ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

Public Health Assessment for

GARDEN CITY GROUNDWATER PLUME NPL SITE

GARDEN CITY, BARTHOLOMEW COUNTY, INDIANA

EPA FACILITY ID: INN000508642

MAY 16, 2018

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
Agency for Toxic Substances and Disease Registry

Comment Period Ends:

JUNE 18, 2018

THE ATSDR PUBLIC HEALTH ASSESSMENT: A NOTE OF EXPLANATION

This Public Health Assessment-Public Comment Release was prepared by ATSDR pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) section 104 (i)(6) (42 U.S.C. 9604 (i)(6), and in accordance with our implementing regulations (42 C.F.R. Part 90). In preparing this document, ATSDR has collected relevant health data, environmental data, and community health concerns from the Environmental Protection Agency (EPA), state and local health and environmental agencies, the community, and potentially responsible parties, where appropriate. This document represents the agency's best efforts, based on currently available information, to fulfill the statutory criteria set out in CERCLA section 104 (i)(6) within a limited time frame. To the extent possible, it presents an assessment of potential risks to human health. Actions authorized by CERCLA section 104 (i)(11), or otherwise authorized by CERCLA, may be undertaken to prevent or mitigate human exposure or risks to human health. In addition, ATSDR will utilize this document to determine if follow-up health actions are appropriate at this time.

This document has previously been provided to EPA and the affected state in an initial release, as required by CERCLA section 104 (i)(6) (H) for their information and review. Where necessary, it has been revised in response to comments or additional relevant information provided by them to ATSDR. This revised document has now been released for a 30-day public comment period. Subsequent to the public comment period, ATSDR will address all public comments and revise or append the document as appropriate. The public health assessment will then be reissued. This will conclude the public health assessment process for this site, unless additional information is obtained by ATSDR which, in the agency's opinion, indicates a need to revise or append the conclusions previously issued.

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Visit our Home Page at: http://www.atsdr.cdc.gov

PUBLIC HEALTH ASSESSMENT

GARDEN CITY GROUNDWATER PLUME NPL SITE

GARDEN CITY, BARTHOLOMEW COUNTY, INDIANA

EPA FACILY ID: INN000508642

Prepared by:

Central Branch
Division of Community Health Investigations
U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry

The findings and conclusions in this report have not been formally disseminated by the Agency for Toxic Substances and Disease Registry and should not be construed to represent any agency determination or policy.

Foreword

The Agency for Toxic Substances and Disease Registry (ATSDR) was established by Congress in 1980 under the Comprehensive Environmental Response, Compensation, and Liability Act, also known as the Superfund law. This law set up a fund to identify and clean up our country's hazardous waste sites. The U.S. Environmental Protection Agency (EPA) and individual states regulate investigation and cleanup of the sites.

Since 1986, ATSDR has been required by law to conduct a public health assessment at each site on the EPA National Priorities List. The aim of these evaluations is to find out if people are being exposed to hazardous substances and, if so, whether that exposure is harmful and should be stopped or reduced. If appropriate, ATSDR also conducts public health assessments when petitioned by concerned individuals. Public health assessments are carried out by environmental and health scientists from ATSDR and from states with which ATSDR has cooperative agreements. The public health assessment program allows the scientists flexibility in the format or structure of their response to the public health issues at hazardous waste sites. For example, a public health assessment could be one document, or it could be a compilation of several health consultations. The structure may vary from site to site, but the public health assessment process is not considered complete until all public health issues at the site are addressed.

Exposure: As the first step in the evaluation, ATSDR scientists review environmental data to see how much contamination is at a site, where it is, and how people might come into contact with it. Generally, ATSDR does not collect its own environmental sampling data; it reviews information provided by EPA, other government agencies, businesses, and the public. When available environmental information is insufficient, the report will indicate what further sampling data are needed.

Health Effects: If the environmental data review shows that people have or could come into contact with hazardous substances, ATSDR scientists evaluate whether or not these contacts might result in harmful effects. ATSDR recognizes that children, because of their play activities and growing bodies, might be more vulnerable than adults to these effects. As a policy, unless data are available to suggest otherwise, ATSDR considers children to be more sensitive and vulnerable to hazardous substances. Thus, ATSDR scientists consider the effect on children's health first when evaluating the potential health threat to a community. The health effects to other high-risk groups within the community (such as the elderly, chronically ill, and people engaging in high-risk practices) also receive special attention during the evaluation.

ATSDR uses existing scientific information to determine the health effects that might result from exposures. This information can include the results of medical, toxicologic, and epidemiologic studies and data collected in disease registries. The science of environmental health is still developing, and sometimes scientific information on the health effects of certain substances is not available. In such cases, the report will suggest further public health actions.

Conclusions: The report presents conclusions about the public health threat, if any, at a site. Threats for high-risk groups (such as children, elderly, chronically ill, and people engaging in high-risk practices) will be summarized in the conclusion section of the report. Ways to stop or reduce exposure will then be recommended in the public health action plan.

ATSDR is primarily an advisory agency, so usually these reports identify what actions are appropriate to be undertaken by EPA, other responsible parties, or the research or education divisions of ATSDR. However, if there is an urgent health threat, ATSDR can issue a public health advisory warning people of the danger. ATSDR can also authorize health education or pilot studies of health effects, full-scale epidemiology studies, disease registries, surveillance studies, or research on specific hazardous substances.

Community: ATSDR also needs to learn what people in the area know about the site and what concerns they have about its effect on their health. Consequently, throughout the evaluation process, ATSDR actively gathers information and comments from people who live or work near a site, including area residents, civic leaders, health professionals, and community groups. To ensure that the report responds to the community's health concerns, ATSDR distributes a version to the public for comment and responds to all comments in the final version of the report.

Comments: If after reading this report you have questions or comments, we encourage you to send them to us.

Letters should be addressed as follows:

Agency for Toxic Substances and Disease Registry
ATTN: Records Center
1600 Clifton Road, NE (Mail Stop F-09)
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Contents

Acronyms and Abbreviations

ADAFs	age-dependent adjustment factors
ATSDR	Agency for Toxic Substances and Disease Registry
CDC	Centers for Disease Control and Prevention
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS	EPA's Comprehensive Environmental Response, Compensation, and Liability Information System
CFR	Code of Federal Regulations
CREG	cancer risk evaluation guide
CSF	cancer slope factor
CV	comparison value
DHHS	U.S. Department of Health and Human Services
EMEG	environmental media evaluation guide
USEPA	U.S. Environmental Protection Agency
ESI	Expanded Site Inspection
g	gram
GAC	granular activated carbon
HED	human equivalent dose
HRS	Hazard Ranking System; scoring system to place site on NPL
IDEM	Indiana Department of Environmental Management
kg	kilogram (1,000 grams)
l	liter
LOAEL	lowest-observed-adverse-effect level
MCL	Maximum Contaminant Level
mg	milligrams (1/1,000 gram)
mg/kg/day	milligrams per kilogram per day
MRL	minimal risk level
NPL	National Priorities List
NTP	National Toxicology Program
PA	Preliminary Assessment
PCE	tetrachloroethylene
ppb	parts per billion
ppm	parts per million
RfD	reference dose
RME	reasonable maximum exposure
RMEG	reference dose media evaluation guide
SGSL	soil gas screening levels
SI	Site Inspection
TCE	trichloroethylene
µg	microgram (1/1,000,000 gram)
VISL	vapor intrusion screening levels
VOCs	volatile organic compounds

1. Summary

Introduction

The Agency for Toxic Substances and Disease Registry (ATSDR) in Atlanta, Georgia, is a federal public health agency within the U.S. Department of Health and Human Services (DHHS). ATSDR is the principal federal public health agency charged with evaluating human health effects of exposure to hazardous substances in the environment. ATSDR recognizes that you want to know more about current and future exposures to hazardous substances released from the Garden City Groundwater Plume site. This public health assessment will give you information you need to protect your health.

The Garden City Groundwater Plume site in Garden City, Indiana, was placed on the U.S. Environmental Protection Agency's (EPA) National Priorities List (NPL) in December 2013. ATSDR is required to conduct a public health assessment on the NPL sites. ATSDR uses the public health assessment process to evaluate potential public health effects of current and future exposures to environmental contamination at NPL sites. The public health assessment process serves as a mechanism for identifying appropriate follow-up public health actions for particular communities.

In conducting this public health assessment, ATSDR scientists reviewed site information, data, and findings from previous environmental investigations and scientific literature, and evaluated the potential for exposure to volatile organic compounds (VOCs) in air, soil, and groundwater affected by the release of hazardous substances. ATSDR then evaluated recent environmental sampling data from areas potentially affected by the release of hazardous substances. This assessment considered potential exposures to chemicals for people who live and work in Garden City.

Conclusions

After reviewing the available environmental sampling data and evaluating possible exposure to chemicals, ATSDR reached the following conclusions.

Conclusion 1

ATSDR concludes that as long as the granular activated carbon (GAC) filtration systems are monitored and maintained for residential wells A, B, and E and commercial well #2, people using the filtered drinking water from these wells for domestic and business purposes (e.g., drinking, showering, bathing, dishwasher, washing machine, etc.) are not currently being exposed to trichloroethylene

(TCE). Therefore, the current exposure situation is not expected to harm the health of adults, children, and fetus.

Basis for Conclusion 1

- In 1990, the Indiana Department of Environmental Management (IDEM) installed and has since maintained the GAC filter systems in these three homes with TCE levels in the unfiltered drinking water exceeding the EPA maximum contaminant level (MCL) of 5 ppb for TCE. The IDEM also installed and maintained a GAC filter system in a drive-in restaurant business when TCE levels in unfiltered drinking water exceeded the EPA MCL.

- The GAC filter removes TCE and other VOCs from the unfiltered drinking water prior to the water being used in the home and restaurant. Therefore, if the filtrations systems are maintained and filtered drinking water from the well does not contain TCE, harmful health effects are not expected from adults and children using the filtered water.

- If the GAC filter systems are removed or not adequately maintained, domestic and business use (e.g., drinking, showering, bathing, dishwasher, washing machine, etc.) of the drinking water from these wells would likely result in ingestion, inhalation, and dermal contact exposure to TCE. The current levels of TCE in the unfiltered drinking water from residential well A and B may put adults and children at greater risk for the health effects associated with TCE exposure (e.g. immune and developmental effects, certain types of cancer).

Conclusion 2 ATSDR concludes that residents who use drinking water from the Garden City Mobile Home Park well and residential well C for household purposes (e.g., drinking, showering, bathing, etc.) are currently exposed to low levels of TCE in the drinking water. The current levels of TCE in the drinking water are not expected to harm the health of adults, children, or fetus.

Basis for Conclusion 2

- Children and adults using the drinking water from the Garden City Mobile Home Park wells and residential well C for domestic purposes are exposed to low levels of TCE. TCE exposure can occur from ingestion (drinking the water), inhalation (breathing TCE evaporating from the water while showering, bathing, dishwasher, washing machine, etc), and dermal absorption (skin contact with TCE in water during a shower, bathing, or other household uses). The Garden City Mobile Home Park well is a private community water system that supplies drinking water to 47 mobile homes.

- Exposure to the current low levels of TCE in the drinking water from the Garden City Mobile Home Park and residential well C are not expected to harm the health of an adult, child, or fetus.

Conclusion 3 ATSDR concludes that people working in the office currently using the drinking water from commercial well #4 have minimal exposure to TCE in drinking water. The current exposure situation is not expected to harm the health of people working in the office.

Basis for Conclusion 3

- The water from commercial well #4 is currently used in an office to make coffee, wash hands, and supply water to the toilet which results in minimum exposure from ingestion (drinking coffee), dermal absorption (washing hands), and inhalation (breathing TCE evaporating from the making coffee, washing hands, and use of toilet).

- The current exposure scenario in the office results in estimated total TCE doses well below the ATSDR MRL screening guideline and is not at levels expected to harm the health of people working in the office.

Conclusion 4 ATSDR cannot adequately characterize the public health hazard of exposure to TCE in the drinking water from some residential and commercial wells near the groundwater plume.

Basis for Conclusion 4

- Drinking water from four wells (residential wells D, F, and G and commercial well #5) were sampled only once in 2011 due to access issues. While this drinking water data indicate exposure to low levels of TCE that are not expected to harm health, too few drinking water samples from each well were collected and analyzed for VOCs to adequately characterize TCE exposure over an extended period.

- Drinking water from some wells used for domestic and commercial purposes near the groundwater plume have not been sampled and analyzed for VOCs due to access issues. Drinking water TCE data are not available for these wells, and ATSDR cannot determine whether drinking water in these wells contains contaminants at public health hazard levels.

Conclusion 5 ATSDR does not expect vapor intrusion exposure to TCE or other VOCs at levels that harm the health of adults or children.

Basis for Conclusion 5

- TCE and other VOC levels in the shallow drinking water samples and soil gas samples were below ATSDR's vapor intrusion screening levels.

Next Steps

From its review of available information, ATSDR recommends the following:

1. To adequately characterize potential exposure to TCE in drinking water, EPA should sample and analyze for VOCs in drinking water from all private wells in the vicinity of the TCE groundwater plume. This drinking water sampling should including residential wells D, E, F, G and commercial well #5 sampled only once in 2011, and other private wells near the groundwater plume that have not been sampled due to access issues.

2. If residents do not want to monitor the drinking water from their private well, they should install and maintain a GAC filter system or connect the residence or business to the Columbus municipal water utility to prevent exposure to TCE in drinking water.

3. If TCE is detected in the drinking water from a private well, EPA should continue monitoring the drinking water to ensure TCE concentrations do not increase to levels of health concern.

4. If the TCE concentration in the groundwater increases to levels of health concern, IDEM should either install and maintain a GAC filter system or connect the residence to the Columbus municipal water utility to prevent exposure to TCE in drinking water.

5. IDEM should continue to maintain the GAG filter systems and monitor the drinking water from the filter system in the private wells.

6. ATSDR, IDEM, and the Bartholomew County Health Department should inform people in Garden City, Indiana, of the potential health effects from exposure to TCE levels in drinking water in their residential or commercial wells. Also, inform people how to reduce exposure to TCE in drinking water by using a GAC filter system or connecting to the Columbus municipal water utility.

For more information, call ATSDR at 1-800-CDC-INFO and ask for information on the U.S. Garden City groundwater plume site.

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2. Statement of Issues

The Agency for Toxic Substances and Disease Registry (ATSDR) in Atlanta, Georgia, is a federal agency within the U.S. Department of Health and Human Services (DHHS). ATSDR is the principal federal public health agency charged with evaluating human health effects of exposure to hazardous substances in the environment. ATSDR's purpose is to serve the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent people from coming into contact with harmful toxic substances.

ATSDR is required to conduct public health assessments of sites proposed by USEPA to the National Priorities List (NPL) under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and its amendments. The Garden City Groundwater Plume site in Garden City, Indiana, was placed on the NPL in December 2013.

In conducting its public health assessments, ATSDR scientists evaluate and analyze information from previous studies and investigations. ATSDR uses the public health assessment process to assess potential public health impacts of past, current, and future exposures to environmental contamination from an NPL site. The public health assessment process serves as a means to identify appropriate recommendations for follow-up public health actions. The process is also a way through which the agency responds to specific community health concerns related to hazardous waste sites.

For the Garden City Groundwater Plume public health assessment, ATSDR scientists evaluated the potential for current and future exposure to trichloroethylene (TCE) and other VOCs detected in the drinking water from private residential, commercial, and community wells in Garden City, Indiana, and public municipal wells in the Columbus, Indiana Marr-Glick Well Field south of Garden City. ATSDR scientists assessed the potential for residents to be exposed from ingesting TCE in drinking water, inhaling TCE that volatilized while bathing and showering, and dermal absorption of TCE in the water while bathing and showering. ATSDR scientists evaluated recent environmental sampling data collected by IDEM in 2011, USEPA in 2015 and 2016, and the Garden City Mobile Home Park community water system from 2002 to 2016.

ATSDR scientists then determined whether exposure-related cancerous and noncancerous health effects are possible in local residents. The potentially exposed population included people who use private wells in Garden City, as well as people who use city of Columbus municipal water from the Marr-Glick Well Field. In this report, ATSDR scientists characterize the potential for exposure to hazardous substances and the health implications from such exposures. They also recommend public health actions to prevent or reduce future human exposures.

3. Background

3.1. Site Description

The Garden City Groundwater Plume site is located within the unincorporated town of Garden City, Bartholomew County, Indiana (see Figure 1). The groundwater plume containing TCE is in a major unconfined alluvial (sand and gravel) aquifer located in the flood plain of the East Fork of the White River [USEPA 2013]. The highest TCE concentrations detected in the groundwater plume are located in the alluvial aquifer approximately 45 feet below ground surface. The TCE groundwater plume extends from the former Kiel Brother's property (850 Jonesville Road) to south of intersection of Jonesville Road (State Road 11) and Garden Street (County Road 100 South) in the center of town [USEPA 2013]. The TCE groundwater plume encompasses an area from approximately 500 feet north to 500 feet south of the Garden Street and from approximately 250 feet west to 500 feet east of Jonesville Road [USEPA 2013]. The groundwater flow was primarily to the east, towards the White River [USEPA 2013].

Garden City consists of low-density residential properties, commercial businesses, and the Garden City Mobile Home Park. All homes, businesses, and Garden City Mobile Home Park use private wells for drinking water (see Figure 2) [USEPA 2013]. These private residential, commercial, community wells draw groundwater from the unconfined alluvial aquifer at depths between 40 and 60 feet below ground surface [USEPA 2013]. The area immediately surrounding Garden City is mostly rural except for the City of Columbus, which is one mile north of Garden City. Irrigation farm wells are located in the rural area surrounding Garden City.

The entire Garden City groundwater TCE plume is within the southern wellhead protection area (WHPA) for the city of Columbus, Indiana [USEPA 2013]. Columbus municipal water utility operates 15 groundwater wells in the Marr-Glick Well Field located within this WHPA. The municipal wells closest to Garden City are approximately 0.6 to 0.8 miles south and southeast of the intersection in the center of Garden City and about 3000 to 4000 feet south and southwest of the southernmost boundary of the TCE plume [USEPA 2013] (see Figure 2). The Columbus municipal water utility wells draw water from 80 to 100 feet below ground surface and are typically screened at the base of the unconfined alluvial aquifer on top of the bedrock [USEPA 2013]. The Columbus municipal water utility blends groundwater from all 15 wells in the Marr-Glick Well Field prior to distribution to consumers. The Columbus Marr-Glick Well Field and another well field north of Columbus serve an estimated population of 45,000.

3.2. Site Operational History

In 1989, IDEM investigated a complaint about petroleum odors in drinking water at a Garden City residence [IDEM 2012]. IDEM detected petroleum products and VOCs including benzene, toluene, and TCE in drinking water from private residential and business wells. The drinking water from the well at the Kiel Brothers Oil Company gasoline station had the highest concentration of VOCs [USEPA 2013]. Drinking water samples from several locations exceeded EPA's MCL drinking water standard of 5 parts per billion (ppb) (micrograms per liter [µg/L]) for benzene and TCE, respectively [USEPA 2013]. See Appendix B for ATSDR Tox FAQ – Tricholorethylene.

IDEM installed and maintains granular activated carbon (GAC) filter systems on wells of three affected residences and one commercial business (restaurant) to remove TCE and other VOC contaminants (IDEM 1991). GAC filter systems were installed on wells with TCE concentration levels exceeding the EPA MCL. The restaurant had a point of use carbon filtration system on the drinking water tap prior to the IDEM detecting TCE in the commercial well drinking water sample in 1989 (IDEM 1991). The IDEM changed the filter on the carbon filtration system for the restaurant after the 2009 unfiltered water samples from the restaurant well contained a TCE concentration (5.83 ppb) that exceeded the EPA MCL. The filter was changed again in 2016. TCE was not detected in filtered and unfiltered drinking water samples from the restaurant well in 2015 and 2016.

The 1990 IDEM's Underground Storage Tank Section investigation determined the source of the petroleum products was the Kiel Brothers gasoline station, which was undergoing an underground storage tank upgrade at the time of the initial complaint [USEPA 2013]. In 1991, IDEM's investigation revealed no evidence the Kiel Brothers gasoline station or any of the previous operators used or stored TCE on site and concluded that the TCE contamination was unrelated to any Kiel Brothers underground storage tank [USEPA 2013]. The Kiel Brothers would treat the site as a normal petroleum release situation and would not be responsible for the TCE remediation [USEPA 2013]. The Kiel Brothers site was entered into the EPA's Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) for continued investigation of TCE contamination [USEPA 2013]. The 1991 IDEM Preliminary Assessment (PA) on the Kiel Brothers site detected VOCs in groundwater samples. The two samples taken from Kiel Brothers well and the drive-in restaurant well exceeded the MCL for TCE. No contamination was detected in the municipal wells. IDEM conducted further drinking water sampling in 1992, 1994, 1996, 1997, and 2002 [USEPA 2013]. TCE was consistently detected in drinking water, and occasionally the TCE levels exceeded the MCL in residential and commercial well samples [USEPA 2013]. In 2002, IDEM determined that no further action was required for the Kiel Brothers site, the petroleum product cleanup was completed, and Kiel Brothers is not the source of the TCE in the groundwater and would not be responsible for the TCE remediation [USEPA 2013]. The Kiel Brothers site was archived in CERCLIS in 2002 [USEPA 2013].

In 2002, the Garden City Groundwater Plume was designated as a new CERCLIS site for continued investigation into the source of the TCE in the groundwater. IDEM conducted a combined Preliminary Assessment/Site Inspection (PA/SI) in 2002 and an Expanded Site

