to be related to contamination found at the site. As stated previously, there is not enough information to conclude whether 1,2-dichloroethane and cis-1,2-dichloroethylene in the indoor air of some of the homes is from background contamination or vapor intrusion because these compounds have not been found consistently in groundwater and indoor air. Therefore, for this health consultation, these contaminants are considered to be site-related. **Appendix C** has toxicological summaries for these contaminants of concern.

***Trichloroethylene (TCE)* —** In October 2014, ATSDR published an MRL of 2 $\mu g/m^3$ for chronic (more than 365 days) and intermediate (2 weeks to 365 days) inhalation exposure to TCE [ATSDR 2014]. The ATSDR MRL for TCE is the same as the current TCE RfC (EPA 2013b). This RfC reflects the midpoint between RfC estimates for adverse health effects reported in two studies: 1.9 $\mu g/m^3$ for adult immunological effects in mice and 2.1 $\mu g/m^3$ for fetal heart malformations in rats. The RfC of 2 $\mu g/m^3$ is based on route-to-route extrapolated results from oral studies for the critical effects of heart malformations (in rats) and immunotoxicity (in mice). Kidney toxicity was also reported, but it was not used as a principal basis for the RfC. Although these studies were conducted in rats and mice exposed to TCE in drinking water, physiological-based pharmacokinetic modeling was used to extrapolate oral doses in animals to human equivalent concentrations in air.

Based on animal study data reviewed in the EPA Integrated Risk Information System (IRIS) toxicological profile, EPA predicts that exposure to TCE near or exceeding the following levels might pose a small risk for specific health effects:

- 21 $\mu g/m^3$ — fetal heart malformations in pregnant women
- 30 $\mu g/m^3$ — kidney effects in humans, including toxic nephropathy and increased kidney weights
- 190 $\mu g/m^3$ — decreased thymus weight in humans

Nine of the 11 homes sampled had TCE in the indoor air, indicating vapor intrusion was occurring in these buildings. The EPCs for TCE in these nine homes ranged from 0.42 $\mu g/m^3$ to 21 $\mu g/m^3$ **(Table 6)**. One home (residence B) had TCE detected below the MRL; therefore, adverse non-cancer health effects are not likely. For the eight homes exceeding the ATSDR MRL, one home (residence E) had TCE levels slightly above the MRL at 2.4 $\mu g/m^3$. However, adverse non-cancer health effects from exposure to TCE in this home are not likely, based on available toxicological literature. Although previous concentrations in residence E have been slightly above or below the ATSDR MRL, it is still important to ensure that the mitigation measures in place continue to prevent TCE levels from increasing to levels of health concern. It is also important for the residents of this home to identify any sources of TCE within the home to reduce exposures as much as possible. **Table 7** shows example calculations for the residential scenario.

Table 6. Non-Cancer Health Effects – Residential Properties

Residence	Contaminant of concern	Concentration range (µg/m³)	EPC* (µg/m³)	MRL[†] (µg/m³)	Exceeded MRL
A	Benzene	0.73–6.4	6.4	Benzene = 9.6 1,2-Dichloroethane = 2,400 PCE = 41 TCE = 2 Toluene = 300 Xylenes = 220	No
	TCE	ND–12	12		**Yes**
B	Benzene	0.58–12	12		**Yes**
	1,2-Dichloroethane	ND–6.9	6.9		No
	TCE	ND–0.42	0.42		No
C	Benzene	2.0–5.4	5.4		No
	TCE	ND–9.7	9.7		**Yes**
D	Benzene	0.5–9.3	9.3		No
	1,2-Dichloroethane	ND–0.53	0.53		No
	TCE	ND–6.5	6.5		**Yes**
	Xylenes	ND–244	244		**Yes**
E	Benzene	1.0–3.7	3.7		No
	1,2-Dichloroethane	ND–1.1	1.1		No
	PCE	ND–13	13		No
	TCE	ND–2.4	2.4		**Yes**
F	Benzene	5.8	5.8		No
G	Benzene	0.7–6.4	6.4		No
	1,2-Dichloroethane	ND–17	17		No
	TCE	ND–13	13		**Yes**
H	Benzene	1.3–8.0	8.0		No
	1,2-Dichloroethane	ND–3.0	3.0		No
	TCE	0.3–21	21		**Yes**
I	Benzene	ND–1.9	1.9		No
	TCE	0.23–10	10		**Yes**
J	Benzene	35	35		**Yes**
	Toluene	648	648		**Yes**
K	Benzene	0.96–4.8	4.8		No
	1,2-Dichloroethane	ND–3.7	3.7		No
	TCE	1.6–13	13		**Yes**

EPC = exposure point concentration; ND = not detected; PCE = tetrachloroethylene; TCE = trichloroethylene
* EPC = C x ET x EF (see Table 7); where C = maximum concentration of each contaminant, ET = exposure time, EF = exposure frequency
[†] MRL = ATSDR chronic minimal risk level (exposure greater than 364 days/year)

Table 7. EPC Calculation for Residence A

Residence A	Concentration (µg/m³)	ET (24 hours / 24 hours)	EF (365 days / 365 days)	EPC* (µg/m³)
Benzene	6.4	1	1	6.4
Trichloroethylene (TCE)	12	1	1	12

EPC = exposure point concentration; ET = exposure time; EF = exposure frequency
* EPC= C x ET x EF; where C = maximum concentration

The remaining seven homes have TCE EPC levels ranging from 6.5 µg/m³ to 21 µg/m³. As described above, the most sensitive endpoint of the MRL is an increase in fetal cardiac malformations in rats, with an uncertainty (safety) factor built in. The major milestones for cardiac heart development in humans occur over a 3-week period in the first trimester of pregnancy. Exposures to TCE during this critical period might increase the risk for heart malformations in the developing fetus. With an uncertainty factor of only 10 applied to the effect level for fetal heart development, concentrations of TCE of about three times greater than the MRL might become a concern for health effects. Therefore, the potential for health effects is a concern for pregnant women who might have been exposed to the levels of TCE found in homes A, C, D, G, H, I, and K. If a pregnant woman is exposed to TCE levels above the chronic MRL, it does not mean that fetal heart development will be impaired. However, breathing air exceeding these levels of TCE introduces a small risk for improper fetal development and should be avoided.