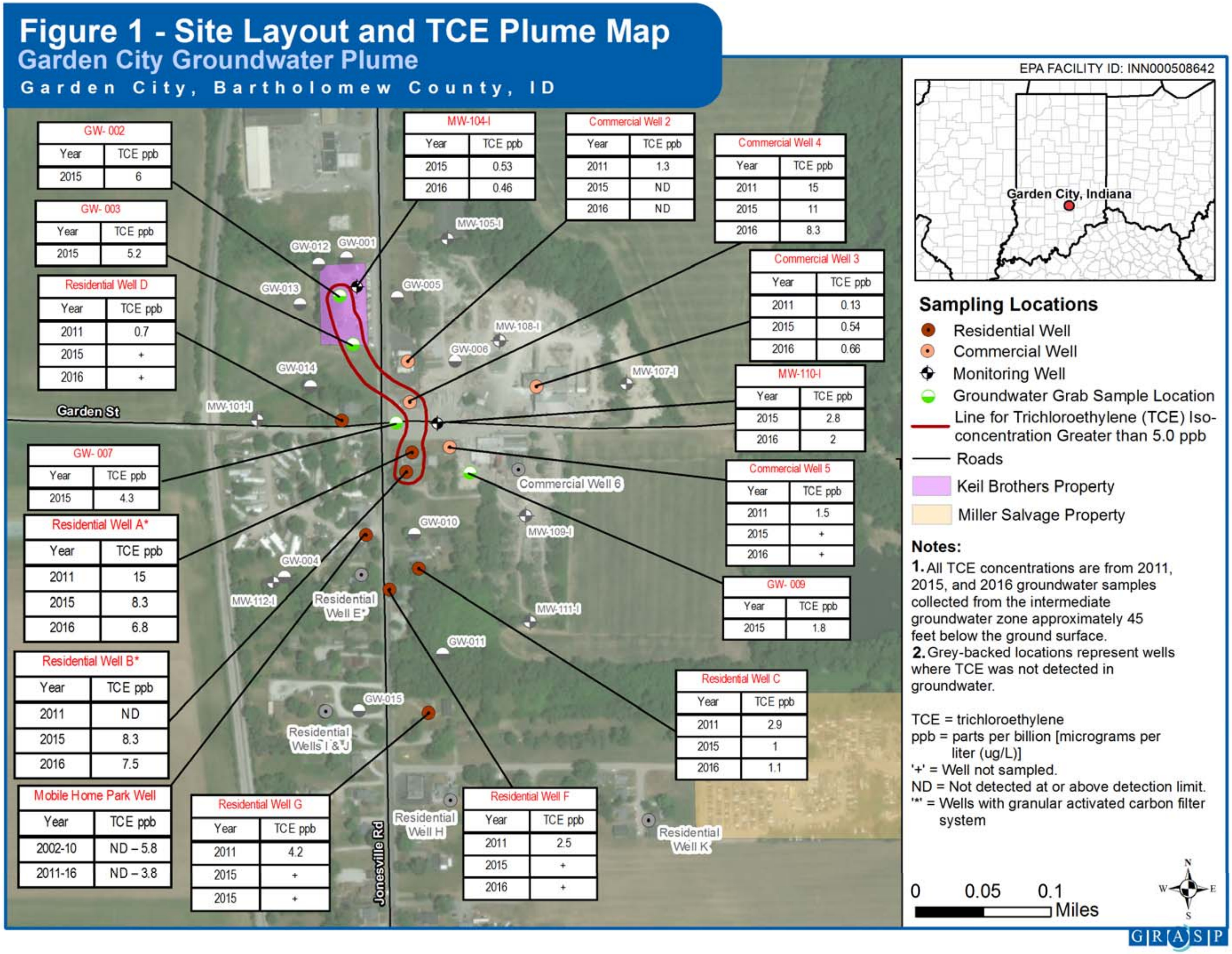


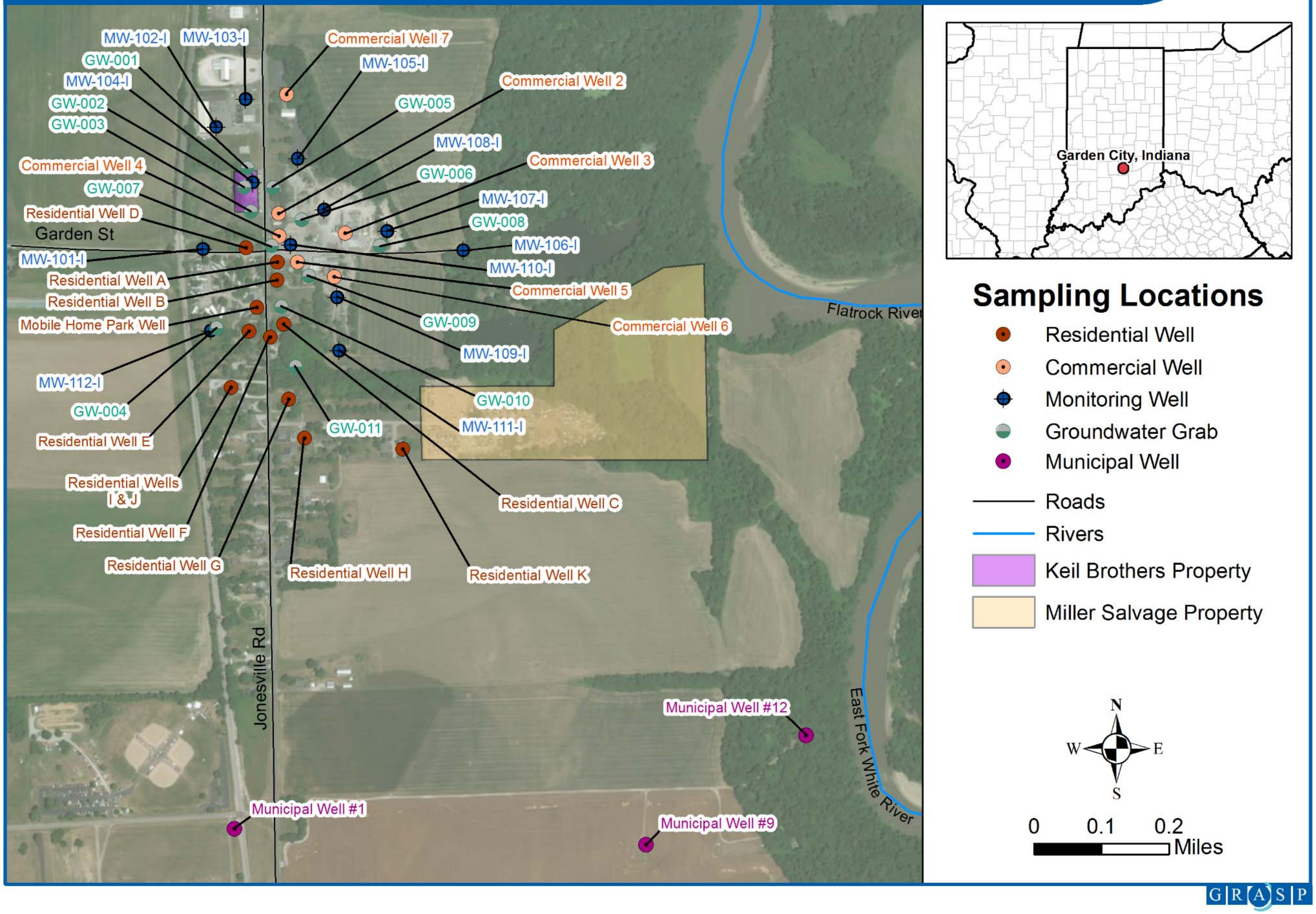
Figure 1 - Site Layout and TCE Plume Map
Garden City Groundwater Plume
Garden City, Bartholomew County, ID
EPA FACILITY ID: INN000508642
Garden City, Indiana
GW- 002
Year TCE ppb
2015 6
GW- 003
Year TCE ppb
2015 5.2
Residential Well D
Year TCE ppb
2011 0.7
2015 +
2016 +
GW- 007
Year TCE ppb
2015 4.3
Residential Well A*
Year TCE ppb
2011 15
2015 8.3
2016 6.8
Residential Well B*
Year TCE ppb
2011 ND
2015 8.3
2016 7.5
Mobile Home Park Well
Year TCE ppb
2002-10 ND – 5.8
2011-16 ND – 3.8
Residential Well G
Year TCE ppb
2011 4.2
2015 +
2015 +
MW-104-I
Year TCE ppb
2015 0.53
2016 0.46
Commercial Well 2
Year TCE ppb
2011 1.3
2015 ND
2016 ND
Commercial Well 4
Year TCE ppb
2011 15
2015 11
2016 8.3
Commercial Well 3
Year TCE ppb
2011 0.13
2015 0.54
2016 0.66
MW-110-I
Year TCE ppb
2015 2.8
2016 2
Commercial Well 5
Year TCE ppb
2011 1.5
2015 +
2016 +
GW- 009
Year TCE ppb
2015 1.8
Residential Well C
Year TCE ppb
2011 2.9
2015 1
2016 1.1
Residential Well F
Year TCE ppb
2011 2.5
2015 +
2016 +
GW-012
GW-001
GW-013
GW-005
MW-105-I
MW-108-I
GW-006
GW-014
MW-107-I
MW-101-I
Garden St
Commercial Well 6
GW-010
MW-109-I
GW-004
MW-112-I
Residential Well E*
MW-111-I
GW-011
GW-015
Residential Wells I & J
Residential Well H
Residential Well K
Jonesville Rd
Sampling Locations
Residential Well
Commercial Well
Monitoring Well
Groundwater Grab Sample Location
Line for Trichloroethylene (TCE) Iso-concentration Greater than 5.0 ppb
Roads
Keil Brothers Property
Miller Salvage Property
Notes:
1. All TCE concentrations are from 2011, 2015, and 2016 groundwater samples collected from the intermediate groundwater zone approximately 45 feet below the ground surface.
2. Grey-backed locations represent wells where TCE was not detected in groundwater.
TCE = trichloroethylene
ppb = parts per billion [micrograms per liter (ug/L)]
'+' = Well not sampled.
ND = Not detected at or above detection limit.
'*' = Wells with granular activated carbon filter system
0 0.05 0.1 Miles
N
W E
S
GRASP

Figure 2 – Site Layout and Groundwater Sampling Locations in 2011, 2015, and 2016

Garden City Groundwater Plume

Garden City, Bartholomew County, ID

EPA FACILITY ID: INN000508642



Inspection (ESI) in 2011. TCE continued to be detected in drinking water samples from private wells at residences, businesses, the Garden City Mobile Home Park, and two Columbus municipal wells. IDEM referred the Garden City Groundwater Plume site to the EPA for National Priorities List (NPL) for Superfund sites because the site requires a long-term response action. In December 2013, EPA added the Garden City Groundwater Plume site to the NPL.

In the 1980s, Miller Salvage and Crating scrap yard (Miller Salvage) in Garden City was investigated under CERCLA [USEPA 2013]. The two-acre Miller Salvage site is located approximately ½ mile southeast of the Garden City intersection and ½ mile north of the City of Columbus Marr-Glick Well Field (see Figure 2) [IDEM 2012, USEPA 2013]. In 1981, Cummins reported disposing an estimated 3.5 million gallons of waste containing 1,1,1-tricholorethane and TCE at Miller Salvage over 17 years, ending in 1969 [USEPA 2013]. Since 1969, Cummins has conducted remedial investigations under the IDEM State Cleanup Section Oversight [USE2013]. In 2010, IDEM determined that no further action is required for the Miller Salvage site because of consistently low groundwater concentrations of contaminants of concern and groundwater flow directions toward the river and not the Marr-Glick Well Field [IDEM 2012]. The groundwater flow through Miller Salvage is generally to the east/southeast, down gradient from Garden City [USEPA 2013]. Groundwater monitoring does not show TCE contamination between the Garden City groundwater plume and Miller Salvage [USEPA 2013].

3.3. Demographic Information

According to 2010 U.S. Census count, within 0.5 miles of the intersection of Jonesville Road and Garden Street in the center of Garden City is an estimated population of 256 (US Census 2010) (see Figure 3). Most of the people identify as Hispanic or Latino (53%, 136 people). In this community, the population consist of 49% white (126 people), 1% Asian (3 people), less than 1% black (2 people), and 48% other (123 people). The census tract southwest of the intersection has the highest number of children 6 years and younger, and the highest number of females of childbearing age. This census track includes Garden City Mobile Home Park.

Approximately 50 individual residences, several businesses, and the Garden City Mobile Home Park containing 47 mobile homes are located in Garden City [USEPA 2013]. All the homes, businesses, and mobile home park use individual private potable wells that are between 40 and 60 feet deep and draw water from the unconfined sand and gravel aquifer [USEPA 2013]. The Garden City Mobile Home Park has a private well and community water delivery system.

3.4. Community Concerns

ATSDR has communicated with other involved federal, state, and local agencies in an effort to understand the concerns of the community. The only documented concern has been that some community members are concerned about potential health effects from using the contaminated water for household purposes. That community concern is addressed in this document.

Figure 3. General Site Profile

EPA FACILITY ID INN000508642

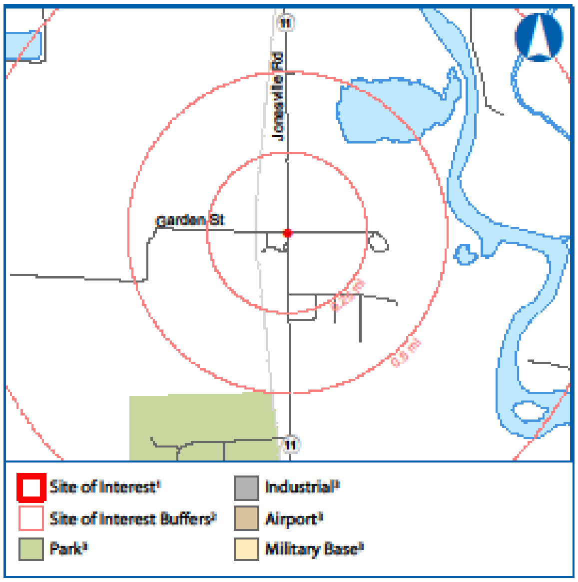
INTRODUCTORY MAP SERIES

Figure 3 - General Site Profile

Garden City Groundwater Plume

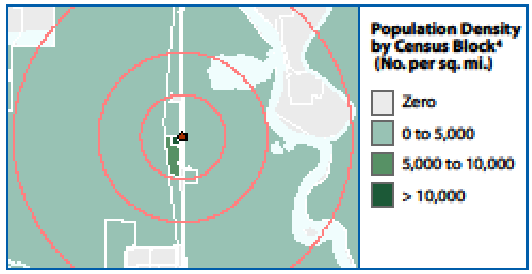
Garden City, Bartholomew County, ID

Site Vicinity Map

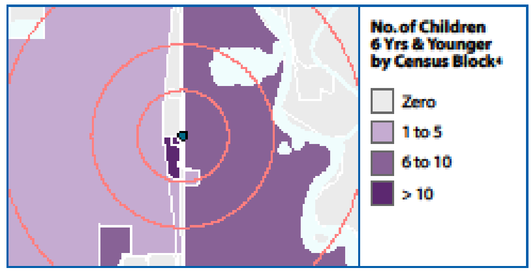


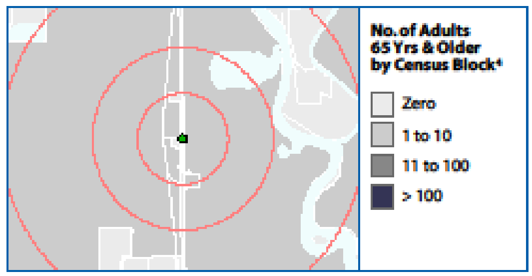
The **General Site Profile Map** depicts the hazardous waste site of interest, along with any airport, industrial, military, or park land uses. It also provides community demographic and housing statistics.

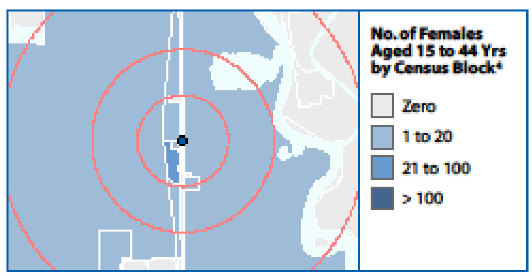
General Population Density



Sensitive Populations







Demographic Statistics[4,5]

Based on 2010 Census data

Measure	0.25 Mi	0.5 Mi	1 Mi
Total Population	210	256	353
White Alone	87	126	216
Black Alone	1	2	2
Am. Indian & Alaska Native Alone	0	0	0
Asian Alone	3	3	3
Native Hawaiian & Other Pacific Islander Alone	0	0	0
Some Other Race Alone	117	123	129
Two or More Races	2	2	3
Hispanic or Latino[6]	130	136	142
Children Aged 6 and Younger	34	42	55
Adults Aged 65 and Older	7	14	21
Females Aged 15 to 44	46	57	80
Housing Units	65	84	120
Housing Units Pre 1950	1	7	296
Businesses	13	24	31

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 Indiana East FIPS 1301 Feet.

PRJ 04903 LSF2 12/13/16

GRASP

Agency for Toxic Substances and Disease Registry

Division of Toxicology and Human Health Sciences

ATSDR

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4. Exposure Pathway Analysis

A critical step in ATSDR's public health assessment process is to assess exposure pathways. ATSDR uses exposure pathways to evaluate the specific ways in which people come into contact with environmental contamination. An exposure pathway is the link between an environmental release and the people that come into contact with, or are exposed to, the environmental contamination.

Exposure or contact drives ATSDR's public health assessments. Contaminants released into the environment have the potential to cause harmful health effects. Nevertheless, a release does not always result in exposure. People can be exposed to a contaminant only if they come into contact with it: if they drink, eat, breathe, or come into skin contact. If no one comes into contact with a contaminant, no exposure and no health effects occur. Often, the public does not have access to the contaminants moving through the environment. This lack of access becomes important in determining whether people could come into contact with the contaminants.

The way the chemical moves through the environment from a source to a person or group of people is the exposure pathway. ATSDR scientists evaluate site-specific conditions to determine how people might come into contact with site-related contaminants. ATSDR identifies and evaluates the five elements of an exposure pathway (see Box, right) to determine whether exposure to contaminated media (air, soil, dust, surface water, groundwater, waste, or even plants and animals) is occurring by inhalation, ingestion, or absorption.

> An exposure pathway has five elements:
>
> 1. a source of contamination,
> 2. an environmental medium,
> 3. a point of exposure,
> 4. a route of human exposure, and
> 5. a receptor population.
>
> The exposure pathway is incomplete if any one of these five elements is missing.
>
> The source is the place where the chemical or radioactive material was released. The environmental media (such as, groundwater, soil, surface water, or air) transport the contaminants. The point of exposure is the place where persons come into contact with the contaminated media. The route of exposure (for example, swallowing, breathing, or touching) is the way the contaminant enters the body. The people actually exposed are the receptor population.

ATSDR identifies an exposure pathway as complete or potential, or eliminates the pathway from further evaluation. An exposure pathway is considered complete if all five elements of an exposure pathway occur at a site linking the receptor population to the contaminant source. For an exposure to occur, a *completed exposure pathway* with all five elements—contact with the contaminant—must exist.

An exposure pathway is considered potentially complete if some of the elements are found and the others cannot be eliminated. A *potentially completed exposure pathway* exists when one or more of the elements are missing but available information indicates possible human exposure might be occurring. A potential exposure pathway is one that ATSDR cannot rule out, even though not all of the five elements are identifiable.

An *eliminated exposure pathway* exists when one or more of the elements are missing. No exposure pathway exists if any of the five elements are known to be absent. Exposure pathways can be ruled out if the site characteristics make human exposures extremely unlikely. If people are not exposed to contaminated areas, the pathway is eliminated from further evaluation because the contaminant cannot cause health effects. Also, an exposure pathway is eliminated if site monitoring reveals that media in accessible areas are not contaminated.

4.1 Exposure Pathways Evaluated at Garden City Groundwater Plume Site

TCE primarily enters the body when a person breathes air or drinks water containing TCE [ATSDR 2014a]. Dermal absorption of TCE is a significant route of exposure from direct contact with skin [ATSDR 2014a]. TCE in water can easily enter the body when a person drinks or touches the water or breathes in steam [ATSDR 2014a]. Most of the TCE from drinking or breathing will quickly move from the stomach or lungs and be absorbed into the bloodstream and into other organs [ATSDR 2014a]. TCE on the skin, or in a liquid such as well water on the skin, can get through the skin into your bloodstream. Once TCE is in the blood, the liver changes much of it into other chemicals [ATSDR 2014a], the majority of which leave the body via urine within a day [ATSDR 2014a]. People also quickly breathe out much of the TCE in their bloodstreams [ATSDR 2014a]. Some TCE or its breakdown products can be stored in body fat for a brief period and thus might build up in the body if exposure continues [ATSDR 2014a].

ATSDR evaluated the drinking water and vapor intrusion exposure pathways to determine if people might come into contact with TCE in the groundwater plume. For domestic use of drinking water, ATSDR evaluated the ingestion, inhalation, and dermal absorption routes of exposure for all age groups, including pregnant women.

Vapor intrusion is the migration of VOC vapors from the subsurface VOC-contaminated groundwater and soil through pore spaces of soil into the indoor air of homes and commercial buildings. TCE can be a frequently occurring chemical in indoor air of buildings as a result of vapor intrusion from nearby TCE contaminated subsurface soil and groundwater. Vapor intrusion can cause health concerns from low-level exposures lasting several weeks to months. [ATSDR 2014a]. Vapor intrusion into indoor air can be a public health concern via the inhalation pathway [ATSDR 2014a]. For the vapor intrusion pathway, ATSDR evaluates the inhalation route of indoor air exposure.

Current and future exposure conditions evaluated are summarized in Table 1.

Table 1. Exposure Pathways Evaluated at the Garden City Groundwater Plume Site

Source	Point of Exposure	Environmental Media	Route of Human Exposure	Exposed Population (years)
TCE Groundwater Plume	Residential Wells Commercial wells Municipal wells	Drinking Water	Ingestion (drinking of water) Inhalation (breathing volatilized TCE while showering, bathing, or other household use) Dermal absorption (skin contact with water while showering, bathing, or other household use)	All Age Groups
	Affected rooms in residence	Indoor Air (Vapor Intrusion)	Inhalation	All Age Groups

5.0 Evaluation of Environmental Data

In this public health assessment, ATSDR evaluates the most recent drinking water sampling data from the 2011 Expanded Site Inspection by IDEM and the 2015 and 2016 Remedial Investigations by EPA [IDEM 2011, EPA 2016a, 2016b]. VOCs on the EPA Target Compound List were analyzed for in the drinking water samples because previous investigations of the site detected elevated levels of TCE and other VOCs in groundwater. Drinking water samples were collected from residential wells, commercial wells, municipal wells, monitoring wells, and boreholes. ATSDR also used the 2002 to 2016 quarterly drinking water data for the Garden City Mobile Home Park well [IDEM 2016].

5.1 Screening Analysis—Identifying Chemicals of Potential Concern

To evaluate the recent Garden City drinking water sampling data, ATSDR used a two-step screening analysis to evaluate all VOCs detected in the drinking water sampling and to identify chemicals of potential public health concern requiring further in-depth evaluation in the public health implication section. ATSDR's screening process enables ATSDR to identify wells with drinking water containing TCE and other VOCs at concentrations of potential public health concern that need closer evaluation.

5.2 Comparing TCE Concentrations to ATSDR Comparison Values

In the first step of the screening process, ATSDR evaluated the drinking water sampling data by comparing the chemical concentrations detected in the drinking water against ATSDR's conservative (protective), comparison values (CV) and EPA's MCL. ATSDR defines a CV as a calculated concentration of a substance that is unlikely to cause harmful (adverse) health effects in exposed people. The CV is used as a screening tool during the public health assessment process. Substances found in amounts greater than their CVs are selected for further evaluation in the second step of the screening process. See Appendix C for discussion on ATSDR's chemical screening process, ATSDR CVs, and results of comparing TCE concentrations to ATSDR CVs .

Residential Drinking Water Data

In 2011, 20015, and 2016, a total of 22 drinking water samples were collected from 11 residential wells used for domestic purposes (see Table 2 and Figure 1). The analysis detected TCE in 11 of the residential drinking water samples from six residential wells (A, B, C, D, F, G).

Table 2. Residential Wells with Drinking Water TCE Concentrations Greater than ATSDR Comparison Value and EPA Maximum Contaminant Level

Residential Well	Samples/Detection	Range of Concentrations (Average Concentration) (ppb)	Detections Exceeding ATSDR Comparison Value of 0.43 ppb	Detections Exceeding EPA MCL of 5 ppb
A *	3/3	6.8 – 15 (10.3)	3	3
B *	3/2	0.5 U – 8.3 (6.3)	2	2
C	3/3	1 – 2.9 (1.7)	3	0
D ‡	1/1	0.71	1	0
E *‡	1/0	0.5 U	0	0
F ‡	1/1	2.5	1	0
G ‡	1/1	4.2	1	0
H	3/0	0.5 U	0	0
I	3/0	0.5 U	0	0
J	1/0	0.5 U	0	0
K	2/0	0.5 U	0	0

Notes: ppb = parts per billion (microgram per liter [µg/L])
U = Chemical not detected at or above the detection limit
CREG = cancer risk evaluation guide, ATSDR health based comparison value
MCL = maximum contaminate level, EPA technology based comparison value
* = Residential well with a granular activated carbon filter since 1990
‡ = Residential well not sampled in 2015 and 2016

Data sources: IDEM 2011, EPA 2016a, EPA 2016b

Garden City Mobile Home Park Well Groundwater Data

The Garden City Mobile Home Park well is used by 47 mobile homes for domestic purposes [IDEM 2012]. The Garden City Mobile Home Park well is a public water system classified as a private community water system because it serves water to a residential population. Since 1997, TCE has been detected in the drinking water from the mobile home park well [IDEM 2012]. Since 2002, the mobile home park drinking water has been monitored for chemicals on a quarterly basis (see Table 3, Figure 1).

Table 3. Garden City Mobile Home Park Drinking Water TCE Concentrations Greater than ATSDR Comparison Value and EPA Maximum Contaminant Level

Year	Samples/Detections	Range of Concentrations (Average Concentration) (ppb)	Detections Exceeding ATSDR Comparison Value (CREG) of 0.43 ppb	Detections Exceeding EPA MCL of 5 ppb
2011	2/2	2.2 (2.2)	2	0
2011-2016 #	24/20	0.5 U – 3.8 (1.9)	20	0
2002 – 2010 #	32/29	0.5 U – 5.8 (4.5)	29	10

Notes: ppb = parts per billion (microgram per liter [µg/L])
U = Chemical not detected at or above the detection limit
CREG = cancer risk evaluation guide, ATSDR health based comparison value
MCL = maximum contaminate level, EPA technology based comparison value
# = Quarterly samples from 2002 to 2016

Data sources: IDEM 2011, IDEM 2002 - 2016

Commercial Well Drinking Water Data

In 2011, 2015, and 2016, 15 drinking water samples were collected from seven commercial wells. TCE was detected in eight samples from four wells (see Table 4 and Figure 1).

Table 4. Commercial Wells with Drinking Water TCE Concentrations Greater than ATSDR Comparison Value and EPA Maximum Contaminant Level

Commercial Well	Samples/Detections	Range of Concentrations (Average Concentration) (ppb)	Detections Exceeding ATSDR Comparison Value (CREG) of 0.43 ppb	Detections Exceeding EPA MCL of 5 ppb
1 ‡	1/0	0.5 U	0	0
2 *	4/1	0.5 U – 1.3 (1.3)	1	0
3	3/3	0.13 – 0.66 (0.54)	2	0
4	4/4	8.3 – 15 (11.4)	3	3
5 +	1/1	1.5	1	0
6 +	1/0	0.5 U	0	0

7	2/0	0.5 U	0	0

Notes: ppb = parts per billion (microgram per liter [µg/L])
U = Chemical not detected at or above the detection limit
CREG = cancer risk evaluation guide, ATSDR health based comparison value
MCL = maximum contaminate level, EPA technology based comparison value
* = Commercial well with filter
‡ = Commercial well not sampled in 2015 and 2016
+ = Commercial well not sampled in 2011 and 2015

Data sources: IDEM 2011, EPA 2016a, EPA 2016b

Municipal Wells Drinking Water Data

In 2011, 2015, and 2016, 11 drinking water samples were collected from four municipal wells (#1, #2, #9, #12) in the Columbus Marr-Glick Well Field (see Table 5 and Figure 2) [IDEM 2012]. The VOC analysis detected TCE in five samples from two municipal wells (#9, #12). In 2015, two drinking water samples from municipal well #9 contained vinyl chloride concentrations (see Table 6 and Figure 2). Since the Columbus municipal water utility blends water from all 15 municipal wells before distributing it to the public, the concentration of TCE and vinyl chloride in municipal well #9 and municipal well #12 will be diluted to much lower concentrations before being consumed.

Table 5. Municipal Wells with Drinking Water TCE Concentrations Greater than ATSDR Comparison Value and EPA Maximum Contaminant Level

Municipal Well	Samples/Detections	Range of Concentrations (Average Concentration) (ppb)	Detections Exceeding ATSDR Comparison Value (CREG) of 0.43 ppb	Detections Exceeding EPA MCL of 5 ppb
1 +	1/0	0.5 U	0	0
2	3/0	0.5 U	0	0
9	5/3	0.5 U – 0.36 (0.35)	0	0
12 ‡	2/2	0.63 – 0.66 (0.65)	2	0

Notes: ppb = parts per billion (microgram per liter [µg/L])
U = Chemical not detected at or above the detection limit
CREG = cancer risk evaluation guide, ATSDR health based comparison value
MCL = maximum contaminate level, EPA technology based comparison value
‡ = Municipal well not sampled in 2016
+ = Municipal well not sampled in 2011 and 2016

Data sources: IDEM 2011, EPA 2016a, EPA 2016b

Table 6. Municipal Wells with Drinking Water Vinyl Chloride Concentrations Greater than ATSDR Comparison Value and EPA Maximum Contaminate Level

Municipal Well	Samples/ Detections	Range of Concentrations (Average Concentration) (ppb)	Detections Exceeding ATSDR Comparison Value (CREG) of 0.025 ppb	Detections Exceeding EPA MCL of 2 ppb
1 +	1/0	0.5 U	0	0
2	3/0	0.5 U	0	0
9	5/2	0.5 U – 0.28 (0.26)	2	0
12 ‡	2/0	0.5 U	0	0

Notes: ppb = parts per billion (microgram per liter [µg/L])
U = Chemical not detected at or above the detection limit
CREG = cancer risk evaluation guide, ATSDR health based screening value
MCL = maximum contaminate level, EPA technology based screening value
‡ = Municipal well not sampled in 2016
\+ = Municipal well not sampled in 2011 and 2016
Data sources: IDEM 2011, EPA 2016a, 2016b, IDEM 2016

Vapor Intrusion Pathway

An evaluation of vapor intrusion warrants consideration at the Garden City groundwater plume site because of the volatile nature of TCE and because the TCE plume runs in the subsurface soil within 100 feet laterally or vertically of occupied homes and commercial buildings (see Figure 1). ATSDR conducted a screening evaluation of vapor intrusion by comparing contaminant concentrations in the shallow groundwater samples and soil gas samples near the water table (approximately 10.5 feet below the ground surface on average) to ATSDR's groundwater vapor intrusion screening levels (VISL) and soil gas screening levels (SGSL) [ATSDR2016]. The 16 shallow groundwater grab samples were collected from 14 locations near the TCE groundwater plume in September 2015 and April 2016 (see Figure 1). All the VOCs except for tetrachloroethylene (PCE) were detected in the shallow groundwater grab samples at concentrations below ATSDR's groundwater VISL. PCE was detected in one shallow groundwater grab sample collected at GW-014 location near the southwest corner of the former Kiel Brothers property. The PCE level of 45 ppb is greater than the ATSDR groundwater VISL of 5.26 ppb (based on the ATSDR cancer risk evaluation guide [CREG]) and less than the ATSDR groundwater VISL of 56.71 ppb (based on ATSDR environmental media evaluation guide [EMEG]) [ATSDR 2016]. Since an occupied commercial building is located within 30 feet of this groundwater sample location, 5 soil gas samples were collected approximately 1 to 2 feet above the top of the water table near the GW-014 location of the shallow groundwater grab sample with the elevated PCE. TCE and PCE soil gas concentrations were detected above the detection limits but below the ATSDR SGSL (see Table 7). Therefore, ATSDR does not expect vapor intrusion exposure to TCE, or PCE at levels of harm the health of adults or children.

Therefore, vapor intrusion of VOCs is not expected to cause health effects, is not considered a health hazard, and is not further evaluated.

Table 7 Soil Gas Sampling Data Compared to ATSDR's Soil Gas Screening Levels

Chemical	Samples/ Detections	Range of Concentrations (Average Concentration) ($\mu g/m^3$)	ATSDR Soil Gas Comparison Value (SGSL) ($\mu g/m^3$)	Detections Exceeding ATSDR Comparison Value (SGSL)
Tetrachloroethene (PCE)	5/4	0.7 U – 1.8	127	0
Trichloroethene (TCE)	5/4	0.5 U – 1.3	7.3	0

Notes: $\mu g/m^3$ = microgram per meter cube
U = Chemical not detected at or above the detection limit
SGSL = soil gas screening levels based on ATSDR cancer risk evaluation guide (ATSDR health based screening value)

5.3 Summary Results of Comparison Value Screening

At each residential, commercial, Garden City Mobile Home Park, and municipal well, ATSDR compared the concentrations of VOCs detected in the groundwater with ATSDR's health-based groundwater CVs. Table 8 lists 12 wells with TCE groundwater concentrations greater than ATSDR's CREG CV of 0.43 ppb TCE and 4 wells with TCE groundwater concentrations greater than the EPA MCL of 5 ppb TCE. ATSDR will further analyze the TCE concentrations in these 12 wells in the second step of the screening process.

Vinyl chloride is the only other VOC detected at concentrations greater than ATSDR's health-based groundwater CVs. Vinyl chloride was detected in two 2015 drinking water samples from municipal well #9 at concentrations greater than the ATSDR CREG CV of 0.025 ppb. Therefore, ATSDR will further evaluate the vinyl chloride concentrations in municipal well #9 in the second step of the screening process.

Table 8. Wells with Drinking Water Containing a TCE Concentration Greater than EPA's MCL and ATSDR Groundwater Comparison Value

Wells with TCE Concentration Greater than EPA MCL (5 ppb)	Wells with TCE Concentration Greater than ATSDR CREG (0.43 ppb)
A residence B residence 2002-2010 Garden City Mobile Home Park commercial #4	A residence B residence C residence D residence F residence G residence commercial #2 commercial #3 commercial #4 commercial #5 2002-20010 Garden City Mobile Home Park 2011-20016 Garden City Mobile Home Park Municipal #12

Notes: ppb = parts per billion (microgram per liter [µg/L])
CREG = cancer risk evaluation guide, ATSDR health based comparison value
MCL = maximum contaminate level, EPA technology based comparison value

5.4 Comparing Estimated TCE Exposure Doses to Health Guideline Values

In the second step of the screening process, ATSDR further evaluated the drinking water TCE levels in each of the 12 wells in Table 8 with drinking water containing a maximum TCE concentration above the ATSDR CREG CV of 0.43 ppb. In this second step of the screening process, ATSDR evaluated all exposure pathways from domestic use of the drinking water to calculate the total TCE exposure dose and the total excess cancer risk for different age groups.

5.5 Non-cancer Screening Evaluation

For each of the 12 wells, ATSDR calculated chronic total TCE doses (annual doses averaged over 1 year of exposure) for different age groups using the contaminated drinking water for drinking and showering. ATSDR paid special attention to TCE exposure of young children and pregnant women because the scientific data on TCE indicate that fetuses and young children may be especially sensitive to the toxic effects of TCE [ATSDR 2014a]. ATSDR calculated within each age group for each well the TCE doses from ingestion exposure, dermal contact exposure, and inhalation exposure. For each well, the total chronic total TCE doses within each age group were calculated by combining the ingestion, dermal, and inhalation doses. ATSDR combined the exposure doses from ingestion, inhalation, and dermal contact because TCE is rapidly absorbed into the bloodstream and distributed to the target organs regardless of exposure route.

ATSDR's conservative (protective), health-based noncancer screening guideline for TCE is the chronic and intermediate oral minimal risk level (MRL) of 5.0 x 10^{-4} mg/kg/day. ATSDR compared the estimated total TCE exposure doses to the MRL for TCE to determine whether TCE concentrations in well drinking water requires further in-depth evaluation in this report's Public Health Implication section [ATSDR 2014a]. See Appendix D for discussion of the ATSDR non-cancer screening evaluation process, ATSDR's health guideline values, and results of non-cancer screening evaluation of comparing estimated total doses to ATSDR MRL for TCE. See Appendix E for exposure does equations and assumptions. See Table 1, Table 2, and Table 3 in Appendix F for estimated total TCE exposure doses and comparison with ATSDR's MRL for TCE.

5.6 Summary Results of Non-cancer Screening Evaluation

In Table 9, five wells (three residential wells A, B, G; Garden City Mobile Home Park well; and commercial well #4) have high-end total TCE doses greater than ATSDR's chronic oral MRL value for TCE (See Table 1 in Appendix F). Three wells (two residential wells A and B, and commercial well #4) in Table 9 have typical total TCE doses greater than ATSDR's chronic oral MRL value for TCE (See Table 2 in Appendix F). Therefore, in the Public Health Implications section, ATSDR will further evaluate exposure pathways and conduct an in-depth health effects evaluation of exposure to TCE in the drinking water from the five wells in Table 9.

The maximum concentration of 0.28 ppb vinyl chloride in the drinking water from municipal well #9 results in high-end vinyl chloride dose for all age groups to be much less than ATSDR's chronic oral MRL value of 3.0 x 10^{-3} mg/kg/day for vinyl chloride. Therefore, ATSDR will not further evaluate noncancer health effects from exposure to vinyl chloride from this well.

Table 9. Wells and Age Groups with Total TCE Doses Greater than ATSDR's Chronic Oral Minimum Risk Levels (MRL) for TCE

Wells	Age Groups With High-End Total TCE Doses Greater than ATSDR's MRL (Years) (Based on Maximum Concentration, RME Ingestion, and CTE Dermal Contact and Inhalation)	Age Groups With Typical Total TCE Doses Greater than ATSDR's MRL (Years) (Based on Average Concentration, CTE Ingestion, Dermal Contact, and Inhalation)
Residential Well A	All Age Groups	Birth to <1 1 to <2 2 to <6 6 to <11
Residential Well B	Birth to <1 1 to <2 2 to <6 6 to <11 Pregnant women	Birth to <1 1 to <2
Residential Well G	Birth to <1 1 to <2	None
Garden City Mobile Home Park (2002-20010)	Birth to <1 1 to <2 2 to < 6 6 to <11	None
Garden City Mobile Home Park (2011-20016)	Birth to <1 1 to <2	None
Commercial Well #4	All Age Groups	Birth to <1 1 to <2 2 to <6 6 to <11 11 to <16

Note: RME=Reasonable Maximum Exposure
CTE = Central Tendency Exposure
MRL = ATSDR chronic oral minimum risk level for TCE (5.0 x 10^{-4} mg/kg/day), ATSDR health guideline

5.7 Cancer Evaluation

The National Toxicology Program (NTP) classifies TCE as reasonably anticipated to be a human carcinogen based on limited evidence of carcinogenicity from studies in humans, sufficient evidence of carcinogenicity from studies in experimental animals, and information from studies on mechanisms of carcinogenesis [NTP 2011]. The human studies were epidemiological studies that showed increased rates of liver cancer and non-Hodgkin's lymphoma, primarily in workers exposed to TCE on the job. The animal studies showed increased numbers of liver, kidney, testicular, and lung tumors by two different routes of exposure.

EPA characterizes TCE as "carcinogenic to humans" by all exposure routes (ingestion, inhalation, and dermal contact) [USEPA 2011a]. This conclusion is based on human epidemiology studies showing the strongest associations between human TCE exposure and kidney cancer, with more limited evidence for non-Hodgkin's lymphoma, and liver cancer [USEPA 2011a]. EPA also concluded that TCE is carcinogenic by a mutagenic mode of action for induction of kidney tumors [USEPA 2011a].

In Table 10, the total excess cancer risk (from combining the excess risks for kidney cancer, non-Hodgkin's lymphoma, and liver cancer) for children and adults using drinking water from each of the 12 wells are all at a lower risk for cancer effects, and not likely to harm people's health. Therefore, the cancer risks to children and adults from domestic use of TCE contaminated drinking water from the municipal well are a low increased risk and will not be evaluated further. ATSDR calculated potential excess cancer risk using the equation, exposure parameters, age-dependent adjustments factors (ADAF), and EPA oral cancer slope factors described in Appendix G. See Table 2 – 14 in Appendix G for the calculation of total cancer risk to children and adults at each well in Table 8.

Table 10. Summary of Estimated Total Excess Cancer Risk For Residents Exposed To TCE in Drinking Water via Ingestion Exposure, Dermal Contact, and Inhalation Exposure

Well	Estimated Total Excess Cancer Risk		Are cancerous effects likely?	
	Children (Birth to <21 Years)	Adults (+21 Years)	Children	Adults
Residential Well A	2.6 E-05	1.9 E-05	No	No
Residential Well B	1.5 E-05	1.0 E-05	No	No
Residential Well C	5.0 E-06	3.5 E-06	No	No
Residential Well D	1.2 E-06	9.5 E-07	No	No
Residential Well F	4.3 E-06	2.1 E-06	No	No
Residential Well G	7.3 E-06	7.8 E-06	No	No
Mobile Home Park Well 2011 to 2016	6.7 E-06	4.7 E-06	No	No
Mobile Home Park Well 2002 to 2010	1.0 E-05	6.4 E-06	No	No
Commercial Well #2	2.2 E-06	1.8 E-06	No	No
Commercial Well #3	9.3 E-07	6.2 E-07	No	No
Commercial Well #4	2.6 E-05	1.9 E-05	No	No
Commercial Well #5	2.5 E-06	1.2 E-06	No	No
Municipal Well #12	7.3 E-07	5.6 E-07	No	No

EPA characterizes vinyl chloride as human carcinogen by all exposure routes (ingestion, inhalation, and dermal). This conclusion is based on human epidemiology studies of inhalation exposure, animal studies of ingestion exposure, and by inference the dermal route because it acts systemically. The most compelling evidence for the carcinogenic potential of vinyl chloride in humans comes from the cluster of reports of greater than expected incidences of angiosarcoma of the liver in workers occupationally exposed to vinyl chloride. The most compelling evidence for the carcinogenic potential of vinyl chloride from ingestion comes from rat studies with significant increases in hepatic angiosarcoma of the liver, neoplastic nodules of the liver, and hepatocellular carcinoma. Based on these rat studies, EPA estimated the oral slope factor for continuous lifetime exposure from birth to be 1.4 $(mg/kg/day)^{-1}$.

The excess risk for liver cancer in children (5.1 E-06) and adults (3.1 E-06) from chronic reasonable maximum exposure to vinyl chloride in the drinking water from municipal well #9 are at a lower risk for cancer effects, and not likely to harm people's health. Also, the combined liver cancer risk in children (5.1 E-06) and adults (3.2 E-06) from reasonable maximum TCE and vinyl chloride exposure in the drinking water from municipal well #9 is at a lower risk for cancer effects. Therefore, the cancer risks to children and adults from domestic use of vinyl chloride contaminated drinking water from the municipal well are a low increased cancer risk and will not be evaluated further. Also, as previously noted, the Columbus water utility blends water from all 15 municipal wells prior to distribution to consumers which would lower the vinyl chloride concentrations prior to being consumed.

5.8 Data Limitations

ATSDR made every attempt to accurately assess the potential impact that the TCE contamination had on the community's health, but the environmental data used to make the assessment had limitations. When limitations existed, ATSDR chose to be more conservative in an effort to be protective of the community's health. Therefore, actual exposures may have been different from those described in this document. The major limitations are as follows:

- The contaminant dose that a person receives depends on the concentration of TCE in the well at a given time. However, we have limited sampling data, or no sampling data, about wells that may have been contaminated in the past, may be currently contaminated, or may become contaminated in the future if the plume migrates. Therefore, it is difficult to accurately estimate the contaminant levels people might have been exposed to in the past or may be exposed to in the future. ATSDR assumed that the data collected in 2011, 2015, and 2016 are reflective of prior years of exposure; however, the actual exposures may have been higher or lower. We also selected a range of TCE concentrations that residents may have been potentially exposed based on the TCE concentrations in the water of each well.

- Another major limitation is that the exact duration of exposure to contaminated water is unknown. The VOC contamination was first detected in 1990; however, the wells could have been contaminated earlier. By 1990, wells known to have contaminated water were being fitted with filtration systems, but the source of the contamination has not yet been identified. Assuming that people were exposed to the contamination beginning in the mid-1960s and that the chronic long-term exposures continued until 1990, it is reasonable to assume 33 years of exposure to estimate total excess cancer risk. For chronic long-term exposure, 33 years is the default time used to evaluate a person living at a single residence. The duration of exposure limitation also applies to the non-cancer short-term exposure dose calculations. Short-term exposure calculations are used to estimate TCE exposure doses to women for a 2 week time period during pregnancy which could result in fetal heart malformations. Because the exact length of time people might have been exposed cannot yet be determined, the actual duration of exposure could be greater or less.

6. Public Health Implications

This section of the public health assessment evaluates the public health implications of exposure to TCE in the groundwater plume by further evaluating exposure pathways and conducting an in-depth health effects evaluation of exposure to TCE in the five wells listed in Table 9.

If people are exposed, will they get sick?

Exposure does not always result in harmful health effects. The type and severity of health effects a person might have as the result of contact with a contaminant depend on several factors:

- Exposure concentration (how much)
- Frequency (how often) and duration of exposure (how long)
- Route or pathway of exposure (ingestion, inhalation, or skin absorption)

For a public health hazard to exist, people must come in contact with contamination (chemicals) at levels high enough and for long enough to affect their health. Characteristics such as age, sex, nutritional status, genetics, lifestyle, and health status also influence how an exposed person's body absorbs, distributes, metabolizes, and excretes the contaminant. Taken together, these factors and characteristics determine the health effects that can occur from exposure to a contaminant in the environment.

6.1 Evaluation of Exposure Pathways

ATSDR evaluated potential exposure pathways to drinking water from wells in the vicinity of the groundwater plume. See Table 11 for summary of exposure pathway analysis of TCE in groundwater plume.

Table 11. Summary of Exposure Pathway Analysis of the Garden City Groundwater Plume Site

Point of Exposure	Source	Environmental Media	Route of Exposure	Receptor Population (years)	Completed, Potential, Eliminated Exposure Pathways	Comments
Residential Well A Residential Well B Residential Well E Commercial Well 2	TCE Groundwater Plume	Well Water	Ingestion (drinking of water) Inhalation (breathing volatilized TCE while showering, bathing, or other household use) Dermal absorption (skin contact with water while showering, bathing, or other household use)	All Age Groups	Eliminated Exposure Pathway	In 1990 a granular activated carbon (GAC) filter system was installed on these wells to remove TCE from the drinking water prior to the water being used in the residence. Water samples collected after the GAC filter did not contain TCE. Therefore, exposure to TCE in the drinking water is not occurring. The GAC filter system should be properly maintained to prevent future exposure to TCE and other VOCs in the drinking water from ingestion, inhalation, and dermal absorption.
Residential Well C	TCE Groundwater Plume	Well Water	Ingestion (drinking of water) Inhalation (breathing volatilized TCE while showering, bathing, or other household use) Dermal absorption (skin contact with water while showering, bathing, or other household use)	All Age Groups	Completed Exposure Pathway	Residential well C does not have a GAC filter system to remove the TCE that has been detected in the drinking water at this home. Therefore, people using the drinking water from this residential well for domestic purposes may currently be exposed to TCE in the groundwater. Drinking water from this well is not monitored on regular basis for TCE and other VOCs.
Garden City Mobile Home Park Well (2002-20010)	TCE Groundwater Plume	Well Water	Ingestion (drinking of water) Inhalation (breathing volatilized TCE while showering, bathing, or other household use) Dermal absorption (skin contact with water while showering, bathing, or other household use)	All Age Groups	Completed Exposure Pathway	This private community water system does not have a GAC filter system to remove the TCE detected in the drinking water. Therefore, the people in the 47 mobile homes using drinking water from this water system for domestic purposes may currently be exposed to low levels of TCE. The Garden City Mobile Home Park is located in the census block with the highest number of children 6 years and younger, and females of childbearing age (see Figure 3).

						The drinking water from this private community water system is monitored quarterly for VOCs, including TCE as part of the Safe Drinking Water Act to ensure that people in this community are not exposed to levels of TCE in their water supply that may harm their health.
Commercial Well #4	TCE Groundwater Plume	Well Water	Ingestion (drinking coffee made with well water) Inhalation (breathing volatilized TCE from the coffee maker and use of bathroom) Dermal absorption (skin contact from washing hands)	Adults	Completed Exposure Pathway	Commercial well #4 suppling drinking water to an office does not have a GAC filter system to remove TCE detected in the drinking water. Therefore, the adults using the drinking water from this commercial well could have minimal exposure to TCE from ingesting coffee, inhalation of volatilized TCE from the coffee maker and bathroom use of water, and dermal absorption from washing hands. Drinking water from this well is not monitored on a regular basis for TCE and other VOCs.
Wells Sampled Once (Residential Well D) (Residential Well F) (Residential Well G) (Commercial Well 5)	TCE Groundwater Plume	Well Water	Ingestion (drinking of water) Inhalation (breathing volatilized TCE while showering, bathing, or other household use) Dermal absorption (skin contact with water while showering, bathing, or other household use)	All Age Groups	Potential Exposure Pathway	These residential and commercial wells do not have a GAC filter system to remove the TCE that was detected in the 2011 drinking water samples. Drinking water from these wells were only sampled once because of access issues. The limited available data does not provide an understanding of the TCE exposures over time. The drinking water from these wells are not monitored on a regular basis for TCE and other VOCs.
Residential and Commercial Wells Not Sampled	TCE Groundwater Plume	Well Water	Ingestion (drinking of water) Inhalation (breathing volatilized TCE while showering, bathing, or other household use) Dermal absorption (skin contact with water while showering, bathing, or other household use)	All Age Groups	Potential Exposure Pathway	Drinking water from some wells near the groundwater plume were not sampled because of access issues. Therefore, TCE data is not available. Without adequate data, exposures to well users in the general vicinity of the Garden City TCE groundwater plume cannot be assessed.

6.2 Health Effects Evaluation

In this section of the public health assessment, ATSDR evaluates health implications of exposure to TCE in the drinking water from the five wells in Table 9, with estimated total TCE doses greater than the ATSDR MRL for TCE. This in-depth health effects evaluation includes a discussion of the current scientific information on TCE's disease-causing potential. The discussion also evaluates potential health effects of TCE exposure based on comparison of total TCE doses from both high-end exposure scenarios (see Table 1 and Table 3 in Appendix F) and typical exposure scenarios (See Table 2 in Appendix F) to TCE doses in studies that have been shown to cause harmful health effects. This section offers a perspective on the plausibility of harmful health outcomes from exposure to TCE at each well.

Available human and animal studies identify the kidney, liver, immune system, and developing fetuses as potential targets of TCE toxicity [ATSDR 2014a]. Results from animal studies suggest that developmental fetal heart malformations and immune system effects are the most sensitive adverse health effects from TCE exposure [ATSDR 2014a]. These effects are not exposure-route specific; similar effects can be elicited via ingestion, inhalation, and dermal exposure routes [ATSDR 2014a]. See Appendix D for detail discussion of the toxicological studies on TCE.

See Table 12 for summary of health implication of exposure to TCE in the drinking water at each well. See Appendix H for a discussion of the in-depth health effects evaluation comparing the estimated total TCE doses at each well to TCE doses shown to cause harmful health effect in studies.

Table 12. Summary of Public Health Implications of Exposure to TCE in Garden City Groundwater Plume

Wells	Exposure Routes Evaluated	Completed Exposure Pathways	Potentially Affected Populations (years)	Public Health Implications	Comments
Residential Well A	Ingestion of Water Inhalation of volatilized TCE Dermal Absorption of TCE	No Completed Exposure Pathway	None	No Public Health Implications Expected	The residents are not currently being exposed to TCE in the drinking water from residential well A because the GAC filter removes TCE from the drinking water prior to the water being used in the home. Therefore, health effects are not expected from the current exposure situation. However, if the GAC filter is removed or not properly maintained, residents could be exposed to TCE in the drinking water putting them at risk for health effects associated with TCE (i.e., fetal heart malformation, immune system effects, and cancer). Therefore, continued use of the GAC filter is recommended to prevent potential adverse health effects. Residents need to be informed of potential health effects and encouraged to maintain their current GAC system or connect to the Columbus municipal water utility for water.
Residential Well B	Ingestion of Water Inhalation of volatilized TCE Dermal Absorption of TCE	No Completed Exposure Pathway	None	No Public Health Implications Expected	The residents are not currently being exposed to TCE in the drinking water because the GAC filter removes TCE from the drinking water prior to the water being used in the home. Therefore, health effects are not expected from the current exposure situation. However, if the GAC filter is removed or not properly maintained, residents could be exposed to TCE in the drinking water. Estimated total TCE doses for pregnant women, adults, and children are not at levels associated with an increased risk of fetal heart malformations or immunological effects. Exposure to TCE in drinking water from residential well B is not at levels expected to harm the health of adults, children or fetus. Continued use of the GAC filter is recommended to prevent potential adverse health effects. Residents need to be informed of potential health effects and encouraged to maintain their current GAC system or connect to the Columbus municipal water utility for drinking water.
Residential Well E	Ingestion of Water Inhalation of volatilized TCE Dermal Absorption of TCE	No Completed Exposure Pathway	None	No Public Health Implications Expected	The people are not currently being exposed to TCE in the drinking water from these two wells because the GAC filter removes TCE from the drinking

Commercial Well #2	Ingestion of Water Inhalation of volatilized TCE Dermal Absorption of TCE	No Completed Exposure Pathway	None	No Public Health Implications Expected	water prior to the water being used in the home. Therefore, health effects are not expected from the current exposure situation. If the GAC filter is removed or not properly maintained, residents may be exposed to TCE in the drinking water. The level of TCE in drinking water from commercial well #2 resulted in estimated total TCE doses below the ATSDR MRL and is not currently at levels expected to harm the health of adults, children or fetus. TCE was not detected in the one 2011 unfiltered sample collected from residential well E. ATSDR cannot adequately characterize the current public health hazard of exposure to TCE in unfiltered drinking water from residential well E. Too few water samples were collected from residential well E because of access issues. TCE level in drinking water from a well can vary over time. Wells with previously detected low TCE levels may currently or in the future contain elevated TCE. These wells should be resampled to adequately characterize current exposure to TCE in unfiltered drinking water and potential health effects from exposure to TCE. Continued use of the GAC filter is recommended to prevent potential adverse health effects. Residents need to be informed of potential health effects and encouraged to maintain their current GAC system or connect to the Columbus municipal water utility for drinking water.
Residential Well C	Ingestion of Water Inhalation of volatilized TCE Dermal Absorption of TCE	Yes Completed Exposure Pathway	All Age Groups	No Public Health Implications Expected	The residents using drinking water from residential well C for domestic purposes maybe exposed to low levels of TCE in the drinking. This well does not have a GAC filter to remove TCE from the drinking water. The level of TCE in drinking water samples from residential well C results in estimated total TCE doses below the ATSDR MRL and not at levels expected to harm the health of adults, children or fetus. However, TCE level in drinking water from a well can vary over time. Wells with previously detected low TCE levels may currently or in the future contain elevated TCE. This well should be resampled to characterize current exposure to TCE in drinking water and potential for health effects. Residents should be informed of the possibility of any potential health effects from TCE exposure. They should also be informed of alternatives to eliminate TCE exposure using a GAC filter system to remove TCE from the drinking water or connect to the Columbus municipal water utility for drinking water.