The levels of TCE detected in these seven homes also were approaching the associated health effect levels for kidneys and the immune system, as described in toxicological studies. Therefore, past exposures to TCE at the levels found in these seven homes would be considered a health concern for these effects.

All but one of these homes (residence K) have had mitigation measures taken to prevent current and future exposures to elevated TCE levels in indoor air. The occupants of residence K refused mitigation. Residents in this home might still be at an increased risk for health effects from exposure to TCE and other subsurface contaminants. The most recent indoor air sampling data for residence K collected in June 2015 detected TCE at 4.7 µg/m³. Based on this most recent concentration, adverse non-cancer health effects would be unlikely. However, this data represents a single point in time and current levels might be higher or lower.

As shown in **Table 8**, the EPC for TCE in the NBTHS building was below the ATSDR MRL. Therefore, adverse non-cancer health effects would not be expected.

***1,2-Dichloroethane* —** This contaminant was found in six homes above its applicable cancer comparison value, however, all levels were below the ATSDR MRL. Therefore, adverse non-cancer health effects are not likely.

***cis-1,2-Dichloroethylene* —** This contaminant was detected in two homes. There is no comparison value available for this contaminant. Therefore, this substance could not be evaluated for its implications to public health.

Non-Site Related Contaminants

Benzene – As shown in **Table 6**, benzene exceeded its chronic inhalation MRL in two homes (residences B and J). The non-cancer EPCs for benzene in these homes were 12 μg/m^3 and 35 μg/m^3, respectively. The chronic inhalation MRL for benzene (9.6 μg/m^3) is based on a cross-sectional study of 250 workers (approximately two thirds were female) exposed to benzene at two shoe manufacturing facilities in Tianjin, China, who were employed for an average of 6 years. The EPA used dose modeling software to derive a LOAEL of 320 μg/m^3, which corresponds to decreased B cell counts in the blood. The MRL was derived by adjusting from the 8-hour worker exposure to a continuous exposure concentration (24 hours/day) [ATSDR 2007]. Based on the EPCs for benzene detected above the MRL in these homes, adverse non-cancer health effects are not likely. The maximum EPC for benzene of 35 μg/m^3 is approximately nine times lower than the LOAEL.

As shown in **Table 8,** the EPC for benzene did not exceed the ATSDR MRL for the high school. Therefore, non-cancer health effects for students and faculty are not likely from exposure to benzene in indoor air. No other contaminants exceeded their respective health-based comparison values for non-cancer health effects for the homes or the high school. Therefore, adverse non-cancer health effects from exposure to these substances would be unlikely. **Table 9** shows example calculations using the school exposure scenario.

Table 8. Non-Cancer Health Effects — North Brunswick Township High School

Population	Contaminant of concern	Concentration range (μg/m^3)	Concentration* (μg/m^3)	EPC† (μg/m^3)	MRL (μg/m^3)	Exceeded MRL
Students and faculty	Benzene	ND–2.0	0.96	0.2	9.6	No
	Trichloroethylene (TCE)	ND–3.0	3.0	0.5	2	No

EPC = exposure point concentration; MRL = ATSDR chronic minimal risk level (exposure greater than 364 days/year); ND = not detected
* Concentration for benzene was derived using ProUCL version 5.0.00 [EPA 2013]; concentration for TCE was based on the maximum concentration.
† EPC for school scenario = C x ET x EF (see Table 9), where C = concentration, ET = exposure time, and EF = exposure frequency

Table 9. Non-Cancer EPC Calculation — North Brunswick Township High School

Students and faculty	Concentration* (μg/m^3)	ET (8 hours / 24 hours)	EF (180 days / 365 days)	EPC† (μg/m^3)
Benzene	0.96	0.3333	0.4932	0.2
Trichloroethylene (TCE)	3.0	0.3333	0.4932	0.5

EF = exposure frequency; EPC = exposure point concentration; ET = exposure time
* Concentration for benzene was derived using ProUCL version 5.0.00 [EPA 2013]; concentration for TCE was based on the maximum concentration.
† EPC = C x ET x EF, where C = concentration

Toluene – Toluene exceeded its chronic inhalation MRL of 300 μg/m^3 in one home (residence J). The non-cancer EPC for toluene in this home was 648 μg/m^3. The chronic inhalation MRL for toluene is based on a study of three groups of Croatian workers:

- 46 shoe factory workers exposed to average levels of 131,898 µg/m^3 of toluene
- 37 workers employed at a printing press who were exposed to average levels of 587,887 µg/m^3 of toluene
- 90 workers not occupationally exposed to any solvents or known neurotoxic agents

The workers were interviewed and given medical examinations, which included color vision testing. The average age of the workers was 41 years. Information on smoking and alcohol use was assessed for each worker. Indoor air samples were collected at 11 locations in the shoe factory and eight locations in the printing press. Toluene levels were measured in blood samples taken from the workers at the beginning of the work shift.

This study of Croatian workers demonstrated a statistically significant impairment of color vision in workers chronically exposed to 587,887 µg/m^3 of toluene, compared with controls. When the data were adjusted to allow for the confounding effects of alcohol consumption and age, a significant difference was also reported for workers exposed to 131,898 µg/m^3 of toluene, compared with controls. This LOAEL was adjusted from the worker exposure scenario to a continuous exposure (24 hours/day) with an uncertainty factor of 100 for use of the LOAEL and human variability to derive the MRL of 300 µg/m^3. The level of toluene found in residence J is about 200 times below the lowest LOAEL for impaired color vision. Therefore, adverse non-cancer health effects are not likely from exposure to toluene in this residence.