Garden City Mobile Home Park Well (2002-20010)	Ingestion of Water Inhalation of volatilized TCE Dermal Absorption of TCE	Yes Completed Exposure Pathway	All Age Groups	No Public Health Implications Expected	People in the Garden City Mobile Home Park using the drinking water from the private community water system well are exposed to low levels of TCE in the drinking water based on the available data. Since 2002, TCE levels exceeded the EPA MCL of 5 ppb in 10 samples. The average TCE level from all the water samples collected from this well since 2002 is 4.5 ppb. This community water system does not have a GAC filter to remove the TCE from the water prior to being used in the home. Pregnant women and young children using the water from the Garden City Mobile Home Park community water system well are not exposed to TCE at levels of public health concern for developmental heart malformations in fetuses or harmful immunological effects in young children. Exposure to TCE in drinking water from the community water system well is not at levels expected to harm the health of adults, children or fetus Residents should be informed of the possibility of any potential health effects from TCE exposure. The community water system drinking water should continue to be monitored on a quarterly basis due to the fluctuation of TCE levels in the drinking water. The residents should be notified if the TCE levels in the drinking water exceed the EPA MCL of 5 ppb. The residents should be informed about eliminating TCE exposure by using a GAC filter system to remove TCE from the drinking water or connect to the Columbus municipal water utility for drinking water.
Commercial Well #4	Ingestion of Water Dermal Absorption of TCE	Yes Completed Exposure Pathway	Adults	No Public Health Implications Expected	People in the office have minimal exposure to TCE in the drinking water from commercial well #4. Drinking water samples contain an average TCE level (11.4 ppb) greater than the EPA MCL (5 ppb). The limited exposure to TCE in the water from ingesting coffee, dermal absorption from washing hands, and inhalation of TCE from making coffee, washing hands, and using the toilet would result in estimated total TCE doses below the ATSDR MRL health guideline and would not be expected to harm the health of people who work in the office. Office workers need to be informed of potential health effects if large quantities (2 to 3 liters a day) of well water are consumed by office worker. Use a GAC filter or connect to the Columbus water utility for drinking water to prevent potential exposure to TCE.
Wells Sampled Once (Residential Well D) (Residential Well F) (Residential Well G) (Commercial Well 5)	Ingestion of Water Inhalation of volatilized TCE Dermal Absorption of TCE	Potential Exposure Pathway	All Age Groups	No Public Health Implications Expected	The residents using the drinking water from these residential and commercial wells for domestic and business purposes may be exposed to low levels of TCE in the drinking water based on the limited sampling data. These wells do not have a GAC filter to remove the TCE from water.

					ATSDR cannot adequately characterize the public health hazard of exposure to TCE in the drinking water from these four wells near the groundwater plume. Too few water samples from each well were collected and analyzed for TCE and other VOCs because of access issues. Based on the one 2011 drinking water sample from residential well G, adults, pregnant women, and young children using the water are not exposed to TCE levels that would increase the risk for developmental heart malformations in fetuses or increase the risk for harmful immunological effects in young children. The levels of TCE in one 2011 drinking water sample from residential wells D and F, and commercial well #5 result in estimated total TCE doses below the ATSDR MRL. Exposure to TCE in drinking water from these wells is not at levels expected to harm the health of adults, children or fetus. However, TCE level in drinking water from a well can vary over time. Wells with previously detected low TCE levels may currently or in the future contain elevated TCE. These well should be resampled to determine the current conditions of the water and to adequately characterize exposure and potential health effects from exposure to TCE in drinking water. Residents should be informed of the possibility of any potential health effects from TCE exposure. They should also be informed of alternatives to eliminate TCE exposure, such as using a GAC filter system to remove TCE from the drinking water or connecting to the Columbus municipal water utility for drinking water.
Wells Not Sampled	Ingestion of Water Inhalation of volatilized TCE Dermal Absorption of TCE	Unknown	Unknown	Public Health Implications Cannot Be Determined	Drinking water TCE data is not available for some private wells in Garden City. Drinking water from some wells were not sampled and analyzed for TCE and other VOCs because of access issues. Without analytical drinking water results, ATSDR cannot characterize TCE exposure and determine whether drinking water from these wells contains contaminants at levels of public health concern. All private wells near the TCE groundwater plume should be sampled for TCE and other VOCs to adequately characterize exposure and potential health effects from exposure to TCE in drinking water. Residents should be informed of potential health effects of exposure to elevated levels of TCE in water. Depending on the TCE levels in the water, they should also be informed of alternatives to eliminate TCE exposure using a GAC filter system to remove TCE from the drinking water or connect to the Columbus municipal water utility for drinking water.

6.3 Child Health Considerations

In communities faced with environmental contamination, children could be at greater risk than adults from certain kinds of exposure to hazardous substances. The many physical differences between children and adults demand special emphasis. This public health assessment uses child-specific exposure factors, such as body weights and intake rates, as the basis for calculating exposures to contaminants in drinking water. Children's lower body weight and high water ingestion intake rates result in a greater dose of hazardous substance per kilogram (kg) body weight. An infant who drinks formula prepared with contaminated drinking water is likely to have a higher exposure dose because of the large volume of water they consume relative to their body size. TCE intake from the ambient air is expected to be greater in infants and children than adults because infants and children have increased ventilation rates per kg body weight and increased cardiac output per kg body weight. The resulting exposure doses for children are higher than for adults. If high enough during critical growth stages, toxic exposure levels can permanently damage a child's developing body systems. ATSDR also considers children at greater risk than adults from TCE exposure because young children and unborn children of pregnant women are more sensitive to the effects of TCE. Finally, children are dependent on adults for access to housing, for access to medical care, and for risk identification. Thus, adults need as much information as possible to make informed decisions regarding their health.

7. Conclusions

For the Garden City Groundwater Plume site, ATSDR evaluated past, current and future exposure of local residents to VOCs in the drinking water and from vapor intrusion. ATSDR reviewed EPA environmental data from drinking water samples collected in 2011, 2015, and 2016 from residential and commercial wells and soil gas sampling in 2016. From this evaluation, ATSDR concludes the following:

1. As long as the GAC filtration systems are monitored and maintained for residential wells A, B, and E and commercial well #2, people using the filtered drinking water for domestic and business purposes (e.g., drinking, showering, bathing, dishwasher, washing machine, etc.) are not currently being exposed to TCE at levels of health concern. The current exposure situation is not expected to harm the health of adults, children, and fetus.

    - IDEM installed GAC filter systems in 1990 in these three homes with previous TCE levels in the unfiltered drinking water exceeding the EPA MCL of 5 ppb for TCE. The IDEM also installed a GAC filter system in a drive-in restaurant business when TCE levels in unfiltered drinking water exceeded the EPA MCL. ATSDR understands that IDEM maintains these GAC filter systems.

- The GAC filter removes TCE and other VOCs from unfiltered drinking water prior to use in the home and restaurant. Therefore, if the GAC filters are maintained, filtered drinking water from residential wells and commercial well #2will not contain TCE and exposure to the filtered water is not expected to harm the health of adults, children, and fetuses.

- If the GAC filter systems are removed or not adequately maintained, domestic and business use of the water (e.g., drinking, showering, bathing, dishwasher, washing machine, etc.) from these wells would result in ingestion and inhalation, exposure to TCE in the drinking water plume. The current levels of TCE in the drinking water from residential well A and B may put adults and children at greater risk for the health effects associated with TCE exposure (e.g., immune and developmental effects, certain types of cancer).

2. Residents who use drinking water from Garden City Mobile Home Park well and residential well C for household purposes (e.g., drinking, showering, bathing, dishwasher, washing machine, etc.) are not currently exposed to levels of TCE expected to harm the health of adults, children, or fetus.

   - Children and adults using the water from the Garden City Mobile Home Park well, and residential well C for domestic purposes are currently exposed to low levels of TCE in drinking water. The Garden City Mobile Home Park well is a private community water system that supplies water to 47 mobile homes.

   - Exposure to low levels of TCE in drinking water from the Garden City Mobile Home Park and residential well C is not at levels expected to harm the health of adults, children, or fetuses.

3. People working in the office currently using the water from commercial well #4 have minimal exposure to TCE in the drinking water. The current exposure situation is not expected to harm the health of people working in the office.

   - The water from commercial well #4 is currently used in an office to make coffee, wash hands, and supply water to the toilet, resulting in minimum exposure from ingestion (drinking coffee), dermal absorption (washing hands), and inhalation (breathing TCE evaporating from the making coffee, washing hands, and use of toilet).

- The current exposure scenario for the office results in estimated total TCE doses well below the ATSDR MRL screening guideline and is not at a level expected to harm the health of adults or children in the office

4. ATSDR cannot adequately characterize the exposure to TCE in the drinking water from some residential and commercial wells near the groundwater plume.

   - Drinking water from four wells (residential wells D, F, and G and commercial well #5) were sampled only once in 2011 due to access issues. While this drinking water data indicate low level of TCE that are not expected to harm health, too few drinking water samples from each well were collected and analyzed for VOCs to adequately characterize exposure to TCE over an extended period.

   - Some wells used for domestic and commercial purposes near the groundwater plume have not been sampled for TCE and other VOC contamination due to access issues. ATSDR cannot determine whether drinking water in these wells contains contaminants at levels of public health concern.

5. ATSDR does not expect vapor intrusion exposure to TCE or other VOCs at levels that harm the health of adults or children.

   - TCE and other VOC levels in the shallow drinking water samples and soil gas samples were below ATSDR's vapor intrusion screening levels.

8. Recommendations

After review of available information, ATSDR recommends the following for EPA, in conjunction with appropriate federal, state, or local personnel:

1. Conduct frequent monitoring of TCE and other VOCs in the drinking water of all private wells used for domestic and commercial purposes in the vicinity of the TCE groundwater plume to adequately characterize the potential exposure to TCE and other VOCs. Including residential wells D, E, F, G and commercial well #5 that were sampled only once in 2011 and other private wells that have not been sampled due to access issues.

2. If residents do not want to monitor the drinking water in their private well, they should install and maintain a GAC filter system or connect the residents to the Columbus municipal water utility to prevent exposure to TCE in drinking water.

3. If TCE or other VOCs are detected in the drinking water from a private well, EPA should continue monitoring the drinking water to ensure concentrations of TCE or other VOCs do not increase to levels of health concern.

4. If the concentration of TCE or other VOCs in the drinking water increases to levels of health concern, install and maintain a GAC filter system or connect the residence or business to the Columbus municipal water utility to prevent exposures to these drinking water contaminants.

5. Continue to maintain the GAG filter systems and monitor the drinking water from the filter system in the private wells to prevent exposure to TCE or other VOCs in the groundwater.

6. Inform people in Garden City, Indiana, of the potential health effects from exposure to TCE levels in drinking water from their residential or commercial wells. Also, inform people how to reduce exposure to TCE and other VOCs in drinking water by using a GAC filter system or connecting to the Columbus municipal water utility.

9. Public Health Action Plan

A Public Health Action Plan ensures that this health assessment 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. The Public Health Action Plan includes public health actions that have been taken and those that are recommended.

9.1. Public Health Actions Undertaken

1. Since 1990, IDEM installed and maintained GAC filter systems on wells in three homes identified as having TCE levels in the drinking water exceeding the EPA MCL of 5 ppb for TCE.

9.2. Recommended Public Health Actions

1. To adequately characterize potential exposure to TCE and other VOCs, EPA should monitor drinking water on a frequent basis for VOCs from all private wells near the groundwater plume used for domestic and commercial purposes.

2. Continue to maintain the GAG filter systems and monitor the drinking water from the filter system in the private wells.

3. ATSDR, IDEM, and Bartholomew County Health Department should inform people in Garden City, Indiana, of the potential health effects from exposure to TCE levels in drinking water from their residential or commercial well.

4. Residents and businesses should consider using a GAC filter system or connecting to the Columbus municipal water utility to eliminate potential exposure to TCE and other VOCs.

5. Copies of this public health assessment will be provided to local health and public officials and other interested parties near the Garden City groundwater plume site. Copies will also be available on ATSDR's website at https://www.atsdr.cdc.gov/.

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11. References

[Andelman 1990]. Total exposure to volatile organic compounds in potable water. In: Ram NM, Christman RF, Cantor KP, editors. Significance and treatment of volatile organic compounds in water supplies. Chelsa, Michigan: Lewis Publishers, p.485-504.

[ATSDR 2013]. Agency for Toxic Substances and Disease Registry. 2013. Addendum to the Toxicological Profile for Trichloroethylene.

[ATSDR 2014a]. Toxicological Profile for Trichloroethylene. Atlanta (GA): US Department of Health and Human Services, Agency for Toxic Substances and Disease Registry; October 2014.

[ATSDR 2014b]. Agency for Toxic Substances and Disease Registry. 2014. Exposure Dose Guidance for Water Ingestion. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. November 2014.

[ATSDR 2016]. Agency for Toxic Substances and Disease Registry. 2016. Evaluating Vapor Intrusion Pathways, Guidance for ATSDR's Division of Community Health Investigations. Atlanta, GA

[Cal EPA 2005]. Guidance for the Evaluation and Mitigation of Subsurface Vapor Intrusion to Indoor Air. Department of Toxic Substances Control California Environmental Protection Agency.

[Giardino and Andelman 1996]. Giardino N.J. and Andelman J.B. Characterization of the emissions of trichloroethylene, chloroform, and 1,2-dibromo-3-chloropropane in a full-size, experimental shower. *J Expos Anal Environ Epidemiol* 1996: 6(4): 413–423

[IDEM 2012] Indiana Department of Environmental Management. 2012. Garden City Ground Water Plume Expanded Site Inspection Report. VFC document Number 47774955.

[IDEM] Indiana Department of Environmental Management. Drinking Water Branch Website. https://myweb.in.gov/IDEM/DWW/. Garden City Mobile Home Park Water System. Number IN5203005.

[Johnson et. al 2002] Johnson P, Goldberg S, Mays M, Dawson B. 2003. Threshold of trichloroethylene contamination in maternal drinking waters affecting fetal heart development in the rat. Environ Health Perspect, 111, 289-292. Cited in: [USEPA 2011a] US Environmental Protection Agency. 2011. Integrated risk information system. Trichloroethylene (CASRN 79-01-6). Available from: http://www.USEPA.gov/IRIS/subst/0199.htm

[Kiel *et. al*. 2009] Kiel, D. E.; Peden-Adams, M. M.; Wallace, S.; Ruiz, P.; Gilkeson, G. S. 2009. Assessment of trichloroethylene (TCE) exposure in murine strains genetically-prone and non-prone to develop autoimmune disease. J Environ Sci Health A Tox Hazard Subst Environ

Eng, Vol. 44, p. 443-453. Cited in: [USEPA 2011a] US Environmental Protection Agency. 2011. Integrated risk information system. Trichloroethylene (CASRN 79-01-6). Available from: http://www.USEPA.gov/IRIS/subst/0199.htm

[Moya *et al*. 1999]. Moya J, Howard-Reed C, and Corsi RL, 1999. Volatization of chemicals from tap water to indoor air from contaminated water used for showering. Environm Sci Technol 33:2321-2327.

[NTP 2011] NTP Trichloroethylene Report on Carcinogens, Twelfth Edition. Department of Health and Human Services National Toxicology Program. June 2011.

[NTP 1988]. Toxicology and carcinogenesis studies of trichloroethylene (CAS No. 79-01-6) in four strains of rats (ACI, August, Marshall, Osborne-Mendel) (gavage studies). Research Triangle Park, NC: Public Health Service, U.S. Department of Health and Human Services. Retrieved from http://ntp.niehs.nih.gov/ntp/htdocs/LT_rpts/tr273.pdf. Cited in: [USEPA 2011a] US Environmental Protection Agency. 2011. Integrated risk information system. Trichloroethylene (CASRN 79-01-6). Available from: http://www.USEPA.gov/IRIS/subst/0199.htm

[Maine DEP/DHS 1992] Maine Department of Environmental Protection and Department of Health Services. 1992. Draft Guidance Manual for Human Health Assessments at Hazardous Waste Substance Sites. Augusta, ME: Maine Department of Environmental Protection and Department of Health Services. Sept.

[Peden-Adams *et. al*. 2006] Peden-Adams, M.; Eudaly, J.; Heesemann, L.; Smythe, J.; Miller, J.; Gilkeson, G.; Kiel, D. 2006. Developmental immunotoxicity of trichloroethylene (TCE): studies in B6C3F1 mice. J Environ Sci Health A Tox Hazard Subst Environ Eng, Vol. 41, p. 249-271. Cited in: [USEPA 2011a] US Environmental Protection Agency. 2011. Integrated risk information system. Trichloroethylene (CASRN 79-01-6). Available from: http://www.USEPA.gov/IRIS/subst/0199.htm

[USEPA 2011a] US Environmental Protection Agency. 2011. Integrated risk information system. Trichloroethylene (CASRN 79-01-6). Available from: http://www.USEPA.gov/IRIS/subst/0199.htm

[USEPA 2011b] US Environmental Protection Agency. 2011. Exposure factor handbook: 2011 Final. Washington DC: National Center for Environmental Assessment, USEPA/600/R-09/052F.

[USEPA 2013] US Environmental Protection Agency. 2013. Garden City Ground Water Plume Hazard Ranking System Documentation Record. Chicago, IL: US Environmental Protection Agency, Region V. May.

[USEPA 2015]. OSWER Technical Guidance for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air. Office of Solid Waste and Emergency Response. June 2015.

[USEPA 2016a] US Environmental Protection Agency. 2016. Garden City Ground Water Plume Phase 1, 2, and 3 Remedial Investigation – Data Evaluation Summary Report Chicago, IL: US Environmental Protection Agency, Region V. February.

[USEPA 2016a] US Environmental Protection Agency. 2016. Garden City Ground Water Plume Phase 4 Remedial Investigation – Data Evaluation Summary Report Chicago, IL: US Environmental Protection Agency, Region V. July.

[Woolhiser *et al.,* 2006] Woolhiser, M. R.; Krieger, S. M.; Thomas, J.; Hotchkiss, J. A. 2006. Trichloroethylene (TCE): Immunotoxicity potential in CD rats following a 4-week vapor inhalation exposure. Midland, MI. Cited in: [USEPA 2011a] US Environmental Protection Agency. 2011. Integrated risk information system. Trichloroethylene (CASRN 79-01-6). Available from: http://www.USEPA.gov/IRIS/subst/0199.htm

Appendix A: ATSDR Glossary of Environmental Health Terms

The Agency for Toxic Substances and Disease Registry (ATSDR) is a federal public health agency with headquarters in Atlanta, Georgia, and 10 regional offices in the United States. ATSDR's mission is to serve the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent harmful exposures and diseases related to toxic substances. ATSDR is not a regulatory agency, unlike the EPA, which is the federal agency that develops and enforces environmental laws to protect the environment and human health. This glossary defines some of the words used by ATSDR in communications with the public.

Absorption: The process of taking in. For a person or animal, absorption is the process of a substance getting into the body through the eyes, skin, stomach, intestines, or lungs.

Background level: An average or expected amount of a substance in a specific environment, or typical amounts of substances that occur naturally in an environment.

Cancer: Any one of a group of diseases that occur when cells in the body become abnormal and grow or multiply out of control.

Cancer risk: A statistical probability for getting cancer if a given population is exposed to a substance, typically calculated for an exposure of every day for 70 years (a lifetime exposure). The actual occurrence of cancer in that population might be different from this probability.

Carcinogen: A substance that causes cancer.

Chronic exposure: Contact with a substance that occurs over a long time (more than 1 year).

Comparison value (CV): The calculated concentration of a substance in air, water, food, or soil that is unlikely to cause harmful (adverse) health effects in exposed people. The CV is used as a screening level during the public health assessment process. Substances found in amounts greater than their CV might be selected for further evaluation in the public health assessment process.

Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA): CERCLA, also known as Superfund, is the federal law that concerns the removal or cleanup of hazardous substances in the environment and at hazardous waste sites. ATSDR, which was created by CERCLA, is responsible for assessing health issues and supporting public health activities related to hazardous waste sites or other environmental releases of hazardous substances.

Concentration: The amount of a substance present in a certain amount of soil, water, air, food, blood, hair, urine, breath, or other media.

Contaminant: A substance that is present either in an environment where it does not belong or at levels that might cause harmful (adverse) health effects.

Dermal contact: Contact with (touching) the skin.

Dose: The amount of a substance to which a person is exposed over some period. A measurement of exposure, dose is often expressed as milligrams (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An exposure dose is how much of a substance is encountered in the environment. An absorbed dose is the amount of a substance got into the body through the eyes, skin, stomach, intestines, or lungs.

Dose-response relationship: The relationship between the amount of exposure [dose] to a substance and the resulting changes in body function or health (response).

Environmental media: Soil, water, air, biota (plants and animals), or any other parts of the environment that can contain contaminants.

Exposure: Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term (acute exposure), of intermediate duration, or long-term (chronic exposure).

Exposure assessment: The process of finding out how people come into contact with a hazardous substance, how often and for how long they are in contact with the substance, and how much of the substance they contact.

Exposure pathway: The route a substance takes from its source (where it began) to its end point (where it ends), and how people can come into contact with (or get exposed to) it. An exposure pathway has five parts:

1. a source of contamination (such as an abandoned business),
2. an environmental media and transport mechanism (such as movement through groundwater),
3. a point of exposure (such as a private well),
4. a route of exposure (eating, drinking, breathing, or touching), and
5. a receptor population (people potentially or actually exposed).

When all five parts are present, the exposure pathway is termed a completed exposure pathway. In most cases, response actions like remedial actions or removal actions are designed to interrupt the exposure pathway in order to reduce or eliminate harm.

Groundwater: Water beneath the earth's surface in the spaces between soil particles and rock surfaces.

Hazard: A source of potential harm from past, current, or future exposures.

Hazardous substances: Substances that may cause harm to people or the environment under some circumstances. In the United States, hazardous substances are defined by the EPA under the authority provided in pollution laws such as CERCLA. See 40 CFR 302 (https://www.gpo.gov/fdsys/pkg/CFR-2011-title40-vol28/pdf/CFR-2011-title40-vol28-part302.pdf). Most hazardous wastes are also considered hazardous substances, but hazardous substances might not always be hazardous wastes.

Hazardous waste: Potentially harmful substances that have been released or discarded into the environment. In the United States, hazardous wastes are defined by the EPA under its authority provided by the Resource Conservation and Recovery Act. See 40 CFR 260 (http://nepis.epa.gov/Adobe/PDF/30006ATU.PDF).

Ingestion: The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way.

Inhalation: The act of breathing. A hazardous substance can enter the body this way.

Minimal risk level (MRL): An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk for harmful (adverse), noncancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified period (acute, intermediate, or chronic). MRLs should not be used as predictors of harmful (adverse) health effects.

National Priorities List (or NPL): EPA's list of the most serious uncontrolled or abandoned hazardous waste sites in the United States. The NPL is updated on a regular basis. After a site is nominated for the NPL, certain actions in conjunction with a series of partner agencies are required of ATSDR by law.

Point of exposure: The place where someone can come into contact with a substance present in the environment.

Prevention: Actions that reduce exposure or other risks, keep people from getting sick, or keep disease from getting worse.

Public health action: A list of steps to protect public health.

Public health assessment: An ATSDR document that examines hazardous substances, health outcomes, and community concerns at a hazardous waste site to determine whether people could be harmed from coming into contact with those substances. The public health assessment also lists actions that need to be taken to protect public health.

Reference dose (RfD): An EPA estimate, with uncertainty factors built in, of the daily dose of a substance that is unlikely to cause harm in humans over a lifetime of exposure.

Remedial investigation: The CERCLA process of determining the type and extent of hazardous material contamination at an NPL site. The data from a remedial investigation may be used to help determine the feasibility and scope of actions to clean up the site.