Xylenes – Xylenes exceeded the ATSDR chronic MRL of 220 µg/m^3 in one home (residence D). The non-cancer EPC for xylenes in this home was 244 µg/m^3. A single chronic inhalation MRL was derived for xylenes, factoring in mixed xylenes and the individual isomers. The reason for this is that the isomers have similar toxicokinetic properties with similar toxicological effects. The chronic inhalation MRL for xylenes is based on a study of 175 workers who were exposed to xylenes in Chinese factories during the production of rubber boots or plastic coated wire, or in printing work. For comparison, 241 non-exposed workers were recruited from the same or other factories. Exposures were measured with a diffusive sampler and indicated that xylenes accounted for more than 70% of the total exposure, with m-xylene accounting for 50% of the xylene exposure, followed by p-xylenes and o-xylenes. The workers were evaluated for subjective symptoms in a questionnaire and examined for objective parameters such as serum biochemistry, hematology, and urinalysis. Exposures were corroborated by measuring xylene metabolites in urine.

A LOAEL of 60,810 µg/m^3 xylene, the time-weighted average geometric mean, was identified for subjective symptoms of neurotoxicity (anxiety, forgetfulness, floating sensation), respiratory toxicity (nasal irritation and sore throat), and eye irritation. The geometric mean was chosen over the arithmetical mean because it is a better representation of central tendency. The MRL of 220 µg/m^3 was derived by applying uncertainty factors for use of a LOAEL, human variability, and to account for the lack of supporting studies evaluating the chronic neurotoxicity of xylene. The EPC of 244 µg/m^3 for xylenes found in residence D is approximately 250 times lower than the LOAEL. Therefore, adverse non-cancer health effects are not likely from exposure to xylenes in this residence.

Cancer Health Effects

The site-specific lifetime excess cancer risk (LECR) estimates the cancer-causing potential of contaminants. LECR estimates are usually expressed in terms of excess cancer cases in an exposed population. For perspective, the lifetime risk of being diagnosed with cancer in the United States is 44 per 100 males and 38 per 100 females (ACS 2011). Typically, comparison values developed for carcinogens are based on one excess cancer case per 1 million persons. The NJDOH considers estimated cancer risks of less than one additional cancer case among 1 million persons exposed as insignificant or no increased risk (expressed exponentially as 10^{-6}).

Exposure point concentrations for cancer health effects to indoor air contaminants were calculated using the following formula [EPA 2009]:

$$EPC_{cancer} = \frac{C \ x \ ET \ x \ EF \ x \ ED}{AT}$$

where

EPC = exposure point concentration of contaminant in air ($\mu g/m^3$),
C = 95% UCL or maximum concentration of contaminant in air ($\mu g/m^3$),
ET = exposure time (hours/day),
EF = exposure frequency (days/year),
ED = exposure duration (years), and
AT = averaging time (78 years).

LECRs were calculated using the following formula [EPA 2009]:

$$LECR = EPC_{cancer} \times IUR$$

where

EPC_{cancer} = exposure point concentration of contaminant in air ($\mu g/m^3$); and
IUR = inhalation unit risk of contaminant in air $(\mu g/m^3)^{-1}$.

The LECR for residents was calculated by multiplying the cancer exposure point concentration in indoor air by the inhalation unit risk (IUR). EPA defines the IUR as the upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 $\mu g/m^3$ in air [EPA 2008). The inhalation IUR for carcinogens detected in indoor air was used to estimate the LECR to exposed persons.

Table 10 shows the site-specific exposure assumptions [EPA 2011] used to calculate exposures doses to residents and high school students and faculty. For the residential exposure duration, 21 years was used because the homes were built in the mid-1990s. For the high school, a duration of 4 years was used for the students and 40 years was used for faculty. This is because the school was built in 1973 and some teachers could have been at the school for their entire teaching careers.

Table 10. Exposure Assumptions — Cancer Health Effects

Exposed population	Exposure time	Exposure frequency	Exposure duration
Adult/Child residents	24 hours/day	365 days/ 365 days	21 years
Adult faculty and students	8 hours/day	180 days/ 365 days	4 years students 40 years adult faculty

The data collected between April 2004 and June 2015 was used to evaluate the cancer risk to adults and children from past exposures through breathing indoor air contaminated with VOCs. Specifically, cancer risks were evaluated for the nearby residences and for students and faculty of the high school. The cancer risk evaluation included site-related and non-site–related contaminants. Because of the mutagenic mode of action for TCE and kidney cancer, the age-dependent adjustment factor model was used to calculate the LECRs for children exposed to TCE [EPA 2013b].

Cancer Risk – Residences

Based on the cancer EPCs for VOC exposure concentrations in the indoor air at eight homes, the range of LECRs for adults and children were estimated to be approximately one to eight in 100,000 persons. This is considered to be a low cancer risk. The LECRs for three homes (residences G, H, and K) were approximately one to two in 10,000 persons, which is considered to be an increased cancer risk (**see Table 11**). To put this risk in perspective, based on U.S. cancer rates, the lifetime risk for developing cancer in the general population is about four out of every 10 persons. **Table 12** shows an example LECR calculation.

Table 11. Lifetime Excess Cancer Risk — Residential Properties

Residence	Contaminant of concern	Concentration range* (µg/m³)	EPC (µg/m³)	IUR (µg/m³) -1	LECR†	Total approximate LECR
A	Benzene	0.73–6.4	1.7	Benzene = 7.80E-06 1,2-Dichloroethane = 2.60E-05 PCE = 2.60E-07 TCE‡	1.34E-05	7.00E-05
	TCE	ND–12	12		5.63E-05	
B	Benzene	0.58–12	3.2		2.52E-05	8.00E-05
	1,2-Dichloroethane	ND–6.9	1.9		4.83E-05	
	TCE	ND–0.42	0.4		1.97E-06	
C	Benzene	2.0–5.4	1.5		1.13E-05	6.00E-05
	TCE	ND–9.7	9.7		4.55E-05	
D	Benzene	0.5–9.3	2.5		1.95E-05	5.00E-05
	1,2-Dichloroethane	ND–0.53	0.1		3.71E-06	
	TCE	ND–6.5	6.5		3.05E-05	
E	Benzene	1.0–3.7	1.0		7.77E-06	3.00E-05
	1,2-Dichloroethane	ND–1.1	0.3		7.70E-06	
	PCE	ND–13	3.5		9.10E-07	
	TCE	ND–2.4	2.4		1.13E-05	
F	Benzene	5.8	1.6		1.22E-05	1.00E-05
G	Benzene	0.7–6.4	1.7		1.34E-05	2.00E-04
	1,2-Dichloroethane	ND–17	4.6		1.19E-04	
	TCE	ND–13	13		6.10E-05	
H	Benzene	1.3–8.0	2.2		1.68E-05	1.00E-04
	1,2-Dichloroethane	ND–3.0	0.8		2.10E-05	
	TCE	0.3–21	21		9.85E-05	
I	Benzene	ND–1.9	0.5		3.99E-06	5.00E-05
	TCE	0.23–10	10		4.69E-05	
J	Benzene	35	9.5		7.37E-05	7.00E-05
K	Benzene	0.96–4.8	1.3		1.01E-05	1.00E-04
	1,2-Dichloroethane	ND–3.7	1.0		2.59E-05	
	TCE	1.6–13	13		6.10E-05	

EPC = Exposure point concentration; IUR = U.S. Environmental Protection Agency inhalation unit risk; LECR = lifetime excess cancer risk; ND = not detected; PCE = tetrachloroethylene; TCE = trichloroethylene

* EPC based on maximum concentrations

† EPC = C x ET x EF x ED/AT (see table 12); where C = the maximum concentration of each contaminant in air, ET = exposure time, EF = exposure frequency, ED = exposure duration, and AT = averaging time

‡ The cancer risk for TCE was determined using the age-dependent adjustment factor (ADAF) model to account for the mutagenic mode of action of TCE.

Table 12. Example of Lifetime Excess Cancer Risk Calculations — Residence A

Residence A	Maximum concentration (µg/m³)	ET (24 hours / 24 hours)	EF (365 days / 365 days)	ED (years)	AT (years)	EPC* (µg/m³)	IUR (µg/m³) -1	LECR	Total approximate LECR
Benzene	6.4	1	1	21	78	1.7	7.80E-06	1.34E-05	7.00E-05
TCE†	12	1	1	21	78	12†	ADAF†	5.63E-05	

ADAF = age-dependent adjustment factor; AT = averaging time; EPC = exposure point concentration; ET = exposure time; EF = exposure frequency; ED = exposure duration; IUR = EPA inhalation unit risk; LECR = lifetime excess cancer risk; TCE = trichloroethylene

* EPC = C x ET x EF x ED/AT; where C = concentration

† The cancer risk for TCE was determined using the ADAF model to account for the mutagenic mode of action of TCE; therefore, the maximum TCE levels (EPCs) for each home were used in the model

Cancer Risk – North Brunswick Township High School

Based on the cancer EPCs for VOC exposure concentrations in indoor air at the high school, the LECR for students was less than one in 1 million persons, which is considered to be an unlikely increase in risk of cancer. The calculated LECR for faculty at the high school was approximately two in 1 million persons, which is considered to be a low cancer risk (**see Table 13**). **Table 14** shows example LECR calculations for the school scenario.

Table 13. Exposure-Related Lifetime Excess Cancer Risk — North Brunswick Township High School

Population	Contaminant of concern	Concentration range (µg/m³)	Concentration* (µg/m³)	EPC† (µg/m³)	IUR (µg/m³)-1	LECR	Total approximate LECR
Students	Benzene	ND–2.0	0.96	0.0081	7.80E-06	6.31E-08	2.00E-07
	TCE	ND–3.0	3	0.5	ADAF‡	1.31E-07	
Faculty	Benzene	ND–2.0	0.96	0.0809	7.80E-06	6.31E-07	2.00E-06
	TCE	ND–3.0	3	0.2529	ADAF‡	1.04E-06	

ADAF = ATSDR age-dependent adjustment factor; EPC = exposure point concentration; IUR = EPA inhalation unit risk; LECR = lifetime excess cancer risk; ND = not detected; TCE = trichloroethylene

* Concentration for benzene derived using ProUCL version 5.0.00 [EPA 2013]; concentration for TCE based on the maximum concentration

† EPC = C x ET x EF X ED/AT (see Table 14); where C = concentration, ED = exposure duration, EF = exposure frequency, and ET = exposure time

‡ The cancer risk for TCE was performed using the ADAF model to account for the mutagenic mode of action of TCE. The ADAF adjustment for students = 3, for faculty = 1.

Table 14. Example LECR Calculation for North Brunswick Township High School

Population	Contaminant	Concentration* (µg/m³)	ET (8 hours/ 24 hours)	EF (180 days/365 days)	ED (years)	AT (years)	EPC† (µg/m³)	IUR (µg/m³) ⁻¹	LECR
Students	TCE	3	0.3333	0.4932	4	78	0.5	ADAF‡	1.31E-07
Faculty	Benzene	0.96	0.3333	0.4932	40	78	0.0809	7.80E-06	6.31E-07

ADAF = ATSDR age-dependent adjustment factor; AT = averaging time; ED = exposure duration; EF = exposure frequency; EPC = exposure point concentration; ET = exposure time; IUR = U.S. Environmental Protection Agency inhalation unit risk; LECR = lifetime excess cancer risk; TCE = trichloroethylene

* Concentration for benzene derived using ProUCL version 5.0.00 [EPA 2013]; concentration for TCE was the maximum concentration

† EPC = C x ET x EF x ED/AT; where C = concentration

‡ The cancer risk for TCE was performed using the ADAF model to account for the mutagenic mode of action of TCE. Specifically, the ADAF model was adjusted to account for the 4-year exposure duration and ages for the students attending the high school using the 0.5 µg/m³ adjusted concentration.