Remedial action: Remedial actions under Superfund are clean-up operations to resolve those hazards identified in the remedial investigation. Remedial actions may take years to complete and are often broken up into phases or specific portions of the site called operable units.

Removal action: Removal actions under Superfund are generally shorter-term response actions than remedial actions to address specific hazards at a site. Removals can happen at any time in the process from initial discovery until the site cleanup is determined to be complete.

Risk: The risk for harm exists when there is an exposure to a hazard. If the hazard can be removed, there is no further risk of harm. If the amount of exposure can be reduced, the risk of harm is also reduced. The management and elimination of risk resulting from exposure to hazardous substances at uncontrolled waste site is the reason why the Superfund process was put into place.

Sample: A portion or piece of a whole. An environmental sample (for example, a small amount of soil or water) might be collected to measure contamination in the environment at a specific location.

Soil/Sediment: Sediments are soil samples taken from a streambed, lake, or other body of water. As opposed to soil samples, sediment samples usually have a high moisture content and may be more conducive to biological degradation of some chemicals than surface or subsurface soils.

Source of contamination: The place where a hazardous substance comes from, such as a landfill, waste pond, incinerator, storage tank, or drum. A source of contamination is the first part of an exposure pathway.

Substance: As used here, a chemical.

Superfund: see Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA).

Surface/Subsurface Soil Samples: Depending on the circumstances, the difference in depth between surface and subsurface samples is somewhat discretionary. Generally speaking, ATSDR assumes surface samples will be collected from a depth of 0–2 inches. With ground cover and caps, depths of up to 6 inches may be considered surface soils. Normally, ATSDR would classify any sample taken from deeper than 6 inches as a subsurface sample.

Surface water: Water on the surface of the earth, such as in lakes, rivers, streams, ponds, and springs (compare with groundwater).

Survey: A systematic collection of information or data. A survey can be conducted to collect information from a group of people or from the environment.

Transport mechanism: Transport mechanisms move contaminants from the source to points where human exposure can occur. The environmental media and transport mechanism is the second part of an exposure pathway.

Toxicological profile: An ATSDR document that examines, summarizes, and interprets information about a hazardous substance to determine harmful levels of exposure and associated health effects. A toxicological profile also identifies significant gaps in knowledge on the substance and describes areas where further research is needed.

Toxicology: The study of the harmful effects of substances on humans or animals.

Appendix B: ATSDR ToxFAQ - Trichloroethylene

Trichloroethylene - ToxFAQs™

CAS # 79-01-6

This fact sheet answers the most frequently asked health questions (FAQs) about trichloroethylene. For more information, call the CDC Information Center at 1-800-232-4636. This fact sheet is one in a series of summaries about hazardous substances and their health effects. It's important you understand this information because this substance may harm you. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present.

HIGHLIGHTS: Trichloroethylene is used as a solvent for cleaning metal parts. Exposure to very high concentrations of trichloroethylene can cause dizziness, headaches, sleepiness, incoordination, confusion, nausea, unconsciousness, and even death. The Environmental Protection Agency (EPA) and the International Agency for Research on Cancer (IARC) classify trichloroethylene as a human carcinogen. Trichloroethylene has been found in at least 1,045 of the 1,699 National Priorities List sites identified by the EPA.

What is trichloroethylene?

Trichloroethylene is a colorless, volatile liquid. Liquid trichloroethylene evaporates quickly into the air. It is nonflammable and has a sweet odor.

The two major uses of trichloroethylene are as a solvent to remove grease from metal parts and as a chemical that is used to make other chemicals, especially the refrigerant, HFC-134a. Trichloroethylene was once used as an anesthetic for surgery.

What happens to trichloroethylene when it enters the environment?

- Trichloroethylene can be released to air, water, and soil at places where it is produced or used.
- Trichloroethylene is broken down quickly in air.
- Trichloroethylene breaks down very slowly in soil and water and is removed mostly through evaporation to air.
- It is expected to remain in groundwater for long time since it is not able to evaporate.
- Trichloroethylene does not build up significantly in plants or animals.

How might I be exposed to trichloroethylene?

- Breathing trichloroethylene in contaminated air.
- Drinking contaminated water.
- Workers at facilities using this substance for metal degreasing are exposed to higher levels of trichloroethylene.
- If you live near such a facility or near a hazardous waste site containing trichloroethylene, you may also have higher exposure to this substance.

How can trichloroethylene affect my health?

Exposure to moderate amounts of trichloroethylene may cause headaches, dizziness, and sleepiness; large amounts may cause coma and even death. Eating or breathing high levels of trichloro¬ethylene may damage some of the nerves in the face. Exposure to high levels can also result in changes in the rhythm of the heartbeat, liver damage, and evidence of kidney damage. Skin contact with concentrated solutions of trichloroethylene can cause skin rashes.

There is some evidence exposure to trichloroethylene in the work place may cause scleroderma (a systemic autoimmune disease) in some people. Some men occupationally-exposed to trichloroethylene and other chemicals showed decreases in sex drive, sperm quality, and reproductive hormone levels.

How likely is trichloroethylene to cause cancer?

There is strong evidence that trichloroethylene can cause kidney cancer in people and some evidence for trichloroethylene-induced liver cancer and malignant lymphoma. Lifetime exposure to trichloroethylene resulted in increased liver cancer in mice and increased kidney cancer and testicular cancer in rats.

The IARC and the EPA determined that there is convincing evidence that trichloroethylene exposure can cause kidney cancer. The National Toxicology Program (NTP) is recommending a change in cancer classification to "known human carcinogen" http://ntp.niehs.nih.gov/ntp/roc/monographs/finaltce_508.pdf.

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

ATSDR

CS256651A

Trichloroethylene

CAS # 79-01-6

How can trichloroethylene affect children?

It is not known whether children are more susceptible than adults to the effects of trichloroethylene.

Some human studies indicate that trichloroethylene may cause developmental effects such as spontaneous abortion, congenital heart defects, central nervous system defects, and small birth weight. However, these people were exposed to other chemicals as well.

In some animal studies, exposure to trichloroethylene during development caused decreases in body weight, increases in heart defects, changes to the developing nervous system, and effects on the immune system.

How can families reduce the risk of exposure to trichloroethylene?

- Avoid drinking water from sources that are known to be contaminated with trichloroethylene. Use bottled water if you have concerns about the presence of chemicals in your tap water. You may also contact local drinking water authorities and follow their advice.
- Discourage your children from putting objects in their mouths. Make sure that they wash their hands frequently and before eating.
- Prevent children from playing in dirt or eating dirt if you live near a waste site that has trichloroethylene.
- Trichloroethylene is used in many industrial products. Follow instructions on product labels to minimize exposure to trichloroethylene.

Is there a medical test to show whether I've been exposed to trichloroethylene?

Trichloroethylene and its breakdown products (metabolites) can be measured in blood and urine. However, the detection of trichloroethylene or its metabolites cannot predict the kind of health effects that might develop from that exposure. Because trichloroethylene and its metabolites leave the body fairly rapidly, the tests need to be conducted within days after exposure.

Has the federal government made recommendations to protect human health?

The EPA set a maximum contaminant goal (MCL) of 0.005 milligrams per liter (mg/L; 5 ppb) as a national primary drinking standard for trichloroethylene.

The Occupational Safety and Health Administration (OSHA) set a permissible exposure limit (PEL) of 100 ppm for trichloroethylene in air averaged over an 8-hour work day, an acceptable ceiling concentration of 200 ppm provided the 8 hour PEL is not exceeded, and an acceptable maximum peak of 300 ppm for a maximum duration of 5 minutes in any 2 hours.

The National Institute for Occupational Safety and Health (NIOSH) considers trichloroethylene to be a potential occupational carcinogen and established a recommended exposure limit (REL) of 2 ppm (as a 60-minute ceiling) during its use as an anesthetic agent and 25 ppm (as a 10-hour TWA) during all other exposures.

References

This ToxFAQs™ information is taken from the 2014 Toxicological Profile for Trichloroethylene (Draft for Public Comment) produced by the Agency for Toxic Substances and Disease Registry, Public Health Service, U.S. Department of Health and Human Services.

Where can I get more information?

For more information, contact the Agency for Toxic Substances and Disease Registry, Division of Toxicology and human Health Sciences, 1600 Clifton Road NE, Mailstop F-57, Atlanta, GA 30329-4027.

Phone: 1-800-232-4636.

ToxFAQs™ Ion the web: www.atsdr.cdc.gov/toxFAQs.

ATSDR can tell you where to find occupational and environmental health clinics. Their specialists can recognize, evaluate, and treat illnesses resulting from exposure to hazardous substances. You can also contact your community or state health or environmental quality department if you have any more questions or concerns.

Tetrachloroethylene - ToxFAQs™

CAS # 127-18-4

This fact sheet answers the most frequently asked health questions (FAQs) about tetrachloroethylene. For more information, call the CDC Information Center at 1-800-232-4636. This fact sheet is one in a series of summaries about hazardous substances and their health effects. It's important you understand this information because this substance may harm you. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present.

HIGHLIGHTS: Tetrachloroethylene is a manufactured chemical used for dry cleaning and metal degreasing. Exposure to very high concentrations of tetrachloroethylene can cause dizziness, headaches, sleepiness, confusion, nausea, difficulty in speaking and walking, unconsciousness, and death. Tetrachloroethylene has been found in at least 771 of the 1,430 National Priorities List (NPL) sites identified by the Environmental Protection Agency (EPA).

What is tetrachloroethylene?

(Pronounced tět'rə-klôr' ō-ěth'ə-lēn')

Tetrachloroethylene is a manufactured chemical that is widely used for dry cleaning of fabrics and for metal-degreasing. It is also used to make other chemicals and is used in some consumer products.

Other names for tetrachloroethylene include perchloroethylene(PERC), PCE, and tetrachloroethene. It is a nonflammable liquid at room temperature. It evaporates easily into the air and has a sharp, sweet odor. Most people can smell tetrachloroethylene when it is present in the air at a level of 1 part tetrachloroethylene per million parts of air (1 ppm) or more, although some can smell it at even lower levels.

What happens to tetrachloroethylene when it enters the environment?

- Much of the tetrachloroethylene that gets into water or soil evaporates into the air.
- Microorganisms can break down some of the tetrachloroethylene in soil or underground water.
- In the air, it is broken down by sunlight into other chemicals or brought back to the soil and water by rain.
- It does not appear to collect in fish or other animals that live in water.

How might I be exposed to tetrachloroethylene?

- When you bring clothes from the dry cleaners, they will release small amounts of tetrachloroethylene into the air.
- When you drink water containing tetrachloroethylene, you are exposed to it.

How can tetrachloroethylene affect my health?

High concentrations of tetrachloroethylene (particularly in closed, poorly ventilated areas) can cause dizziness, headache, sleepiness, confusion, nausea, difficulty in speaking and walking, unconsciousness, and death.

Irritation may result from repeated or extended skin contact with it. These symptoms occur almost entirely in work (or hobby) environments when people have been accidentally exposed to high concentrations or have intentionally used tetrachloroethylene to get a "high."

In industry, most workers are exposed to levels lower than those causing obvious nervous system effects. The health effects of breathing in air or drinking water with low levels of tetrachloroethylene are not known.

Results from some studies suggest that women who work in dry cleaning industries where exposures to tetrachloroethylene can be quite high may have more menstrual problems and spontaneous abortions than women who are not exposed. However, it is not known if tetrachloroethylene was responsible for these problems because other possible causes were not considered.

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Division of Toxicology and Human Health Sciences
ATSDR

CS249955-AH

Tetrachloroethylene

CAS # 127-18-4

Results of animal studies, conducted with amounts much higher than those that most people are exposed to, show that tetrachloroethylene can cause liver and kidney damage. Exposure to very high levels of tetrachloroethylene can be toxic to the unborn pups of pregnant rats and mice. Changes in behavior were observed in the offspring of rats that breathed high levels of the chemical while they were pregnant.

How likely is tetrachloroethylene to cause cancer?

The Department of Health and Human Services (DHHS) has determined that tetrachloroethylene may reasonably be anticipated to be a carcinogen. Tetrachloroethylene has been shown to cause liver tumors in mice and kidney tumors in male rats.

Is there a medical test to show whether I've been exposed to tetrachloroethylene?

One way of testing for tetrachloroethylene exposure is to measure the amount of the chemical in the breath, much the same way breath-alcohol measurements are used to determine the amount of alcohol in the blood.

Because it is stored in the body's fat and slowly released into the bloodstream, tetrachloroethylene can be detected in the breath for weeks following a heavy exposure.

Tetrachloroethylene and trichloroacetic acid (TCA), a breakdown product of tetrachloroethylene, can be detected in the blood. These tests are relatively simple to perform. These tests aren't available at most doctors' offices, but can be per formed at special laboratories that have the right equipment.

Because exposure to other chemicals can produce the same breakdown products in the urine and blood, the tests for breakdown products cannot determine if you have been exposed to tetrachloroethylene or the other chemicals.

Has the federal government made recommendations to protect human health?

The EPA maximum contaminant level for the amount of tetrachloroethylene that can be in drinking water is 0.005 milligrams tetrachloroethylene per liter of water (0.005 mg/L).

The Occupational Safety and Health Administration (OSHA) has set a limit of 100 ppm for an 8-hour workday over a 40-hour workweek.

The National Institute for Occupational Safety and Health (NIOSH) recommends that tetrachloroethylene be handled as a potential carcinogen and recommends that levels in workplace air should be as low as possible.

Glossary

Carcinogenicity: The ability of a substance to cause cancer.

CAS: Chemical Abstracts Service.

Milligram (mg): One thousandth of a gram.

Nonflammable: Will not burn.

References

This ToxFAQs™ information is taken from the 1997 Toxicological Profile for Tetrachloroethylene (update) produced by the Agency for Toxic Substances and Disease Registry, Public Health Service, U.S. Department of Health and Human Services, Public Health Service in Atlanta, GA.

Where can I get more information?

For more information, contact the Agency for Toxic Substances and Disease Registry, Division of Toxicology and Human Health Sciences, 1600 Clifton Road NE, Mailstop F-57, Atlanta, GA 30333.

Phone: 1-800-232-4636.

ToxFAQs™ Internet address via WWW is http://www.atsdr.cdc.gov/toxfaqs/index.asp.

ATSDR can tell you where to find occupational and environmental health clinics. Their specialists can recognize, evaluate, and treat illnesses resulting from exposure to hazardous substances. You can also contact your community or state health or environmental quality department if you have any more questions or concerns.

Appendix C: Chemical Screening Process - Comparing Drinking Water TCE Concentrations to ATSDR Comparison Value

ATSDR Chemical Screening Process - Comparing Drinking Water TCE Concentrations to ATSDR Comparison Values

In the first step of the chemical screening process, ATSDR evaluates the drinking water sampling data by comparing the chemical concentrations detected in the drinking water against ATSDR's conservative (protective), comparison values (CV). ATSDR developed health-based comparison values for chemicals in drinking water, soil, and air. Comparison values are developed from available scientific literature concerning exposure and health effects. A health-based comparison value is a concentration of a chemical not likely to cause harmful health effects over a specified exposure duration. To be conservative and protective of public health, comparison values are generally based on chemical concentrations *many times lower than levels at which no effects were observed* in experimental animals or human studies. ATSDR does not use screening values to predict the occurrence of adverse health effects but rather to serve as a health protective first step in the evaluation process.

In this public health assessment, ATSDR used comparison values for chronic exposure (365 days and longer), including ATSDR's cancer risk evaluation guides (CREGs), environmental media evaluation guides (EMEGs), and reference environmental media evaluation guideline (RMEG). CREGs, EMEGs, and RMEGs are non-enforceable, health-based comparison values developed by ATSDR for screening environmental contamination for further evaluation.

ATSDR defines a comparison value (CV) as a calculated concentration of a substance in air, water, food, or soil that is unlikely to cause harmful (adverse) health effects in exposed people. The CV is used as a screening tool during the public health assessment process. Substances found in amounts greater than their CVs are selected for further evaluation in the public health assessment process.

ATSDR also used EPA's maximum contaminant level (MCL) as a comparison value. MCLs are enforceable drinking water regulations developed to protect public health, taking feasibility and cost into consideration. Other factors that become important in deciding which chemicals to evaluate further include the frequency of detection and a chemical's inherent toxicity.

Because ATSDR comparison values reflect concentrations much lower than those found to cause adverse health effects, comparison values are protective of public health in most exposure situations. As a result, **exposures to chemical concentrations detected at or below ATSDR's comparison values are not expected to cause health effects in people, are not considered a health hazard, and are not further evaluated.**

Although concentrations at or below the relevant comparison value can reasonably be considered safe, it does not automatically follow that any environmental concentration exceeding a comparison value would produce adverse health effects. **If contaminant concentrations are above comparison values, ATSDR further analyzes the contaminants in the second step of**

the screening process by calculating exposure doses using exposure variables (for example, duration and frequency of exposure) and comparing them to conservative (protective) health guidelines for the evaluation of non-cancer health effects. Doses that exceed health guidelines must undergo further toxicological study evaluation before a determination can be made about the potential of health effects. For carcinogens, exposure doses are combined with cancer potency information (cancer slope factors) to evaluate the lifetime excess cancer risk. The excess cancer risk is the number of increased cases of cancer in a population over a lifetime above background that may result from exposure to a contaminant under the assumed exposure conditions. Because of the uncertainties and conservatism (protective) inherent in deriving the cancer slope factor, this is only an estimate of risk: the true risk is unknown.

Results of Chemical Screening Process of Comparing Drinking Water TCE Concentrations to ATSDR Comparison Values

Residential Drinking Water Data

In 2011, 20015, and 2016, a total of 22 drinking water samples were collected from 11 residential wells used for domestic purposes (see Table 1 and Figure 1). The VOC analysis detected TCE in 11 of the residential drinking water samples from six residential wells (A, B, C, D, F, and G). The TCE concentrations in the drinking water from the six residential wells range of 0.71 ppb to 15 ppb. The six residential wells with TCE in the drinking water are near and south of Jonesville Road (State Route 11) and Garden Street (County Road 100 South) intersection. TCE concentrations exceed the ATSDR comparison value (cancer risk evaluation guide [CREG] of 0.43 ppb) in eleven samples from six residential wells and exceeded the EPA MCL of 5 ppb in five samples from two residential wells (A and B). Other VOCs detected were at levels below the ATSDR comparison values.

Three residential wells (A, B, and E) sampled have a GAC filter system provided by IDEM since 1990. The 2011, 2015, and 2016 unfiltered drinking water samples collected before GAC filter on residential wells A and B contain an average TCE concentrations of 10.3 ppb and 6.3 ppb, respectively, which are both greater than the ATSDR CREG and EPA MCL. In 2015 and 2016, six filtered tap water samples collected from residential wells A and B after the GAC filters did not contain TCE. The 2011 unfiltered drinking water sample from residential well E did not contain TCE and the drinking water was not sampled in 2015-16.

Eight private residential wells sampled do not have a GAC filter. TCE was detected in six drinking water samples from four residential wells (C, D, F, and G) without GAC filter at concentrations greater than the ATSDR CREG but lower than the EPA MCL. Three of these residential wells (D, F, G) were sampled in 2011 but not in 2015 and 2016.

Garden City Mobile Home Park Well Drinking Water Data

The Garden City Mobile Home Park well is used by 47 mobile homes for domestic purposes [IDEM 2012] (see Figure 1). The depth of the mobile home park well is approximately 58 feet below the ground surface [IDEM 2012]. The Garden City Mobile Home Park well is a public water system classified as a private community water system because it serves water to a residential population. Since 1997, TCE has been detected in the drinking water from the mobile home park well [IDEM 2012]. The Garden City Mobile Home Park well is monitoring on a quarterly basis for chemicals.

From 2002 to 2010, the drinking water from the Garden City Mobile Home Park well was sampled 32 times on a quarterly basis (see Table 2). TCE was detected in 29 of the samples, with a TCE concentration range of 1.6 ppb to 5.8 ppb and an average concentration of 4.5 ppb. Ten samples contained TCE concentrations greater than the EPA MCL of 5 ppb, 29 samples contained TCE concentrations greater than the ATSDR CREG of 0.43 ppb, and the average TCE concentration of 4.5 ppb in the mobile home park well drinking water samples collected from 2002 to 2010 exceeds ATSDR's CREG of 0.43 ppb.

From 2011 to 2016, 24 drinking water samples were collected from the Garden City Mobile Home Park well. The TCE concentration range of 0.9 ppb to 3.8 ppb and with average concentration of 1.9 ppb. TCE was detected in 20 of the samples at concentrations greater than the ATSDR CREG and the average TCE concentration from 2010 to 2016 samples exceeded ATSDR's CREG. None of the samples contained TCE concentrations greater than the MCL of 5 ppb.

In 2011, IDEM collected two drinking water samples from the Garden City Mobile Home Park well [IDEM 2012]. The VOC analysis detected TCE concentrations of 2.2 ppb in the untreated drinking water. The mobile home park well was not sampled by EPA during the remedial investigation sampling in 2015 and 2016.

Commercial Well Drinking Water Data

In 2011, 2015, and 2016, 15 drinking water samples were collected from seven different commercial wells (see Table 3 and Figure 1). TCE was detected in eight samples from four commercial wells with a concentration range of 0.13 to 15 ppb. TCE concentrations exceeded the ATSDR CREG of 0.43 ppb in seven samples from four commercial wells (2, 3, 4, 5) and exceeded the EPA MCL of 5 ppb in three samples from one commercial well (4).

The three drinking water samples collected from commercial well (#4) contained TCE concentrations of 15 ppb in 2011, 11 ppb in 2015, and 8.3 ppb in 2016 with an average concentration of 11.4 ppb. The average concentration of TCE is greater than the ATSDR CREG of 0.43 ppb and the EPA MCL of 5 ppb. The drinking water from this well is used in an office to supply the bathroom and to make coffee and wash hands.

The 2011 unfiltered drinking water sample collected before GAC filter from commercial well #2 contained a TCE concentration of 1.3 ppb that is greater than ATSDR CREG of 0.43 ppb. Filtered tap water samples were not collected after GAC filter in 2011. In 2009, the GAC filter was replaced after a TCE level of 5.85 ppb was detected in an unfiltered drinking water sample. In 2015 and 2016, TCE was not detected in the three unfiltered drinking water samples collected before the GAC filter and three filtered drinking water samples collected after the GAC filtered from commercial well #2. The filter was last replaced 2016.

In 2016, the drinking water sample collected from commercial well (#5) contained a TCE concentration of 1.5 ppb. Drinking water from this well was not sampled in 2011 or 2015. The drinking water samples collected from commercial well (#3) contained a TCE concentration of 0.13 ppb in 2011, 0.84 ppb in 2015, and 0.66 ppb in 2016 with an average concentration of 0.54 ppb that is greater than the ATSDR CREG of 0.43 ppb. Commercial wells (#3 and #5) are used to supply water to small buildings on the property of a concrete block and brick company.

Municipal Wells Drinking Water Data

In 2011, 2015, and 2016, 11 drinking water samples were collected from four municipal wells (#1, #2, #9, #12) in the Columbus Marr-Glick Well Field approximately one half mile south/southeast of the center of Garden City at the intersection of Jonesville Road and Garden Street (see Table 4 and Figure 2) [IDEM 2012]. The municipal wells are installed at depths ranging from 77 to 96 feet below the surface.

The VOC analysis detected TCE in five samples from two municipal wells (#9, #12) at a concentration range of 0.35 to 0.66 ppb. Two drinking water samples from municipal well #12 in 2011 and 2015 contained TCE concentration of 0.66 ppb and 0.63 ppb with an average of 0.64 ppb. These TCE concentrations are greater than the ATSDR CREG of 0.43 ppb. No samples were collected from municipal well #12 in 2016.

Three drinking water samples from municipal well #9 in 2011 and 2015 contained TCE at concentration of 0.35 ppb and 0.36 ppb with an average of 0.36 ppb. These TCE concentrations are less than the ATSDR CREG. In 2016, TCE was not detected in two samples collected from municipal well #9.

TCE was not detected in two municipal well #2 drinking water samples in 2011 and 2016 or the one municipal well #1 drinking water sample in 2015.

In 2015, two drinking water samples from municipal well #9 contained vinyl chloride concentrations of 0.26 ppb and 0.28 ppb, which are greater than the ATSDR CREG of 0.025 ppb (see Table 5). The three drinking water samples collected in 2011 and 2016 from municipal well #9 did not contain vinyl chloride.

Appendix D: Non-cancer Screening Evaluation Process - Comparing Estimated Total TCE Exposure Doses to Health Guidelines

Non-cancer Screening Evaluation Process - Comparing Estimated Total TCE Exposure Doses to Health Guidelines

In the second step of the screening process, ATSDR further evaluated the drinking water TCE levels in each of the 12 wells in Table 8 with drinking water containing a maximum TCE concentration above the ATSDR CREG comparison value of 0.43 ppb. In this non-cancer screening evaluation, ATSDR calculated chronic total TCE doses (annual doses averaged over 1 year of exposure) for different age groups, ranging from an infant to an adult and including pregnant women, using the contaminated drinking water for ingestion and showering. ATSDR paid special attention to TCE exposure of young children and pregnant women because the scientific data on TCE indicate that fetuses and young children may be especially sensitive to the toxic effects of TCE [ATSDR 2014a].

An exposure dose (usually expressed as milligrams [amount] of chemical per kilogram of body weight per day, or "mg/kg/day") is an estimate of how much of a substance actually got into a person's body from contaminated water based on their actions and habits.