Child Health Considerations

ATSDR recognizes that the unique vulnerabilities of infants and children demand special emphasis in communities faced with contamination in their environment. Children are at greater risk than adults from certain kinds of exposures to hazardous substances because they eat and breathe proportionally more than adults do. Children also play outdoors and often bring food into contaminated areas. Children are smaller, resulting in higher doses of chemical exposure per body weight. The developing body systems of children can sustain permanent damage if toxic exposures occur during critical growth stages. Most importantly, children depend completely on adults for risk identification and management decisions, housing decisions, and access to medical care.

Based on the sampling data, past inhalation exposures to TCE in indoor air posed an increased risk for fetal heart malformations to have occurred from maternal exposures to indoor air containing elevated levels of TCE in pregnant women living in seven homes. Exposures at six of these residences have been interrupted since mitigation measures were taken between April 2004 and September 2009. One home has refused mitigation. Therefore, residents in that home might currently be exposed to elevated levels of TCE. However, because levels from the most recent sampling data in June 2015 were only slightly above the ATSDR MRL, adverse non-cancer health effects are not likely. There is no current data available to determine whether TCE levels have increased since the last sampling event. The most recent sampling event for this home indicates TCE levels are approaching levels of health concern.

It is important to note that the data collected for these residences represents one point in time. Conditions within these homes might have changed over time and historical concentrations of TCE might have been higher or lower.

Conclusions

After reviewing and assessing environmental data associated with the vapor intrusion investigation from April 2004 through June 2015, the NJDOH and ATSDR reached the following conclusions regarding exposures to students and faculty at the North Brunswick Township High School site and nearby residents:

1. *The NJDOH and ATSDR conclude that past exposures to TCE in seven homes might have harmed people's health.* Past exposure to elevated levels of TCE in seven homes were approaching levels of health concern for fetal heart malformations, kidney, and immune system damage to residents of these homes. Residents in three of these homes (residences G, H, and K) also were found to have an increased risk for cancer, based on the cumulative risk for site-related and non-site–related indoor air contaminants. Mitigation measures have been taken in six of these homes (residents A, C, D, G, H, and I) to eliminate current and future exposures to sub-surface contaminants. Post-mitigation levels of TCE in residences C and D were elevated during one sampling event. These elevated levels were attributed to an indoor source. Residents of one home (residence K) have refused mitigation measures.

2. *The NJDOH and ATSDR conclude that current and future exposures to TCE in one home might harm people's health.* Of the seven homes with elevated TCE levels, residents of one home (residence K) have refused mitigation measures and therefore might currently be exposed to TCE and other contaminants through vapor intrusion. The most recent data for this home from June 2015 indicate that at that time, adverse non-cancer health effects would be unlikely. However, no current data are available to determine whether TCE levels have increased since the last sampling event. The most recent sampling event indicates TCE levels are approaching levels of health concern.

3. *The NJDOH and ATSDR conclude that past exposure to volatile organic chemicals at North Brunswick Township High School and four nearby residences was not likely to harm people's health.* Based on the data reviewed by the NJDOH, the levels of indoor air contaminants at the high school were below health-based comparison values for non-cancer health effects and cancer risks were determined to be low for students and faculty. One residence (residence E) had TCE levels slightly above its non-cancer health-based comparison value. Two residences (residences B and J) had benzene levels above its non-cancer health-based comparison value. Residence J also had toluene above its non-cancer health-based comparison value. However, non-cancer health effects are not likely, based on available toxicological literature, and the cancer risks for these homes were determined to be low. Levels at the remaining home (residence F) did not exceed health based comparison values for non-cancer health effects and the cancer risk for this home was also determined to be low.

Recommendations

1. The NJDOH and ATSDR recommend that residents affected by vapor intrusion who are concerned about past exposures to site contaminants contact their primary health care physician to discuss these concerns.

2. The NJDOH and ATSDR recommend that the Township of North Brunswick encourage residence K to have mitigation measures put in place to prevent current and future exposures to site contaminants through vapor intrusion.

3. The NJDOH and ATSDR recommend that the Township of North Brunswick continue to monitor and evaluate the extent of groundwater contamination and conduct indoor air sampling, as appropriate, to ensure that additional homes are not being affected by site contaminants.

4. The NJDOH and ATSDR recommend that the Township of North Brunswick continue to monitor the indoor air for the high school and nearby residences with mitigation measures in place. This will ensure that these measures continue to prevent vapor intrusion of TCE and other subsurface contaminants.

Public Health Action Plan

The purpose of a public health action plan is to ensure that this health consultation not only identifies public health hazards, but also provides a plan of action designed to mitigate and prevent adverse human health effects resulting from exposure to hazardous substances in the environment. Included is a commitment on the part of the NJDOH to follow-up on this plan to ensure that it is implemented. The public health actions to be implemented by the NJDOH are as follows:

Public Health Actions Taken

1. The NJDOH reviewed information and relevant data from the consultant representing the Township of North Brunswick to evaluate the potential health implications to people exposed to contaminants by breathing indoor air at NBTHS and nearby residences.

2. The NJDOH attended public meetings in December 2008, May 2009, and January 2014 to address community concerns relating to possible health effects from exposures to site contaminants, including TCE.

3. The NJDOH has prepared previous documents to evaluate the public health implications from exposures to the North Brunswick Township site. These documents include a public health assessment released in January 2009 and three health consultations, one released in August 2005 and two in September 2009. These documents evaluate the public health implications from exposures to various environmental media including soil and indoor air on the school property and surrounding properties. One of the two health consultations

released in September 2009 specifically evaluated cancer incidence for the area in response to community concerns.

Public Health Actions Planned

1. Copies of this health consultation will be provided to North Brunswick Township. This document will also be provided to the NJDEP and to affected residents. It will be available at the township library and on the Internet. Additionally, residents can contact the NJDOH for help in understanding the findings of this report.

2. The NJDOH will continue to review and evaluate data as it becomes available.

3. Residents with health concerns regarding past exposures to site-related contaminants can ask the NJDOH for help with outreach between the resident's physician and trained experts specializing in occupational and environmental exposures to hazardous substances.

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Report Preparation

This health consultation for the North Brunswick Township High School site was prepared by the New Jersey 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, and 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.

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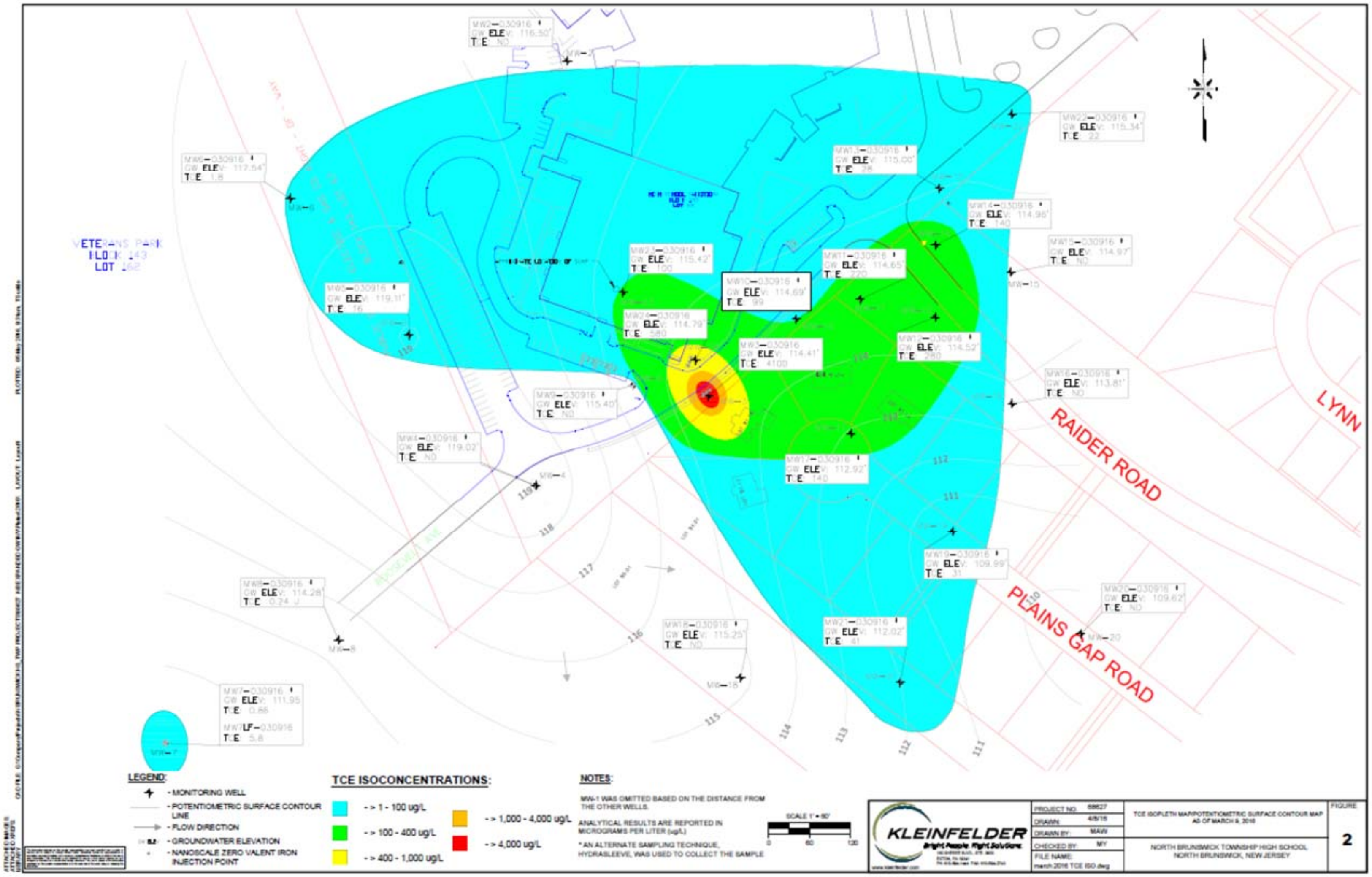
Figures

Figure 2 – Area Map

Figure 3 – TCE Groundwater Plume Map – March 2016



Appendices

Appendix A: Demographic Maps

EPA FACILITY ID NJD103805370

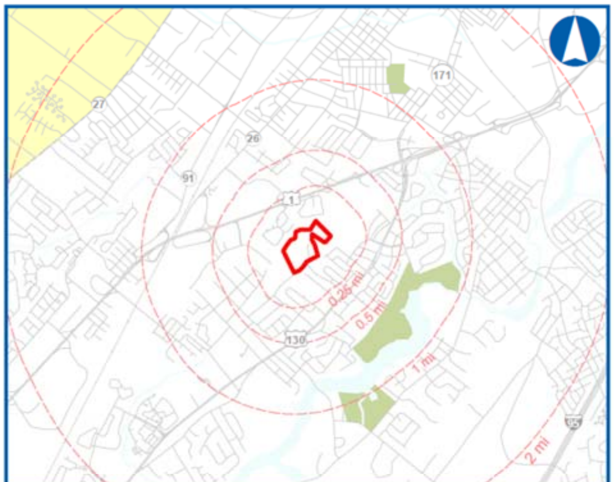
INTRODUCTORY MAP SERIES

North Brunswick Township High School

North Brunswick Township, Middlesex County, NJ

GENERAL SITE PROFILE

Site Vicinity Map



Site of Interest[1]
Site of Interest Buffers[2]
Park[3]
Industrial[3]
Airport[3]
Military Base[3]