The total TCE exposure dose for each age group was calculated by combining TCE doses within each age group from three domestic exposure pathway scenarios:

- Ingestion: Residents and worker drank well water.
- Dermal (skin) Contact: Residents absorbed TCE through their skin while showering with well water.
- Inhalation: Residents breathed in TCE volatilizing from water while showering with well water.

ATSDR combined the exposure doses from ingestion, inhalation, and dermal contact because TCE is rapidly absorbed into the bloodstream and distributed to the target organs regardless of exposure route. Ingestion exposure (i.e., drinking of water) is typically the most significant intake route of exposure to hazardous substances in drinking water. However, in the case of VOC contamination, inhalation exposure (i.e., breathing VOCs evaporating from water during showering, bathing, or other household use as dishwashing and laundry) and dermal absorption exposure (i.e., skin contact with water while showering, bathing, or other household use) can make a significant contribution to the total exposure dose from domestic use of contaminated water. Studies have shown that exposure to VOCs from routes other than direct ingestion might be as large as the exposure from ingestion alone.

Showering is considered a major contributor to overall exposure because TCE evaporates quickly from hot water into the air, and showering is typically done in a small, enclosed space where TCE concentrations might build up. The inhalation dose resulting from volatilization during a shower may equal the ingestion dose, and 50% to 90% of VOCs in water may volatize during showering, laundering, and other activities [Moya *et. al*. 1999; Giardino and Andelman 1996]. In addition to breathing in TCE from the air, people can absorb the chemicals through their skin. The dermal dose from VOCs has been estimated to equal 30% of the ingested dose [Maine DEP/DHS 1992].

Estimating Exposure Doses

For this public health assessment, in the absence of actual site-specific information on domestic household drinking water exposure, ATSDR calculated within each age group for each well the TCE doses from ingestion exposure, dermal contact exposure, and inhalation exposure. For these calculations, ATSDR used conservative default exposure assumptions about physical characteristics (i.e., body weight, skin surface, water ingestion rates, inhalation rates, and average life span) of infants, children, and adults, how they may have been exposed, and how often they may have been exposed (see Appendix E for non-cancer exposure dose equations and assumptions). For each well, the total chronic total TCE doses within each age group were calculated by combining the ingestion, dermal, and inhalation doses.

For each well of the 12 wells, ATSDR calculated high-end total TCE exposure doses for each age group using the maximum TCE concentration in the drinking water, the reasonable maximum exposure for the ingestion exposure pathway scenario, and the central tendency exposure for dermal contact and inhalation exposure pathway scenarios. See high-end total TCE doses in Table 1 in Appendix F. The reasonable maximum exposure ingestion scenario refers to people at the high end of water intake (consumption) rates with higher than average water-intake rates. ATSDR believes the reasonable maximum exposure scenario is a health-protective assumption. It overestimates the average consumption of water but remains within a realistic exposure range.

To provide a broad perspective of possible realistic exposures, ATSDR also calculated typical total TCE exposure doses using the mean TCE concentration in the drinking water and the central tendency exposure for ingestion, dermal contact, and inhalation exposure pathway scenarios. See typical total TCE doses in Table 2 in Appendix F.

For more typical and realistic TCE exposure doses, the mean concentration of TCE in drinking water of each well was also used because people are more likely to be exposed to a range of concentrations over time; the mean estimates a more probable exposure dose over time. The central tendency exposure refers to a more realistic exposure scenario with persons who have average or typical water intake rate and average or typical time in the shower and in the bathroom after showering.

ATSDR's Non-cancer Health Guideline Value

In Tables 1, 2, and 3 in Appendix F, ATSDR compared the estimated total TCE exposure doses to ATSDR's conservative (protective), health-based noncancer screening guideline, ATSDR's chronic oral minimal risk level (MRL) of 5.0 x 10^{-4} mg/kg/day for TCE [ATSDR 2014a]. ATSDR compared the estimated total TCE doses to ATSDR's MRL to determine whether TCE concentrations in well drinking water are a potential concern for adverse non-cancer health effects**. In the event a total exposure dose is greater than the health guideline, the TCE concentration in the drinking water requires in-depth evaluation in the report's Public Health Implication section to determine the likelihood of harmful health effects.**

ATSDR adopted EPA's RfD of 0.0005 mg/kg/day as its chronic oral MRL in January 2013 [ATSDR 2013]. An ATSDR MRL is a dose estimate of daily human exposure to a hazardous substance likely without an appreciable risk of adverse noncancer health effects over a specified route and duration of exposure. The EPA RfD is a dose estimate of daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of harmful effects during a lifetime.

The scientific literature indicates available human and animal studies identify the kidney, liver, immune system, and developing fetuses as potential targets of TCE toxicity [ATSDR 2014a]. Results from animal studies suggest that the immune system and developing fetuses may be particularly sensitive targets [ATSDR 2014a]. These effects are not exposure-route specific; similar effects can be elicited via ingestion, inhalation, and dermal exposure routes [ATSDR 2014a].

The EPA RfD of 5.0×10^{-4} mg/kg/day for TCE is supported by multiple noncancer effects observed in multiple studies. The most sensitive noncancer adverse effects observed in animal studies were used as the primary basis for the ATSDR MRL and EPA RfDs for TCE. The TCE RfD is based on three principal and two supporting animal studies used to develop five RfDs for the most sensitive endpoints within each type of TCE toxicity [USEPA 2011a]. The RfDs for effects in the five studies are in the relatively narrow range of 3.4×10^{-4} to 8.0×10^{-4} mg/kg/day [USEPA 2011a]. The RfD of 5.0×10^{-4} mg/kg/day for TCE is within 25% of each candidate RfD and reflects the midpoint among the similar candidate RfDs: 3.7×10^{-4} mg/kg/day for developmental immunotoxicity in mice, 5.1×10^{-4} mg/kg/day for developmental heart malformations in rats, 4.8×10^{-4} mg/kg/day decreased thymus weights in mice [USEPA 2011a]. This TCE RfD is also within approximately a factor of 2 of the supporting effect estimates of 3.4×10^{-4} mg/kg/day for toxic nephropathy in rats and 8.0×10^{-4} mg/kg/day for increased kidney weight in rats [USEPA 2011a]. Thus, there is strong, robust support for an RfD of 5.0×10^{-4} mg/kg/day provided by the concordance of estimates derived from multiple effects from multiple studies [USEPA 2011a].

The three principal toxicological studies used to develop RfDs identify the lowest doses shown to cause the most sensitive critical adverse health effects.

- A rat study showed increase rates of developmental heart defects in newborn rats born to mothers who were exposed to TCE in drinking water during gestation [USEPA 2011a, Johnson *et al*., 2003]. EPA applied physiologically based pharmacokinetics (PBPK) models of TCE metabolism in rats and humans to the animal study results to obtain a 99th percentile human equivalent dose (HED^{99}) of 0.0051 mg/kg/day [USEPA 2011a]. The HED_{99} is the dose derived from animal studies that takes into account the physiologic and pharmacokinetic differences in animal models and humans. An HED_{99} can be interpreted as an ingestion dose in humans for which there is 99% likelihood that a randomly selected individual will have an internal human dose less than or equal to the internal animal dose in the study [USEPA 2011a]. An HED_{99} of 5.1×10^{-3} mg/kg/day TCE derived for a 1 percent response rate of fetal heart malformation in humans maybe consistent with the critical effects dose associated with heart malformations in rats. To account for the possibility that humans may be more sensitive than rats and for differences in human sensitivity, EPA applied a composite uncertainty factor of 10 to the HED_{99} to derive the RfD for heart malformation [USEPA 2011a]. ATSDR uses this HED_{99} health effect level of 0.0051 mg/kg/day to evaluate the potential for developmental heart defects in babies from pregnant women exposure to TCE during the three week window of critical fetal heart development in the first trimester of pregnancy.

- A study of female adult mice showed immune system effects (decreased thymus weight) after exposure to TCE in a thirty-week drinking water study [USEPA 2011a, Kiel *et. al*. 2009]. EPA converted the lowest-observed-adverse-effect level (LOAEL) of 0.35 mg/kg/day to obtain a HED_{99} of 0.048 mg/kg/day [USEPA 2011a]. A HED_{99} of 4.8×10^{-2} mg/kg/day TCE derived for a 1 percent response rate of immune system effects in humans maybe consistent with the critical effects dose associated with decreased thymus weight in rats. To account for the use of a LOAEL, the possibility that humans may be more sensitive than rats, and the differences in human sensitivity, EPA applied a composite uncertainty factor of 100 to the HED_{99} to derive the RfD for immune system effects [USEPA 2011a]. ATSDR uses this HED_{99} health effect level of 0.048 mg/kg/day to evaluate the potential non-cancer health effects (i.e., immune system effects) for all age groups.

- A study of mice exposed to TCE in drinking water during gestation and following birth showed problems with immune system development (increased delayed-type hypersensitivity) [USEPA 2011a; Peden-Adams *et. al*. 2006]. EPA used the lowest observed adverse effect level (LOAEL) of 0.37 mg/kg/day as a point of departure [USEPA 2011a]. To account for the use of a LOAEL for multiple effects, the possibility that humans may be more sensitive than rats, and the differences in human sensitivity, EPA applied a composite uncertainty factor of 1000 to the HED_{99} to derive the RfD for developmental immune effects [USEPA 2011a]. ATSDR uses this LOAEL of 0.37

mg/kg/day to evaluate the potential non-cancer health effects (i.e., developmental immunotoxicity effects) for all age groups.

Additional support for the RfD was based on adverse effects in the kidney [EPA 2011a, Woolhiser *et al.* 2006], increased kidney weights in rats, HED_{99} of 7.9×10^{-3} mg/kg/day TCE; and [EPA 2011a, NTP 1988], kidney effects, and toxic nephropathy in rats, HED_{99} of 3.4×10^{-3} mg/kg/day TCE].

The ATSDR MRL of 3.0×10^{-3} mg/kg/day for vinyl chloride is supported by studies of humans and animals with similar results being exhibited in all species. The liver is the most sensitive target organ for chronic low level inhalation and oral exposures. The sensitivity of the liver to vinyl chloride exposure is consistent with the proposed mechanism of action in which the metabolism of vinyl chloride in the liver results in the formation of highly reactive metabolites that have been shown to bind to DNA and hepatocellular proteins. Long duration exposures to low doses in rats have resulted in the manifestation of liver cell polymorphisms and development of hepatic cysts. In addition to noncancer effects, the liver is sensitive to tumor development (liver angiosarcoma, pre-neoplastic baseophilic foci) from chronic low level vinyl chloride exposure.

Estimated exposure doses lower than MRLs or RfDs are not expected to cause health effects, are not considered a health hazard, and are not further evaluated. Note that while estimated total TCE exposure doses at or below the conservative (protective) MRL can be considered safe, estimated total exposure doses higher than the screening guideline value do not necessarily imply adverse health effects. Rather, **if the estimated exposure dose is higher than the MRL that** is only an indication that ATSDR should further evaluate exposure pathways and conduct an in-depth toxicological evaluation of TCE in the Public Health Implications section to determine the likelihood of harmful health effects.

Results of Non-cancer Screening Evaluation of Comparing Estimated Total TCE Exposure Doses to Health Guidelines

In Table 1 in Appendix F, five wells (three residential wells A, B, G; Garden City Mobile Home Park well; and commercial well #4) have high-end total TCE doses greater than ATSDR's chronic oral MRL value of 5.0×10^{-4} mg/kg/day for TCE. Based on high-end domestic household use of drinking water, all age groups using residential well A and commercial well #4 have total TCE dose greater than the ATSDR MRL for TCE. For residential well B, the five youngest age groups and pregnant women have total TCE doses greater than the MRL for TCE. For the mobile home park well (2002 to 2010), the four youngest age groups have total TCE doses greater than the MRL. The two youngest age groups in residential well G and the mobile home park well (2011 to 2016) have total TCE doses greater than the TCE MRL.

In Table 2 in Appendix F, three wells (two residential wells A and B, and commercial well #4) have typical total TCE doses greater than ATSDR's chronic oral MRL value of 5.4 x 10^{-4} mg/kg/day for TCE. Based on typical or realist domestic household use of drinking water, the total TCE dose for the four youngest age groups from residential well A is greater than the ATSDR MRL for TCE. For residential well B, the two youngest age groups have total TCE doses greater than the MRL for TCE. Five of the age groups in commercial well #4 have total TCE doses greater than the TCE MRL. Therefore, in the Public Health Implications section, ATSDR will further evaluate exposure pathways and conduct an in-depth health effects evaluation of exposure to TCE in the drinking water from the wells in Table 7.

Based on the estimated high-end total TCE doses in Table 1 in Appendix F, all the estimated high-end exposure doses are below the MRL screening guideline for residential well C, residential well D, residential well F, commercial well #2, commercial well #3, commercial well #5, and municipal well #12. TCE concentrations in the drinking water from these wells are not expected to cause noncancer health effects and would not be a non-cancer public health hazard for children and adults using the drinking water for domestic purposes. Therefore, ATSDR will not further evaluate noncancer health effects from exposure to TCE in the drinking water from these wells.

The maximum concentration of 0.28 ppb vinyl chloride in the drinking water from municipal well five well #9 results in high-end vinyl chloride dose for all age groups to be much less than ATSDR's chronic oral MRL value of 3.0 x 10^{-3} mg/kg/day for vinyl chloride. Therefore, ATSDR will not further evaluate noncancer health effects from exposure to vinyl chloride in the drinking water from the municipal well.

To evaluate the potential for heart defects among babies exposed to TCE in utero, ATSDR evaluated the potential total TCE doses to pregnant women potentially exposed during the three-week window of critical fetal heart development in the first trimester of pregnancy. ATSDR calculated total TCE doses to pregnant women using the maximum TCE concentration in drinking water, the reasonable maximum exposure for the ingestion exposure pathway scenario, and the central tendency exposure for dermal contact and inhalation exposure pathway scenarios (See Table 3 in Appendix F). ATSDR used the maximum TCE concentration in the drinking water because women could be exposed to the maximum concentration during the entire three-week window for critical fetal heart development during the first trimester. The reasonable maximum exposure ingestion scenario was used as a health-protective assumption because it overestimates the average consumption of water but remains within a realistic exposure range. The central tendency exposure scenario was used a realistic exposure to a woman with an average or typical time in the shower and in the bathroom after showering.

In Table 3 in Appendix F, three wells (two residential wells A and B, and commercial well #4) have total TCE doses to pregnant women greater than ATSDR's chronic oral MRL value of 5.4 x

10^{-4} mg/kg/day for TCE. Exposure of pregnant women to TCE in these three wells and the potential for birth defects will be evaluated further in the Public Health Implication section. The other nine wells have estimated TCE doses below the MRL and will not be evaluated further with regard to potential birth defects.

APPENDIX E: Non-cancer Screening Evaluation - Exposure Dose Equations and Assumptions

Ingestion Exposure Dose Equations and Assumptions

Ingestion exposure (drinking water) is typically the most significant route of exposure to hazardous substances in drinking water. The following general equation and assumptions in Table 1 are used to calculate chronic (1-year annual) exposure dose from ingestion of drinking water.

Water Ingestion Exposure Dose Equation

$$D = \frac{C \ x \ IR}{BW}$$

D = exposure dose in milligrams per kilogram per day, mg/kg/day
C = chemical concentration in milligrams per liter, $(\frac{mg}{L})$
IR = ingestion rate of water in liters per day, $(\frac{L}{day})$
BW = body weight in kilograms, *(kg)*

Table 1. Assumptions for Water Ingestion Exposure Dose Equation

Age Group (years)	Body Weight (kg)	Ingestion Rate of Water (L/day)	
		Reasonable Maximum Exposure (L/day)	Central Tendency Exposure (L/day)
Birth to <1	7.8	1.113	0.504
1 to <2	11.4	0.893	0.308
2 to <6	17.4	0.977	0.376
6 to <11	31.8	1.404	0.511
11 to <16	56.8	2.444	0.637
16 to <21	71.6	1.976	0.770
21+	80	3.1	1.227
Pregnant Women (16 to 45)	73	2.589	0.872

Notes:
Reasonable Maximum Exposure (RME) refers to persons who are at the upper end of the exposure distribution (approximately the 95th percentile). The scenario assesses exposures that are higher than average but still within a realistic exposure range.
Central Tendency Exposure (CTE). CTE refers to persons who have average or typical water intake rate. [ATSDR 2014b].

Inhalation Exposure Dose Equations and Assumptions

VOCs such as TCE can escape, or volatilize, from water used for household purposes, including showering, bathing, or other household use. Inhaling VOCs evaporating from water during showering can make a significant contribution to the total exposure dose from domestic use of contaminated water. ATSDR estimated the inhalation exposure dose is a 3-step process:

1) Calculate the TCE concentration in the bathroom from showering
2) Calculate the amount of TCE inhaled
3) Calculate the inhalation exposure dose

In step 1, ATSDR estimates the TCE concentration in the bathroom as a result of TCE volatilizing while showering using a model developed by Andelman [Andelman 1990] and exposure assumptions in Table 2.

Equation for Air Concentration of TCE in Bathroom/Shower

$$C_a = \frac{k \ x \ F_w \ \ x \ T_s \ x \ C_w \ x \ CF}{V_a}$$

C_a = air concentration in bathroom/shower, in milligrams per cubic meter, $\frac{mg}{m^3}$
k = volatile mass transfer coefficient, unitless (default is 0.6)
F_w = flow rate of water through shower, in liters per min, L/min (default is 8 $\frac{L}{min}$)
T_s = time in shower, in minutes (varies with age, see Table 2)
C_w = TCE concentration in water, in milligrams per liter, $\frac{mg}{L}$
CF = conversion factor (1,000 $\frac{L}{m^3}$)
V_a = bathroom air volume, in liters, L (default is 10,000 L)

In step 2, ATSDR calculates how much TCE in bathroom air will be inhaled by the average person using the equation for inhalation intake of TCE in air and assumptions in Table 2. TCE in air will be breathed in during the shower and during any time in the bathroom after the shower.

Equation for Inhalation Intake of TCE in Bathroom/Shower Air

$$II = peak\ conc\ x\ IR_{st}\ x\ (T_s + T_b)$$

II = inhalation intake during shower and stay in bathroom in (µg)
Peak conc = concentration calculated in Step 1, in ($\frac{\mu g}{m^3}$)
IR_{st} = short-term inhalation (breathing) rate ($\frac{m^3}{min}$)
T_s = time in shower, in minutes (varies with age, See Table B)

T_b = time in bathroom after shower, in minutes (See Table B)

In step 3, ATSDR calculates the inhalation exposure dose expressed as mg/kg/day.

$$ID = \frac{II/1\,day}{BW}/1000$$

ID = inhalation dose during shower and stay in bathroom after shower *(mg/kg/day)*
II = inhalation intake during shower and stay in bathroom *(µg)*
BW = body weight in kilograms, *(kg)*

Table 2. Exposure Assumptions for Inhalation of TCE while Showering

Age Group (years)	Average Shower time (minutes)*	Average Bathroom Stay after Shower (minutes)*	Average Short-term Breathing Rates While Showering (m^3/min)#	Average Long-term Breathing Rates (m^3/day)
1 to <2	10	5	0.012	8.0
2 to <6	10	5	0.011	9.8
6 to <11	15	5	0.011	12.0
11 to <16	15	5	0.013	15.2
16 to <21	15	5	0.012	16.3
21+	15	5	0.012	15.2
Pregnant Women (16 to 45)	15	5	0.016	22

Notes:
* - Average shower time and bathroom stay after shower derived using professional judgment with input from Table 16-32: Time spent (minutes) Showering and in Shower Room Immediately After Showering, EPA Exposure Factors Handbook (2011)
# - Table 6-2: Recommended Short-Term Exposure Values for Inhalation (males and females combined), Light Intensity, EPA Exposure Factors Handbook (2011)
Average represents the mean (50^{th} percentile) value
ATSDR recognize that very young children (>1 year) are likely to take baths, therefore, we did not estimate showering exposures for this age group.

Dermal Exposure Dose Equations and Assumptions

Absorption of VOCs like TCE in water occurs during showers and baths. ATSDR estimated skin intake using the general methods of EPA's Risk Assessment Guidance for Superfund, Part E [EPA 2004]. The following equation and exposure assumptions in Table 3 were used to estimate how much dermal exposure to TCE would occur while showering.

Equation for Dermal Absorption While Showering:

$$2\ x\ FA\ x\ K_p\ x\ C_w\ x\ \frac{1L}{1000\ cm^3}\ x\ SA\ x\ \sqrt{\frac{6\ x\ \tau(hr)x\ T_s}{60\ \frac{min}{hr}\ x\ \pi}}$$

Intake$_{skin}$ = absorbed dose (µg)
FA = fraction absorbed water (assumed to be 1)
K_p = dermal permeability coefficient for TCE (0.012 cm/hr)
C_w = chemical concentration in water (µg/L)
SA = total skin surface area in cm^2 (varies with age, See Table C)
τ_{event} = lag time per event (0.58 hr)
T_s = time in shower (varies with age, See Table B)
π = pi, 3.14

Table 3. Assumptions for Dermal Absorption of TCE while Showering

Age Group	Total Body Surface Area in cm^2 (Average surface area)
1 to <2 years	5,300
2 to <6 years	7,775
6 to <11 years	10,800
11 to <16 years	15,900
16 to <21 years	18,400
21+ years	19,780
Pregnant Women (16 to 45 years old)	19,375

Note:
Agency for Toxic Substances and Disease Registry. 2015. Exposure Dose Guidance for Dermal Exposures to Soil and Sediment. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. October 2015.

APPENDIX F: Non-Cancer Screening Evaluation – Estimated Total TCE Doses Compared to ATSDR Health Guideline

Table 1. High-End Total TCE Dose via Reasonable Maximum Ingestion Exposure and Central Tendency Dermal Contact and Inhalation Exposures While Showering With Maximum TCE Concentration in Drinking Water from Residential Wells, Garden City Mobile Park Well, Commercial Wells, and Municipal Well #12

Well (maximum TCE concentration in drinking water [ppb])	Age Group (years)	TCE Dose From Ingesting Drinking Water Reasonable Maximum Exposure (mg/kg/day)	TCE Dose From Dermal Contact While Showering with Drinking Water Central Tendency Exposure 15 Minute Shower Time (mg/kg/day)	TCE Dose from Inhalation While Showering with Drinking Water and Inhaling Bathroom Air Central Tendency Exposure 15 Minute Shower Time (mg/kg/day)	Total TCE Dose From Ingestion, Dermal Contact, and Inhalation (mg/kg/day)	Estimated Total TCE Dose Exceeds ATSDR Chronic Oral Minimal Risk Level (MRL) Health Guideline (5.4×10^{-4} mg/kg/day)
Residential Well A (15 ppb)	Birth to <1	2.1 E-03	N/A	N/A	2.1 E-03*	Yes
	1 to <2	1.2 E-03	8.5 E-05	1.1 E-03	2.4 E-03	Yes
	2 to <6	8.4 E-04	8.2 E-05	7.0 E-04	1.6 E-03	Yes
	6 to <11	6.6 E-04	6.2 E-05	7.5 E-04	1.5 E-03	Yes
	11 to <16	5.2 E-04	5.1 E-05	4.9 E-04	1.1 E-03	Yes
	16 to <21	5.1 E-04	4.7 E-05	3.6 E-04	9.2 E-04	Yes
	21+	5.8 E-04	4.5 E-05	3.3 E-04	9.6 E-04	Yes
	Pregnant Women (16 to 45)	5.3 E-04	4.9 E-05	4.5 E-04	1.0 E-03	Yes
Residential Well B (8.3 ppb)	Birth to <1	1.3 E-04	N/A	N/A	1.2 E-03*	Yes
	1 to <2	7.0 E-04	4.7 E-05	6.3 E-04	1.3 E-03	Yes
	2 to <6	4.7 E-04	4.5 E-05	3.9 E-04	9.6 E-04	Yes
	6 to <11	3.7 E-04	3.5 E-05	4.1 E-04	8.1 E-04	Yes
	11 to <16	3.0 E-04	2.8 E-05	2.7 E-04	6.0 E-04	Yes
	16 to <21	3.0 E-04	2.6 E-05	2.0 E-04	5.2 E-04	No
	21+	3.2 E-04	2.5 E-05	1.9 E-04	5.3 E-04	No
	Pregnant Women (16 to 45)	2.9 E-04	2.7 E-05	2.5 E-04	5.7 E-04	Yes
Residential Well C (2.9 ppb)	Birth to <1	4.1 E-04	N/A	N/A	4.1 E-04*	No
	1 to <2	2.3 E-04	1.7 E-05	2.2 E-04	4.6 E-04	No
	2 to <6	1.6 E-04	1.6 E-05	1.4 E-04	3.2 E-04	No