0 0.5 1
Miles

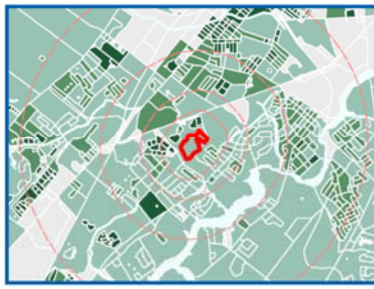
The **General Site Profile Map** depicts the hazardous waste site of interest, along with any airport, industrial, military, or park land uses. It also provides community demographic and housing statistics.

Demographic Statistics[4,5]

Within 1 Miles buffer of site boundary

Measure	2000	2010	Change
Total Population	15,005	14,730	-1%
White Alone	9,769	7,680	-21%
Black Alone	2,198	2,634	+19%
Am. Indian & Alaska Native Alone	12	44	+266%
Asian Alone	1,845	2,563	+38%
Native Hawaiian & Other Pacific Islander Alone	2	0	-100%
Some Other Race Alone	686	1,327	+93%
Two or More Races	494	484	-2%
Hispanic or Latino[6]	1,608	2,748	+70%
Children Aged 6 and Younger	1,438	1,369	-4%
Adults Aged 65 and Older	1,658	1,552	-6%
Females Aged 15 to 44	3,490	3,219	-7%
Housing Units	5,809	5,513	-5%
Housing Units Pre 1950	561	602	+7%

General Population Density



Population Density by Census Block[4] (No. per sq. mi.)

- Zero
- 0 to 5,000
- 5,000 to 10,000
- > 10,000

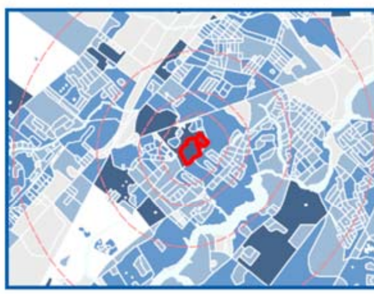
Sensitive Populations

No. of Children 6 Yrs & Younger by Census Block[4]

- Zero
- 1 to 5
- 6 to 10
- > 10

No. of Adults 65 Yrs & Older by Census Block[4]

- Zero
- 1 to 10
- 11 to 100
- > 100



No. of Females Aged 15 to 44 Yrs by Census Block[4]

- Zero
- 1 to 20
- 21 to 100
- > 100

Data Sources: [1]ATSDR GRASP Hazardous Waste Site Boundary Database. [2]ATSDR GRASP. [3]TomTom International BV (2012). [4]US Census 2010. **Notes:** [5]Calculated using area-proportion spatial analysis method. [6]Individuals identifying origin as Hispanic or Latino may be of any race. **Projection:** Projection used for all map panels is NAD 1983 StatePlane New Jersey FIPS 2900 Feet.

PRJ 04821 LTV7 4/13/16

GRASP

Agency for Toxic Substances and Disease Registry
Division of Toxicology and Human Health Sciences

ATSDR

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Appendix B: Uses and Sources of Typical Indoor Air Contaminants Found in Vapor Intrusion Investigations

Chemical	Usage	Sources of Common Exposure
Benzene	Solvents, gasoline, resins and plastics; nylon; paints; adhesives (especially carpet); printing; pesticides; detergents/disinfectants; dyes; photographic processing	Gasoline emissions; cigarette smoke; paints and adhesives; particle board and wood composites; wood smoke
1,2 Dichloroethane	Manufacture of vinyl chloride; formerly used in varnish, paints, finish removers, adhesives, soaps, degreasing agent, polyresin molded decorations (particularly from China)	Fugitive emissions from industries, treatment plants, hazardous waste sites; landfills; occupational settings; ambient air
1,2 Dichloroethene (cis)	Solvent for waxes and resins; in the extraction of rubber; as a refrigerant; in the manufacture of pharmaceuticals and artificial pearls; in the extraction of oils and fats from fish and meat; and in making other organics.	Commonly found in urban ambient (outside) air
Tetrachloroethylene (PCE)	Solvent; degreaser; dry cleaning and textile production; water repellants; pharmaceuticals; pesticides; refrigerants; insulating fluids; correction fluid (e.g., white out) and inks; adhesives	Dry cleaned garments; paint removers; fabric cleaning products (e.g., stain removers, etc.); lubricants; wood products
Toluene	Solvent; gasoline, automobile exhaust, polishes, nail polish, fragrances, paint and paint thinner, scented candles, adhesives and cigarette smoke	Gasoline powered equipment, household products, smoking
Trichloroethylene (TCE)	Solvent; degreaser; dry cleaning and textile production; adhesives, paint removers; correction fluid (e.g., white out) and spot removers	Present main use as a metal degreaser; dry cleaned garments; paint removers; fabric cleaning products (e.g., stain removers, etc.)
Xylenes	Gasoline, water sealer, paint, markers, floor polish	Automobile exhaust, cigarette smoke

References:
ATSDR Toxicological Profile at www.atsdr.cdc.gov
New Jersey Department of Environmental Protection – Common Background Indoor Air Sources

Appendix C

Toxicological Summaries for Site-Related Contaminants

The toxicological summaries provided in this Appendix are based on ATSDR's ToxFAQs (http://www.atsdr.cdc.gov/toxfaq.html). Health effects are summarized in this section for the site-related chemicals of concern found in the indoor air of the North Brunswick High School and nearby residences. The health effects described in the section are typically known to occur at levels of exposure much higher than those that occur from environmental contamination. The chance that a health effect will occur is dependent on the amount, frequency and duration of exposure, and the individual susceptibility of exposed persons.