	6 to <11	1.3 E-04	1.2 E-05	1.4 E-04	2.8 E-04	No
	11 to <16	1.0 E-04	1.0 E-05	1.0 E-04	2.1 E-04	No
	16 to <21	1.0 E-04	9.1 E-06	7.0 E-05	1.8 E-04	No
	21+	1.1 E-04	8.8 E-06	6.0 E-05	1.8 E-04	No
	Pregnant Women (16 to 45)	1.0 E-04	9.5 E-06	9.0 E-05	1.9 E-04	No
Residential Well D (0.71 ppb)	Birth to <1	1.0 E-04	N/A	NA	1.0 E-04*	No
	1 to <2	5.6 E-05	4.0 E-06	5.0 E-05	1.1 E-04	No
	2 to <6	4.0 E-05	3.9 E-06	3.0 E-05	7.4 E-05	No
	6 to <11	3.1 E-05	3.0 E-06	4.0 E-05	7.4 E-05	No
	11 to <16	2.5 E-05	4.2 E-06	2.0 E-05	4.9 E-05	No
	16 to <21	2.4 E-05	2.3 E-06	2.0 E-05	4.6 E-05	No
	21+	2.7 E-05	2.2 E-06	2.0 E-05	4.9 E-05	No
	Pregnant Women (16 to 45)	2.5 E-05	2.3 E-06	2.0 E-05	4.7 E-05	No
Residential Well F (2.5 ppb)	Birth to <1	3.6 E-04	N/A	NA	3.6 E-04*	No
	1 to <2	2.0 E-04	1.4 E-05	1.9 E-04	4.0 E-04	No
	2 to <6	1.4 E-04	1.4 E-05	1.2 E-04	2.7 E-04	No
	6 to <11	1.1 E-04	1.0 E-05	1.2 E-04	2.4 E-04	No
	11 to <16	8.7 E-05	8.6 E-06	8.0 E-05	1.7 E-04	No
	16 to <21	8.5 E-05	8.1 E-06	6.0 E-05	1.5 E-04	No
	21+	9.7 E-05	7.6 E-06	6.0 E-05	1.1 E-04	No
	Pregnant Women (16 to 45)	8.9 E-05	8.2 E-06	7.0 E-05	1.7 E-04	No

Residential Well G (4.2 ppb)	Birth to <1	6.0 E-04	N/A	NA	6.0 E-04*	Yes
	1 to <2	3.3 E-04	2.4 E-05	3.2 E-04	6.7 E-04	Yes
	2 to <6	2.4 E-04	2.3 E-05	2.0 E-04	4.6 E-04	No
	6 to <11	1.8 E-04	1.8 E-05	2.1 E-04	4.0 E-04	No
	11 to <16	1.5 E-04	1.4 E-05	1.4 E-04	3.0 E-04	No
	16 to <21	1.4 E-04	1.4 E-05	1.0 E-04	2.5 E-04	No
	21+	1.6 E-04	1.3 E-05	9.0 E-05	4.0 E-04	No
	Pregnant Women (16 to 45)	1.5 E-04	1.4 E-05	1.2 E-04	2.8 E-04	No
Garden City Mobile Home Park Well 2011 – 2016 (3.8 ppb)	Birth to <1	5.4 E-04	N/A	NA	5.4 E-04*	Yes
	1 to <2	3.0 E-04	3.2 E-05	2.4 E-04	6.2 E-04	Yes
	2 to <6	2.1 E-04	2.1 E-05	1.8 E-04	4.1 E-04	No
	6 to <11	1.7 E-04	1.6 E-05	1.9 E-04	3.8 E-04	No
	11 to <16	1.3 E-04	1.3 E-05	1.3 E-04	2.7 E-04	No
	16 to <21	1.3 E-04	1.2 E-05	5.0 E-05	2.3 E-04	No
	21+	1.5 E-04	1.2 E-05	8.0 E-05	2.4 E-04	No
	Pregnant Women (16 to 45)	1.3 E-04	1.2 E-05	1.1 E-04	2.5 E-04	No
Garden City Mobile Home Park Well 2002 – 2010 (5.8 ppb)	Birth to <1	8.3 E-04	N/A	NA	8.3 E-04*	Yes
	1 to <2	4.5 E-04	3.3 E-05	4.4 E-04	9.2 E-04	Yes
	2 to <6	3.3 E-04	3.2 E-05	2.7 E-04	6.3 E-04	Yes
	6 to <11	2.6 E-04	2.4 E-05	2.9 E-04	5.7 E-04	Yes
	11 to <16	2.0 E-04	2.0 E-05	1.9 E-04	4.1 E-04	No
	16 to <21	2.0 E-04	1.8 E-05	1.4 E-04	3.6 E-04	No
	21+	2.2 E-04	1.8 E-05	1.3 E-04	3.3 E-04	No
	Pregnant Women (16 to 45)	2.1 E-04	1.9 E-05	1.7 E-04	4.0 E-04	No

Commercial Well #2 (1.3 ppb)	Birth to <1	1.9 E-04	NA	NA	1.9 E-04*	No
	1 to <2	1.0 E-04	7.4 E-06	1.0 E-04	2.1 E-04	No
	2 to <6	7.0 E-05	7.1 E-06	6.0 E-05	1.4 E-04	No
	6 to <11	6.0 E-05	5.4 E-06	6.0 E-05	1.2 E-04	No
	11 to <16	4.0 E-05	4.5 E-06	4.0 E-05	8.4 E-05	No
	16 to <21	4.0 E-05	4.2 E-06	3.0 E-05	7.4 E-05	No
	21+	5.0 E-05	3.9 E-06	3.0 E-05	8.4 E-05	No
	Pregnant Women (16 to 45)	4.6 E-05	4.2 E-06	4.0 E-05	9.0 E-05	No
Commercial Well #3 (0.66 ppb)	Birth to <1	9.4 E-05	N/A	NA	9.4 E-05*	No
	1 to <2	5.2 E-05	3.8 E-06	5.0 E-05	1.0 E-04	No
	2 to <6	3.7 E-05	3.6 E-06	3.0 E-05	7.0 E-05	No
	6 to <11	2.9 E-05	2.7 E-06	3.0 E-05	6.0 E-05	No
	11 to <16	2.3 E-05	2.3 E-06	2.0 E-05	4.5 E-05	No
	16 to <21	2.3 E-05	2.1 E-06	2.0 E-05	4.4 E-05	No
	21+	2.6 E-05	2.0 E-06	1.0 E-05	3.8 E-05	No
	Pregnant Women (16 to 45)	2.3 E-05	2.2 E-06	2.0 E-05	4.5 E-05	No
Commercial Well #4 (15 ppb)	Birth to <1	2.1 E-03	N/A	NA	2.1 E-03*	Yes
	1 to <2	1.2 E-03	8.5 E-05	1.1 E-03	2.4 E-03	Yes
	2 to <6	8.4 E-04	8.2 E-05	7.0 E-04	1.6 E-03	Yes
	6 to <11	6.6 E-04	6.2 E-05	7.5 E-04	1.5 E-03	Yes
	11 to <16	5.2 E-04	5.1 E-05	4.9 E-04	1.1 E-03	Yes
	16 to <21	5.1 E-04	4.7 E-05	3.6 E-04	9.2 E-04	Yes
	21+	5.8 E-04	4.5 E-05	3.3 E-04	9.6 E-04	Yes
	Pregnant Women (16 to 45)	5.3 E-04	4.9 E-05	4.5 E-04	1.0 E-03	Yes

Commercial Well #5 (1.5 ppb)	Birth to <1	2.1 E-04			2.1 E-04	No
	1 to <2	1.2 E-04	8.5 E-06	1.1 E-04	2.4 E-04	No
	2 to <6	8.4 E-05	8.2 E-06	7.0 E-05	1.6 E-04	No
	6 to <11	6.6 E-05	6.2 E-06	7.0 E-05	1.4 E-04	No
	11 to <16	5.2 E-05	5.1 E-06	5.0 E-05	1.1 E-04	No
	16 to <21	5.1 E-05	4.7 E-06	4.0 E-05	9.6 E-05	No
	21+	5.8 E-05	4.5 E-06	3.0 E-05	6.1 E-05	No
	Pregnant Women (16 to 45)	5.3 E-05	4.9 E-06	4.2 E-05	1.0 E-04	No
Municipal Well #12 (0.65 ppb)	Birth to <1	9.4 E-05	N/A	NA	9.4 E-05*	No
	1 to <2	5.2 E-05	3.8 E-06	5.0 E-05	1.0 E-04	No
	2 to <6	3.7 E-05	3.6 E-06	3.0 E-05	7.0 E-05	No
	6 to <11	2.9 E-05	2.7 E-06	3.0 E-05	6.0 E-05	No
	11 to <16	2.3 E-05	2.2 E-06	2.0 E-05	4.5 E-05	No
	16 to <21	2.3 E-05	2.1 E-06	2.0 E-05	4.4 E-05	No
	21+	2.6 E-05	2.0 E-06	1.0 E-05	3.8 E-05	No
	Pregnant Women (16 to 45)	2.3 E-05	2.2 E-06	2.0 E-05	4.5 E-05	No

Note: ppb = parts per billion (microgram per liter [µg/L])
mg/kg/day = milligrams per kilogram per day
NA = not applicable, ATSDR did not estimate exposures from showering for children less than 1 year of age because these very young children are more likely to take baths rather than showers.
* = The ingestion dose was used as the total TCE dose for the birth to <1 year age group; does not include dermal contact and inhalation
Bold = total TCE dose from ingestion, dermal contact, and inhalation is greater than the ATSDR chronic oral minimal risk level of 5.4 E-04 mg/kg/day.

Data sources: IDEM 2011, EPA 2016a, EPA 2016b

Table 2. Typical Total TCE Dose via Central Tendency Ingestion Exposure and Central Tendency Dermal Contact and Inhalation Exposures While Showering with the Average TCE Concentration in Drinking Water from Residential Wells, Garden City Mobile Park Well, Commercial Wells, and Municipal Well #12

Well (average TCE concentration [ppb])	Age Group (years)	TCE Dose From Ingesting Drinking Water Central Tendency Exposure (mg/kg/day)	TCE Dose From Dermal Contact While Showering with Drinking Water Central Tendency Exposure 15 Minute Shower Time (mg/kg/day)	TCE Dose From Inhalation While Showering with Drinking Water and Inhaling Bathroom Air Central Tendency Exposure 15 Minute Shower Time (mg/kg/day)	Total TCE Dose From Ingestion, Dermal Contact, and Inhalation (mg/kg/day)	Estimated Total TCE Dose Exceeds ATSDR Chronic Oral Minimal Risk Level (MRL) Health Guideline (5.4×10^{-4} mg/kg/day)
Residential Well A (10.3 ppb)	Birth to <1	6.7 E-04	N/A	N/A	6.7 E-04*	Yes
	1 to <2	2.8 E-04	5.9 E-05	7.8 E-04	1.1 E-03	Yes
	2 to <6	2.2 E-04	5.6 E-05	4.8 E-04	7.6 E-04	Yes
	6 to <11	1.7 E-04	4.3 E-05	5.1 E-04	7.2 E-04	Yes
	11 to <16	1.2 E-04	3.5 E-05	3.4 E-04	5.0 E-04	No
	16 to <21	1.1 E-04	3.3 E-05	2.5 E-04	4.2 E-04	No
	21+	1.6 E-04	3.1 E-05	2.3 E-04	4.4 E-04	No
	Pregnant Women (16 to 45)	1.2 E-04	3.1 E-05	3.1 E-04	4.6 E-04	No
Residential Well B (6.3 ppb)	Birth to <1	4.1 E-04	N/A	N/A	4.1 E-04*	Yes
	1 to <2	1.7 E-04	3.6 E-05	4.8 E-04	6.9 E-04	Yes
	2 to <6	1.4 E-04	3.5 E-05	2.9 E-04	4.6 E-04	No
	6 to <11	1.0 E-04	2.6 E-05	3.1 E-04	4.4 E-04	No
	11 to <16	7.1 E-05	2.2 E-05	2.1 E-04	3.0 E-04	No
	16 to <21	6.8 E-05	2.0 E-05	1.5 E-04	2.4 E-04	No
	21+	1.0 E-04	1.9 E-05	1.4 E-04	1.7 E-04	No
	Pregnant Women (16 to 45)	7.0 E-05	1.9 E-05	1.9 E-04	2.8 E-04	No

Residential Well C (1.7 ppb)	Birth to <1	1.1 E-04	N/A	N/A	1.1 E-04*	No
	1 to <2	5.0 E-05	9.7 E-06	1.3 E-04	1.9 E-04	No
	2 to <6	4.0 E-05	9.3 E-06	8.0 E-05	1.3 E-04	No
	6 to <11	3.0 E-05	7.1 E-06	8.0 E-05	1.2 E-04	No
	11 to <16	2.0 E-05	5.9 E-06	6.0 E-05	8.6 E-05	No
	16 to <21	2.0 E-05	5.5 E-06	4.0 E-05	6.5 E-05	No
	21+	3.0 E-05	5.2 E-06	4.0 E-05	7.5 E-05	No
	Pregnant Women (16 to 45)	2.0 E-05	5.2 E-06	5.0 E-05	7.5 E-05	No
Residential Well D (0.71 ppb)	Birth to <1	4.6 E-05	N/A	NA	4.6 E-05*	No
	1 to <2	1.9 E-05	4.0 E-06	5.0 E-05	7.3 E-05	No
	2 to <6	1.5 E-05	3.9 E-06	3.0 E-05	4.9 E-05	No
	6 to <11	1.1 E-05	3.0 E-06	4.0 E-05	5.4 E-05	No
	11 to <16	8.0 E-06	4.2 E-06	2.0 E-05	3.2 E-05	No
	16 to <21	8.0 E-06	2.3 E-06	2.0 E-05	3.0 E-05	No
	21+	1.1 E-05	2.2 E-06	2.0 E-05	3.2 E-05	No
	Pregnant Women (16 to 45)	8.0 E-06	2.2 E-06	2.0 E-05	3.0 E-05	No
Residential Well F (2.5 ppb)	Birth to <1	1.6 E-04	N/A	NA	1.6 E-04*	No
	1 to <2	6.8 E-05	1.4 E-05	1.9 E-04	2.7 E-04	No
	2 to <6	5.4 E-05	1.4 E-05	1.2 E-04	1.9 E-04	No
	6 to <11	4.0 E-05	1.0 E-05	1.2 E-04	1.7E-04	No
	11 to <16	2.8 E-05	8.6 E-06	8.0 E-05	1.2 E-05	No
	16 to <21	2.7 E-05	8.1 E-06	6.0 E-05	9.5 E-05	No
	21+	3.8 E-05	7.6 E-06	6.0 E-05	1.0 E-04	No
	Pregnant Women (16 to 45)	3.0 E-05	7.6 E-06	7.0 E-05	1.1 E-04	No

Residential Well G (4.2 ppb)	Birth to <1	2.7 E-04	N/A	NA	2.7 E-04*	No
	1 to <2	1.1 E-04	2.4 E-05	3.2 E-04	4.5 E-04	No
	2 to <6	9.0 E-05	2.3 E-05	2.0 E-04	3.1 E-04	No
	6 to <11	6.7 E-05	1.8 E-05	2.1 E-04	3.0 E-04	No
	11 to <16	4.7 E-05	1.4 E-05	1.4 E-04	2.0 E-04	No
	16 to <21	4.5 E-05	1.4 E-05	1.0 E-04	1.8 E-04	No
	21+	6.4 E-05	1.3 E-05	9.0 E-05	1.7 E-04	No
	Pregnant Women (16 to 45)	5.0 E-05	1.3 E-05	1.2 E-04	1.8 E-04	No
Garden City Mobile Home Park Well 2011 – 2016 (1.9 ppb)	Birth to <1	1.2 E-04	N/A	NA	1.2 E-04*	No
	1 to <2	5.1 E-05	1.1 E-05	1.4 E-04	2.0 E-04	No
	2 to <6	4.1 E-05	1.0 E-05	9.0 E-05	1.4 E-04	No
	6 to <11	3.1 E-05	7.9 E-06	9.0 E-05	1.3 E-04	No
	11 to <16	2.1 E-05	6.5 E-06	6.0 E-05	8.7 E-05	No
	16 to <21	2.0 E-05	6.1 E-06	5.0 E-05	7.6 E-05	No
	21+	2.9 E-05	5.8 E-05	4.0 E-05	1.3 E-04	No
	Pregnant Women (16 to 45)	2.3 E-05	5.8 E-05	6.0 E-05	1.4 E-04	No
Garden City Mobile Home Park Well 2002 – 2010 (4.5 ppb)	Birth to <1	2.9 E-04	N/A	NA	2.9 E-04*	No
	1 to <2	1.2 E-04	2.6 E-05	3.4 E-04	4.9 E-04	No
	2 to <6	1.0 E-04	2.5 E-05	2.1 E-04	3.3 E-04	No
	6 to <11	7.2 E-05	1.9 E-05	2.2 E-04	3.1 E-04	No
	11 to <16	5.0 E-05	1.5 E-05	1.5 E-04	2.1 E-04	No
	16 to <21	4.8 E-05	1.5 E-05	1.1 E-04	1.7 E-04	No
	21+	6.9 E-05	1.4 E-05	1.0 E-04	1.7 E-04	No
	Pregnant Women (16 to 45)	5.4 E-05	1.4 E-05	1.3 E-04	1.9 E-04	No

Commercial Well #2 (1.3 ppb)	Birth to <1	8.4 E-05	NA	NA	8.4 E-05*	No
	1 to <2	3.5 E-05	7.4 E-06	1.0 E-04	1.4 E-04	No
	2 to <6	2.8 E-05	7.1 E-06	6.0 E-05	9.5 E-05	No
	6 to <11	2.1 E-05	5.4 E-06	6.0 E-05	8.6 E-05	No
	11 to <16	1.5 E-05	4.5 E-06	4.0 E-05	5.9 E-05	No
	16 to <21	1.4 E-05	4.2 E-06	3.0 E-05	3.4 E-05	No
	21+	2.0 E-05	3.9 E-06	3.0 E-05	5.4 E-05	No
	Pregnant Women (16 to 45)	1.6 E-05	4.0 E-06	4.0 E-05	6.0 E-05	No
Commercial Well #3 (0.54 ppb)	Birth to <1 year	3.5 E-05	N/A	NA	3.5 E-05*	No
	1 to <2	1.5 E-05	3.1 E-06	4.0 E-05	5.8 E-05	No
	2 to <6	1.2 E-05	3.0 E-06	3.0 E-05	4.5 E-05	No
	6 to <11	9.0 E-06	2.3 E-06	3.0 E-05	4.1 E-05	No
	11 to <16	6.0 E-06	1.9 E-06	2.0 E-05	2.8 E-05	No
	16 to <21	6.0 E-06	1.7 E-06	1.0 E-05	1.7 E-05	No
	21+	8.0 E-06	1.6 E-06	1.0 E-05	2.0 E-05	No
	Pregnant Women (16 to 45)	6.0 E-06	1.6 E-06	2.0 E-05	2.8 E-05	No
Commercial Well #4 (11.4 ppb)	Birth to <1	7.4 E-04	N/A	NA	7.4 E-04*	Yes
	1 to <2	3.1 E-04	6.5 E-05	8.6 E-04	1.2 E-03	Yes
	2 to <6	2.5 E-04	6.2 E-05	5.3 E-04	8.4 E-04	Yes
	6 to <11	1.8 E-04	4.8 E-05	5.7 E-04	7.1 E-04	Yes
	11 to <16	1.3 E-04	3.9 E-05	3.8 E-04	5.5 E-04	Yes
	16 to <21	1.2 E-04	3.7 E-05	2.8 E-04	4.4 E-04	No
	21+	1.7 E-04	3.5 E-05	2.5 E-04	4.5 E-04	No
	Pregnant Women (16 to 45)	1.4 E-04	3.5 E-05	3.4 E-04	5.1 E-04	No

Commercial Well #5 (1.5 ppb)	Birth to <1	2.1 E-04	NA	NA	2.1 E-04	No
	1 to <2	1.2 E-04	8.5 E-06	1.1 E-04	2.4 E-04	No
	2 to <6	8.4 E-05	8.2 E-06	7.0 E-05	1.6 E-04	No
	6 to <11	6.6 E-05	6.2 E-06	7.0 E-05	1.4 E-04	No
	11 to <16	5.2 E-05	5.1 E-06	5.0 E-05	1.1 E-04	No
	16 to <21	5.1 E-05	4.7 E-06	4.0 E-05	9.6 E-05	No
	21+	5.8 E-05	4.5 E-06	3.0 E-05	6.1 E-05	No
	Pregnant Women (16 to 45)	5.3 E-05	4.9 E-06	4.0 E-05	1.0 E-04	No
Municipal Well #12 (0.65 ppb)	Birth to <1	4.2 E-05	N/A	NA	4.2 E-05*	No
	1 to <2	1.8 E-05	3.7 E-06	5.0 E-05	7.2 E-05	No
	2 to <6	1.4 E-05	3.6 E-06	3.0 E-05	4.8 E-05	No
	6 to <11	1.0 E-05	2.7 E-06	3.0 E-05	4.3 E-05	No
	11 to <16	7.0 E-06	2.2 E-06	2.0 E-05	2.9 E-05	No
	16 to <21	7.0 E-06	2.1 E-06	2.0 E-05	2.9 E-05	No
	21+	7.0 E-06	2.0 E-06	1.0 E-05	2.9 E-05	No
	Pregnant Women (16 to 45)	8.0 E-06	2.0 E-06	2.0 E-05	3.0 E-05	No

Note: ppb = parts per billion (microgram per liter [µg/L])
mg/kg/day = milligrams per kilogram per day
NA = not applicable, ATSDR did not estimate exposures from showering for children less than 1 year of age because these very young children are more likely to take baths rather than showers.
* = The ingestion dose was used as the total exposure dose for the birth to <1 year age group; does not include dermal contact and inhalation.
Bold = total TCE dose from ingestion, dermal contact, and inhalation is greater than the ATSDR chronic oral minimal risk level of 5.4 E-04 mg/kg/day.

Data sources: IDEM 2011, EPA 2016a, EPA 2016b

Table 3. Total TCE Dose To Pregnant Women via Reasonable Maximum Ingestion Exposure and Central Tendency Dermal Contact and Inhalation Exposures While Showering with the Maximum TCE Concentration in Drinking Water from Residential Wells, Garden City Mobile Park Well, Commercial Wells, and Municipal Well #12

Well (Maximum TCE concentration [ppb])	Age Group (years)	TCE Dose From Ingesting Drinking Water Reasonable Maximum Exposure (mg/kg/day)	TCE Dose From Dermal Contact While Showering with Drinking Water Central Tendency Exposure 15 Minute Shower Time (mg/kg/day)	TCE Dose From Inhalation While Showering with Drinking Water and Inhaling Bathroom Air Central Tendency Exposure 15 Minute Shower Time (mg/kg/day)	Total TCE Dose From Ingestion, Dermal Contact, and Inhalation (mg/kg/day)	Estimated Total TCE Dose Exceeds ATSDR Chronic Oral Minimal Risk Level (MRL) Health Guideline (5.4×10^{-4})
Residential Well A (15 ppb)	Pregnant Women (16 to 45)	5.3 E-04	4.9 E-05	4.5 E-04	1.0 E-03	Yes
Residential Well B (8.3 ppb)	Pregnant Women (16 to 45)	2.9 E-04	2.7 E-05	2.5 E-04	5.7 E-04	Yes
Residential Well C (2.9 ppb)	Pregnant Women (16 to 45)	1.0 E-04	9.5 E-06	9.0 E-05	1.9 E-04	No
Residential Well D (0.71 ppb)	Pregnant Women (16 to 45)	2.5 E-05	2.3 E-06	2.0 E-05	4.7 E-05	No
Residential Well F (2.5 ppb)	Pregnant Women (16 to 45)	8.9 E-05	8.2 E-06	7.0 E-05	1.7 E-04	No
Residential Well G (4.2 ppb)	Pregnant Women (16 to 45)	1.5 E-04	1.4 E-05	1.2 E-04	2.8 E-04	No
Garden City Mobile Home Park Well 2011 – 2016 (3.8 ppb)	Pregnant Women (16 to 45)	1.3 E-04	1.2 E-05	1.1 E-04	2.5 E-04	No
Garden City Mobile Home Park Well 2002 – 2010 (5.8 ppb)	Pregnant Women (16 to 45)	2.1 E-04	1.9 E-05	1.7 E-04	4.0 E-04	No
Commercial Well #2 (1.3 ppb)	Pregnant Women (16 to 45)	4.6 E-05	4.2 E-06	4.0 E-05	9.0 E-05	No

Commercial Well #3 (0.66 ppb)	Pregnant Women (16 to 45)	2.3 E-05	2.2 E-06	2.0 E-05	4.5 E-05	No
Commercial Well #4 (15 ppb)	Pregnant Women (16 to 45)	5.3 E-04	4.9 E-05	4.5 E-04	1.0 E-03	Yes
Commercial Well #5 (1.5 ppb)	Pregnant Women (16 to 45)	5.3 E-05	4.9 E-06	4.2 E-05	1.0 E-04	No
Municipal Well #12 (0.65 ppb)	Pregnant Women (16 to 45)	2.3 E-05	2.2 E-06	2.0 E-05	4.5 E-05	No

Note: ppb = parts per billion (microgram per liter [µg/L])
mg/kg/day = milligrams per kilogram per day
Bold = total TCE dose from ingestion, dermal contact, and inhalation is greater than the ATSDR chronic oral minimal risk level of 5.4 E-04 mg/kg/day.

Data sources: IDEM 2011, EPA 2016a, EPA 2016b

APPENDIX G: Cancer Evaluation — Equations, Cancer Slope Factors, Assumptions, and Estimated Cancer Risks

Evaluating Cancer Health Effects

The National Toxicology Program (NTP) classifies TCE as reasonably anticipated to be a human carcinogen based on limited evidence of carcinogenicity from studies in humans, sufficient evidence of carcinogenicity from studies in experimental animals, and information from studies on mechanisms of carcinogenesis [NTP 2011]. The human studies were epidemiological studies that showed increased rates of liver cancer and non-Hodgkin's lymphoma, primarily in workers exposed to TCE on the job. The animal studies showed increased numbers of liver, kidney, testicular, and lung tumors by two different routes of exposure.