1,2 Dichloroethane. 1,2-Dichloroethane, also called ethylene dichloride, is a manufactured chemical that is not found naturally in the environment. It is a clear liquid and has a pleasant smell and sweet taste. The most common use of 1,2-dichloroethane is in the production of vinyl chloride which is used to make a variety of plastic and vinyl products including polyvinyl chloride (PVC) pipes, furniture and automobile upholstery, wall coverings, housewares, and automobile parts. It is also used to as a solvent and is added to leaded gasoline to remove lead.

People ingesting or breathing large amounts of 1,2-dichloroethane have been reported to have nervous system disorders, liver and kidney diseases, and lung effects. In laboratory animals, breathing or ingesting large amounts of 1,2-dichloroethane have also caused nervous system disorders and liver, kidney, and lung effects. Animal studies also suggest that 1,2-dichloroethane may damage the immune system. Kidney disease has also been seen in animals ingesting low doses of 1,2-dichloroethane for a long time.

Human studies examining whether 1,2-dichloroethane can cause cancer have been considered inadequate. In animals, increases in the occurrence of stomach, mammary gland, liver, lung, and endometrium cancers have been seen following: inhalation, oral, and dermal exposure. The Department of Health and Human Services (DHHS) has determined that 1,2-dichloroethane may reasonably be expected to cause cancer. The EPA has determined that 1,2-dichloroethane is a probable human carcinogen and the International Agency for Cancer Research (IARC) considers it to be a possible human carcinogen.

Cis-1,2-dichloroethene. 1,2-Dichloroethene, also called 1,2-dichloroethylene, is a highly flammable, colorless liquid with a sharp, harsh odor. It is used to produce solvents and in chemical mixtures. There are two forms of 1,2-dichloroethene; one is called cis-1,2-dichloroethene and the other is called trans-1,2-di-chloroethene. Sometimes both forms are present as a mixture. Breathing high levels of 1,2-dichloroethene can make you feel nauseous, drowsy, and tired; breathing very high levels can kill you. When animals breathed high levels of *trans*-1,2-dichloroethene for short or longer periods of time, their livers and lungs were damaged and the effects were more severe with longer exposure times. Animals that breathed very high levels of *trans*-1,2-dichloroethene had damaged hearts. Animals that ingested extremely high doses of *cis*- or *trans*-1,2-dichloroethene died. Lower doses of *cis*-1,2-dichloroethene caused effects on the blood, such as decreased numbers of red blood cells, and effects on the liver.

The long-term (365 days or longer) human health effects after exposure to low concentrations of 1,2-dichloroethene aren't known. One animal study suggested that an exposed fetus may not grow as quickly as one that hasn't been exposed. Exposure to 1,2-dichloroethene hasn't been shown to affect fertility in people or animals. The EPA has determined that *cis*-1,2-dichloroethene is not classifiable as to its human carcinogenicity.

Trichloroethylene (TCE). TCE is a nonflammable, colorless liquid with a somewhat sweet odor and a sweet, burning taste. It is used mainly as a solvent to remove grease from metal parts, but it is also an ingredient in adhesives, paint removers, typewriter correction fluids, and spot removers. TCE dissolves a little in water, and can remain in groundwater for a long time. It quickly evaporates from water, so it is commonly found as a vapor in the air. People can be exposed to TCE by breathing air in and around the home which has been contaminated with TCE vapors from shower water or household products, or by drinking, swimming, or showering in water that has been contaminated with TCE.

Breathing small amounts of TCE may cause headaches, lung irritation, dizziness, poor coordination, and difficulty concentrating. Breathing large amounts of TCE may cause impaired heart function, unconsciousness, and death. Breathing it for long periods may cause nerve, kidney, and liver damage. Drinking large amounts of TCE may cause nausea, liver damage, unconsciousness, impaired heart function, or death. Drinking small amounts of TCE for long periods may cause liver and kidney damage, impaired immune system function, and impaired fetal development in pregnant women, although the extent of some of these effects is not yet clear. Skin contact with TCE for short periods may cause skin rashes.

The USEPA characterizes TCE as carcinogenic to humans by all routes of exposure (USEPA 2013b). This conclusion is based on convincing evidence of a causal association between TCE exposure in humans and kidney cancer. The kidney cancer association cannot be reasonably attributed to chance, bias, or confounding. The human evidence of carcinogenicity from epidemiologic studies of TCE exposure is strong for non-Hodgkin lymphoma (NHL), but less convincing than for kidney cancer, and more limited for liver and biliary tract cancer. In addition to the body of evidence pertaining to kidney cancer, NHL, and liver cancer, the available epidemiologic studies also provide more limited evidence of an association between TCE exposure and other types of cancer, including bladder, esophageal, prostate, cervical, breast, and childhood leukemia.

In September 2011, the USEPA published a revised inhalation unit risk of 4.1×10^{-6} $\mu g/m^3$ reflecting total incidence of kidney, non-Hodgkin's lymphoma, and liver cancers (USEPA 2013b). The USEPA recently concluded, by a weight of evidence evaluation, that TCE is carcinogenic by a mutagenic mode of action for induction of kidney tumors (USEPA 2013b). As a result, increased early-life susceptibility is assumed for kidney cancer, and age-dependent adjustment factors (ADAFs) are used for the kidney cancer component of the total cancer risk when estimating age-specific cancer risks. ADAFs are factors by which cancer risk is multiplied to account for increased susceptibility to mutagenic compounds early in life – standard ADAFs are 10 (for ages below 2 years old), 3 (for ages 2 up to 16 years old), and 1 (for ages greater than 16).