EPA characterizes TCE as "carcinogenic to humans" by all exposure routes (ingestion, inhalation, and dermal contact) [USEPA 2011a]. This conclusion is based on human epidemiology studies showing the strongest associations between human TCE exposure and kidney cancer, with more limited evidence for non-Hodgkin's lymphoma, and liver cancer [USEPA 2011a]. EPA also concluded that TCE is carcinogenic by a mutagenic mode of action for induction of kidney tumors [USEPA 2011a].

In 2011, EPA published an oral cancer slope factor for TCE of 0.046 (milligrams per kilogram per day)$^{-1}$ (mg/kg/day)$^{-1}$ and an inhalation unit risk of 4.1 x 10^{-6} (μg/m^3)$^{-1}$ reflecting total incidence of kidney, non-Hodgkin's lymphoma, and liver cancers [USEPA 2011a]. These slope factors are calculated from data from adult exposure and do not reflect presumed increased early-life susceptibility to kidney tumors for this chemical.

Using a linear low-dose extrapolation approach and separate route-to-route extrapolation, EPA established separate oral cancer slope factors for the three target tissue sites: kidney, lymphoid tissue, and liver [USEPA 2011a]. The separate cancer slope factors are as follows [USEPA 2011a]:

- For kidney cancer: 9.33 x 10^{-3} (mg/kg/day)$^{-1}$
- For non-Hodgkin's lymphoma: 2.16 x 10^{-2} (mg/kg/day)$^{-1}$
- For liver cancer: 1.55 x 10^{-2} (mg/kg/day)$^{-1}$

The methods used to calculate cancer slope factors rely upon several assumptions. The method assumes that high-dose animal data can be used to estimate the risk for low-dose exposures in humans. The methods also assume that no safe level exists for exposure. Little experimental evidence exists to confirm or refute those two assumptions. Lastly, most methods compute the upper 95th percent confidence limit for the risk. The actual cancer risk can be lower, perhaps by several orders of magnitude.

The oral slope factor for kidney cancer risk is without consideration of increased early-life susceptibility as a result of TCE's mutagenic mode of action. When a substance causes cancer by a mutagenic mode of action, there is a greater risk for exposures that occur in early life. EPA developed age-dependent adjustment factors (ADAFs) to account for the greater risk for kidney cancer from exposures that occur in early life. EPA recommends ADAFs when assessing cancer risks for a carcinogen with a mutagenic mode of action especially when exposure scenarios increase the proportion of exposure during early life. This early life increase in exposure results in the ADAF adjustment having a more pronounced impact of the risk. Therefore, in this public health assessment evaluation of kidney cancer risk from TCE exposure to different age groups, ATSDR applied the following ADAFs in Table 2.

Table 1. Age-dependent Adjustment Factors Applied to Calculate Excess Kidney Cancer Risk for TCE

Potentially Exposed Population (Years)	Applied Age-dependent Adjustment Factors
Birth to <1	10
Child 1 to <2	10
Child 2 to <6	3
Child 6 to <11	3
Child 11 to <16	3
Child 16 to <21	1
Adults ≥ 21	0

To estimate the total excess lifetime cancer risk (from kidney cancer, non-Hodgkin's lymphoma, and liver cancer) for children and adults at each of the 12 wells in Table 8, ATSDR first calculated excess risks for kidney cancer, non-Hodgkin's lymphoma, and liver cancer for each age group using the following cancer risk equation. ATSDR multiplied the estimated high-end total TCE dose (from Table 1 in Appendix F) for each age group by the oral cancer slope factors for kidney cancer (applying appropriate ADAFs), non-Hodgkin's lymphoma, and liver cancer; and the friction corresponding to the fraction of a 78-year lifetime under consideration.

Cancer Risk Equation

$$\text{Age-Specific Cancer Risk} = D \times CSF \times (ED / 78)$$

D = age-specific exposure dose in milligrams per kilogram per day (mg/kg/day)
CFS = cancer slope factor in $(mg/kg/day)^{-1}$
ED = age-specific exposure duration in years

Second, the total excess cancer risk for each age group was calculated by combining the excess risks for kidney cancer, non-Hodgkin's lymphoma, and liver cancer within each age group. Finally, the total excess cancer risk for children was calculated by combining the total excess cancer risk for each age group from birth to 21 years of age. Children were assumed to be exposured for 21 years (from birth to 21 years) and adults for a total of 33 years. See Table 2 – 14 in Appendix G for the calculation of total cancer risk to children and adults at each well.

Result of Cancer Evaluation of TCE in Drinking Water

In Table 2 – 14 in Appendix G , the total excess cancer risk (from combining the excess risks for kidney cancer, non-Hodgkin's lymphoma, and liver cancer) for children and adults in each of the 12 wells are all at a lower risk for cancer effects, and not likely to harm people's health. The estimated total excess cancer risks from domestic use (drinking and showering) of TCE contaminated drinking water are based on the maximum TCE concentrations, reasonable maximum ingestion exposure, and central tendency inhalation and dermal contact exposure while showering with drinking water.

The excess cancer risk estimates are expressed as a probability, indicate the excess cancer potential, and are expressed in terms of excess cancer cases in an exposed population in addition to the background rate of cancer. The excess cancer risk is a mathematical estimate used to make public health decisions, not a prediction of the number of specific cancers expected in this community. The cancer risk indicate the portion of a population that might be affected by a carcinogen during a lifetime of exposure. For example, the highest estimated total excess cancer risk is 2×10^{-5}, which means that among 100 thousand children continuously exposed to a TCE for 21 years, two children within that population might get cancer from TCE, compared with the total number who might otherwise develop cancer. Therefore, the cancer risks to children and adults from domestic use of TCE contaminated drinking water from these wells are a low increase risk, not a current public health hazard, and will not be evaluated further.

Cancer Evaluation of Vinyl Chloride

EPA characterizes vinyl chloride as human carcinogen by all exposure routes (ingestion, inhalation, and dermal). This conclusion is based on human epidemiology studies of inhalation exposure, animal studies of ingestion exposure, and by inference the dermal route because it acts systemically. The most compelling evidence for the carcinogenic potential of vinyl chloride in humans comes from the cluster of reports of greater than expected incidences of angiosarcoma of the liver in workers occupationally exposed to vinyl chloride. The most compelling evidence for the carcinogenic potential of vinyl chloride from ingestion comes from rat studies with significant increases in hepatic angiosarcoma of the liver, neoplastic nodules of the liver, and hepatocellular carcinoma. Based on these rat studies, EPA estimated the oral slope factor for continuous lifetime exposure from birth to be 1.4 $(mg/kg/day)^{-1}$.

The excess risk for liver cancer in children (5.1 E-06) and adults (3.1 E-06) from chronic reasonable maximum ingestion exposure to the maximum vinyl chloride concentration in the drinking water from municipal well #9 are at a lower risk for cancer effects, within acceptable levels, and not likely to harm people's health.. Therefore, the cancer risks to children and adults from domestic use of vinyl chloride contaminated drinking water from the municipal well are a low increase risk and will not be evaluated further.

Table 2. Excess Cancer Risk for Residents Exposed to Maximum TCE Concentration in Drinking Water from Residential Well A via Reasonable Maximum Ingestion Exposure and Central Tendency Dermal Contact and Inhalation Exposures While Showering

Age Group (years)	Estimated Total Exposure Dose (All Routes) mg/kg/day	Age Group Duration (years)	Fraction of 78-year Lifetime	Unadjusted Kidney Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	Kidney Cancer ADAF	ADAF-Adjusted Kidney Cancer Risk	Unadjusted Kidney, NHL & Liver Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	NHL& Liver Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	NHL & Liver Cancer Risk	Total Cancer Risk: ADAF-Adjusted Kidney; Unadjusted NHL & Liver
Birth to <1	0.0021	1	0.0128	9.3E-03	10	2.5E-06	4.6E-02	3.7E-02	9.9E-07	3.5E-06
1 to <2	0.0024	1	0.0128	9.3E-03	10	2.9E-06	4.6E-02	3.7E-02	1.1E-06	4.0E-06
2 to <6	0.0016	4	0.0513	9.3E-03	3	2.3E-06	4.6E-02	3.7E-02	3.0E-06	5.3E-06
6 to <11	0.0015	5	0.0641	9.3E-03	3	2.7E-06	4.6E-02	3.7E-02	3.5E-06	6.2E-06
11 to <16	0.0011	5	0.0641	9.3E-03	3	2.0E-06	4.6E-02	3.7E-02	2.6E-06	4.6E-06
16 to <21	0.0009	5	0.0641	9.3E-03	1	5.5E-07	4.6E-02	3.7E-02	2.2E-06	2.7E-06
Total Childhood Exposure		21							**Total Cancer Risk (Children):**	2.6E-05
Adults 21+	0.0010	33	0.4231	9.3E-03	1	3.8E-06	4.6E-02	3.7E-02	1.5E-05	1.9E-05
Total Adult Exposure		33							**Total Cancer Risk (Adults):**	1.9E-05

Note: mg/kg/day = milligrams per kilogram per day
NHL= non-Hodgkin's lymphoma
ADAF = age-dependent adjustment factors

Table 3. Excess Cancer Risk for Residents Exposed to Maximum TCE Concentration in Drinking Water from Residential Well B via Reasonable Maximum Ingestion Exposure and Central Tendency Dermal Contact and Inhalation Exposures While Showering

Age Group (years)	Estimated Total Exposure Dose (All Routes) mg/kg/day	Age Group Duration (years)	Fraction of 78-year Lifetime	Unadjusted Kidney Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	Kidney Cancer ADAF	ADAF-Adjusted Kidney Cancer Risk	Unadjusted Kidney, NHL & Liver Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	NHL& Liver Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	NHL & Liver Cancer Risk	Total Cancer Risk: ADAF-Adjusted Kidney; Unadjusted NHL & Liver
Birth to <1	0.0012	1	0.0128	9.3E-03	10	1.4E-06	4.6E-02	3.7E-02	5.6E-07	2.0E-06
1 to <2	0.0013	1	0.0128	9.3E-03	10	1.6E-06	4.6E-02	3.7E-02	6.1E-07	2.2E-06
2 to <6	0.0010	4	0.0513	9.3E-03	3	1.4E-06	4.6E-02	3.7E-02	1.8E-06	3.2E-06
6 to <11	0.0008	5	0.0641	9.3E-03	3	1.4E-06	4.6E-02	3.7E-02	1.9E-06	3.4E-06
11 to <16	0.0006	5	0.0641	9.3E-03	3	1.1E-06	4.6E-02	3.7E-02	1.4E-06	2.5E-06
16 to <21	0.0005	5	0.0641	9.3E-03	1	3.1E-07	4.6E-02	3.7E-02	1.2E-06	1.5E-06
Total Childhood Exposure		21							**Total Cancer Risk (Children):**	1.5E-05
Adults 21+	0.0005	33	0.4231	9.3E-03	1	2.1E-06	4.6E-02	3.7E-02	8.2E-06	1.0E-05
Total Adult Exposure		33							**Total Cancer Risk (Adults):**	1.0E-05

Note: mg/kg/day = milligrams per kilogram per day
NHL= non-Hodgkin's lymphoma
ADAF = age-dependent adjustment factors

Table 4. Excess Cancer Risk for Residents Exposed to Maximum TCE Concentration in Drinking Water from Residential Well C via Reasonable Maximum Ingestion Exposure and Central Tendency Dermal Contact and Inhalation Exposures While Showering

Age Group (years)	Estimated Total Exposure Dose (All Routes) mg/kg/day	Age Group Duration (years)	Fraction of 78-year Lifetime	Unadjusted Kidney Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	Kidney Cancer ADAF	ADAF-Adjusted Kidney Cancer Risk	Unadjusted Kidney, NHL & Liver Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	NHL& Liver Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	NHL & Liver Cancer Risk	Total Cancer Risk: ADAF-Adjusted Kidney; Unadjusted NHL & Liver
Birth to <1	0.0004	1	0.0128	9.3E-03	10	4.9E-07	4.6E-02	3.7E-02	1.9E-07	6.8E-07
1 to <2	0.0005	1	0.0128	9.3E-03	10	5.5E-07	4.6E-02	3.7E-02	2.2E-07	7.6E-07
2 to <6	0.0003	4	0.0513	9.3E-03	3	4.4E-07	4.6E-02	3.7E-02	5.8E-07	1.0E-06
6 to <11	0.0003	5	0.0641	9.3E-03	3	5.0E-07	4.6E-02	3.7E-02	6.6E-07	1.2E-06
11 to <16	0.0002	5	0.0641	9.3E-03	3	3.8E-07	4.6E-02	3.7E-02	4.9E-07	8.7E-07
16 to <21	0.0002	5	0.0641	9.3E-03	1	1.1E-07	4.6E-02	3.7E-02	4.2E-07	5.3E-07
Total Childhood Exposure		21							**Total Cancer Risk (Children):**	5.0E-06
Adults 21+	0.0002	33	0.4231	9.3E-03	1	7.1E-07	4.6E-02	3.7E-02	2.8E-06	3.5E-06
Total Adult Exposure		33							**Total cancer Risk (Adults):**	3.5E-06

Note: mg/kg/day = milligrams per kilogram per day
NHL= non-Hodgkin's lymphoma
ADAF = age-dependent adjustment factors

Table 5. Excess Cancer Risk for Residents Exposed to Maximum TCE Concentration in Drinking Water from Residential Well D via Reasonable Maximum Ingestion Exposure and Central Tendency Dermal Contact and Inhalation Exposures While Showering

Age Group (years)	Estimated Total Exposure Dose (All Routes) mg/kg/day	Age Group Duration (years)	Fraction of 78-year Lifetime	Unadjusted Kidney Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	Kidney Cancer ADAF	ADAF-Adjusted Kidney Cancer Risk	Unadjusted Kidney, NHL & Liver Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	NHL& Liver Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	NHL & Liver Cancer Risk	Total Cancer Risk: ADAF-Adjusted Kidney; Unadjusted NHL & Liver
Birth to <1	0.0001	1	0.0128	9.3E-03	10	1.2E-07	4.6E-02	3.7E-02	4.7E-08	1.7E-07
1 to <2	0.0001	1	0.0128	9.3E-03	10	1.3E-07	4.6E-02	3.7E-02	5.2E-08	1.8E-07
2 to <6	0.0001	4	0.0513	9.3E-03	3	1.1E-07	4.6E-02	3.7E-02	1.4E-07	2.5E-07
6 to <11	0.0001	5	0.0641	9.3E-03	3	1.3E-07	4.6E-02	3.7E-02	1.7E-07	3.1E-07
11 to <16	0.0000	5	0.0641	9.3E-03	3	8.8E-08	4.6E-02	3.7E-02	1.2E-07	2.0E-07
16 to <21	0.0000	5	0.0641	9.3E-03	1	2.7E-08	4.6E-02	3.7E-02	1.1E-07	1.4E-07
Total Childhood Exposure		21							**Total Cancer Risk (Children):**	1.2E-06
Adults 21+	0.0000	33	0.4231	9.3E-03	1	1.9E-07	4.6E-02	3.7E-02	7.6E-07	9.5E-07
Total Adult Exposure		33							**Total cancer Risk (Adults):**	9.5E-07

Note: mg/kg/day = milligrams per kilogram per day
NHL= non-Hodgkin's lymphoma
ADAF = age-dependent adjustment factors

Table 6. Excess Cancer Risk for Residents Exposed to Maximum TCE Concentration in Drinking Water from Residential Well F via Reasonable Maximum Ingestion Exposure and Central Tendency Dermal Contact and Inhalation Exposures While Showering

Age Group (years)	Estimated Total Exposure Dose (All Routes) (mg/kg/day)	Age Group Duration (years)	Fraction of 78-year Lifetime	Unadjusted Kidney Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	Kidney Cancer ADAF	ADAF-Adjusted Kidney Cancer Risk	Unadjusted Kidney, NHL & Liver Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	NHL& Liver Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	NHL & Liver Cancer Risk	Total Cancer Risk: ADAF-Adjusted Kidney; Unadjusted NHL & Liver
Birth to <1	0.0004	1	0.0128	9.3E-03	10	4.3E-07	4.6E-02	3.7E-02	1.7E-07	6.0E-07
1 to <2	0.0004	1	0.0128	9.3E-03	10	4.8E-07	4.6E-02	3.7E-02	1.9E-07	6.7E-07
2 to <6	0.0003	4	0.0513	9.3E-03	3	3.9E-07	4.6E-02	3.7E-02	5.1E-07	8.9E-07
6 to <11	0.0002	5	0.0641	9.3E-03	3	4.3E-07	4.6E-02	3.7E-02	5.6E-07	9.9E-07
11 to <16	0.0002	5	0.0641	9.3E-03	3	3.0E-07	4.6E-02	3.7E-02	4.0E-07	7.0E-07
16 to <21	0.0002	5	0.0641	9.3E-03	1	8.9E-08	4.6E-02	3.7E-02	3.5E-07	4.4E-07
Total Childhood Exposure		21							**Total Cancer Risk (Children):**	**4.3E-06**
Adults 21+	0.0001	33	0.4231	9.3E-03	1	4.3E-07	4.6E-02	3.7E-02	1.7E-06	2.1E-06
Total Adult Exposure		33							**Total cancer Risk (Adults):**	**2.1E-06**

Note: mg/kg/day = milligrams per kilogramper day
NHL= non-Hodgkin'slymphoma
ADAF = age-dependent adjustment factors

Table 7. Excess Cancer Risk for Residents Exposed to Maximum TCE Concentration in Drinking Water from Residential Well G via Reasonable Maximum Ingestion Exposure and Central Tendency Dermal Contact and Inhalation Exposures While Showering

Age Group (years)	Estimated Total Exposure Dose (All Routes) (mg/kg/day)	Age Group Duration (years)	Fraction of 78-year Lifetime	Unadjusted Kidney Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	Kidney Cancer ADAF	ADAF-Adjusted Kidney Cancer Risk	Unadjusted Kidney, NHL & Liver Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	NHL& Liver Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	NHL & Liver Cancer Risk	Total Cancer Risk: ADAF-Adjusted Kidney; Unadjusted NHL & Liver
Birth to <1	0.0006	1	0.0128	9.3E-03	10	7.2E-07	4.6E-02	3.7E-02	2.8E-07	1.0E-06
1 to <2	0.0007	1	0.0128	9.3E-03	10	8.0E-07	4.6E-02	3.7E-02	3.2E-07	1.1E-06
2 to <6	0.0005	4	0.0513	9.3E-03	3	6.6E-07	4.6E-02	3.7E-02	8.7E-07	1.5E-06
6 to <11	0.0004	5	0.0641	9.3E-03	3	7.2E-07	4.6E-02	3.7E-02	9.4E-07	1.7E-06
11 to <16	0.0003	5	0.0641	9.3E-03	3	5.4E-07	4.6E-02	3.7E-02	7.1E-07	1.2E-06
16 to <21	0.0003	5	0.0641	9.3E-03	1	1.5E-07	4.6E-02	3.7E-02	5.9E-07	7.4E-07
Total Childhood Exposure		21							**Total Cancer Risk (Children):**	7.3E-06
Adults 21+	0.0004	33	0.4231	9.3E-03	1	1.6E-06	4.6E-02	3.7E-02	6.2E-06	7.8E-06
Total Adult Exposure		33							**Total cancer Risk (Adults):**	7.8E-06

Note: mg/kg/day = milligrams per kilogram per day
NHL= non-Hodgkin's lymphoma
ADAF = age-dependent adjustment factors

Table 8. Excess Cancer Risk for Residents Exposed to Maximum TCE Concentration in Drinking Water from Garden City Mobile Home Park Well (2002-2010) via Reasonable Maximum Ingestion Exposure and Central Tendency Dermal Contact and Inhalation Exposures While Showering

Age Group	Estimated Total Exposure Dose (All Routes) mg/kg/day	Age Group Duration (years)	Fraction of 78-year Lifetime	Unadjusted Kidney Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	Kidney Cancer ADAF	ADAF-Adjusted Kidney Cancer Risk	Unadjusted Kidney, NHL & Liver Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	NHL& Liver Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	NHL & Liver Cancer Risk	Total Cancer Risk: ADAF-Adjusted Kidney; Unadjusted NHL & Liver
Birth to <1	0.0008	1	0.0128	9.3E-03	10	9.9E-07	4.6E-02	3.7E-02	3.9E-07	1.4E-06
1 to <2	0.0009	1	0.0128	9.3E-03	10	1.1E-06	4.6E-02	3.7E-02	4.3E-07	1.5E-06
2 to <6	0.0006	4	0.0513	9.3E-03	3	9.0E-07	4.6E-02	3.7E-02	1.2E-06	2.1E-06
6 to <11	0.0006	5	0.0641	9.3E-03	3	1.0E-06	4.6E-02	3.7E-02	1.3E-06	2.4E-06
11 to <16	0.0004	5	0.0641	9.3E-03	3	7.3E-07	4.6E-02	3.7E-02	9.6E-07	1.7E-06
16 to <21	0.0004	5	0.0641	9.3E-03	1	2.1E-07	4.6E-02	3.7E-02	8.5E-07	1.1E-06
Total Childhood Exposure		21							**Total Cancer Risk (Children):**	1.0E-05
Adults 21+	0.0003	33	0.4231	9.3E-03	1	1.3E-06	4.6E-02	3.7E-02	5.1E-06	6.4E-06
Total Adult Exposure		33							**Total cancer Risk (Adults):**	6.4E-06

Note: mg/kg/day = milligrams per kilogram per day
NHL= non-Hodgkin's lymphoma
ADAF = age-dependent adjustment factors

Table 9. Excess Cancer Risk for Residents Exposed to Maximum TCE Concentration in Drinking Water from Garden City Mobile Home Park Well (2011-2016) via Reasonable Maximum Ingestion Exposure and Central Tendency Dermal Contact and Inhalation Exposures While Showering

Age Group (years)	Estimated Total Exposure Dose (All Routes) mg/kg/day	Age Group Duration (years)	Fraction of 78-year Lifetime	Unadjusted Kidney Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	Kidney Cancer ADAF	ADAF-Adjusted Kidney Cancer Risk	Unadjusted Kidney, NHL & Liver Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	NHL& Liver Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	NHL & Liver Cancer Risk	Total Cancer Risk: ADAF-Adjusted Kidney; Unadjusted NHL & Liver
Birth to <1	0.0005	1	0.0128	9.3E-03	10	6.4E-07	4.6E-02	3.7E-02	2.5E-07	9.0E-07
1 to <2	0.0006	1	0.0128	9.3E-03	10	7.4E-07	4.6E-02	3.7E-02	2.9E-07	1.0E-06
2 to <6	0.0004	4	0.0513	9.3E-03	3	5.9E-07	4.6E-02	3.7E-02	7.7E-07	1.4E-06
6 to <11	0.0004	5	0.0641	9.3E-03	3	6.8E-07	4.6E-02	3.7E-02	8.9E-07	1.6E-06
11 to <16	0.0003	5	0.0641	9.3E-03	3	4.8E-07	4.6E-02	3.7E-02	6.4E-07	1.1E-06
16 to <21	0.0002	5	0.0641	9.3E-03	1	1.4E-07	4.6E-02	3.7E-02	5.4E-07	6.8E-07
Total Childhood Exposure		21							**Total Cancer Risk (Children):**	6.7E-06
Adults 21+ years	0.0002	33	0.4231	9.3E-03	1	9.4E-07	4.6E-02	3.7E-02	3.7E-06	4.7E-06
Total Adult Exposure		33							**Total cancer Risk (Adults):**	4.7E-06

Note: mg/kg/day = milligrams per kilogram per day
NHL= non-Hodgkin's lymphoma
ADAF = age-dependent adjustment factors

Table 10. Excess Cancer Risk for Residents Exposed to Maximum TCE Concentration in Drinking Water from Commercial Well #2 via Reasonable Maximum Ingestion Exposure and Central Tendency Dermal Contact and Inhalation Exposures While Showering

Age Group (years)	Estimated Total Exposure Dose (All Routes) (mg/kg/day)	Age Group Duration (years)	Fraction of 78-year Lifetime	Unadjusted Kidney Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	Kidney Cancer ADAF	ADAF-Adjusted Kidney Cancer Risk	Unadjusted Kidney, NHL & Liver Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	NHL& Liver Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	NHL & Liver Cancer Risk	Total Cancer Risk: ADAF-Adjusted Kidney; Unadjusted NHL & Liver
Birth to <1	0.0002	1	0.0128	9.3E-03	10	2.3E-07	4.6E-02	3.7E-02	8.9E-08	3.2E-07
1 to <2	0.0002	1	0.0128	9.3E-03	10	2.5E-07	4.6E-02	3.7E-02	9.9E-08	3.5E-07
2 to <6	0.0001	4	0.0513	9.3E-03	3	2.0E-07	4.6E-02	3.7E-02	2.6E-07	4.6E-07
6 to <11	0.0001	5	0.0641	9.3E-03	3	2.1E-07	4.6E-02	3.7E-02	2.8E-07	5.0E-07
11 to <16	0.0001	5	0.0641	9.3E-03	3	1.5E-07	4.6E-02	3.7E-02	2.0E-07	3.5E-07
16 to <21	0.0001	5	0.0641	9.3E-03	1	4.4E-08	4.6E-02	3.7E-02	1.7E-07	2.2E-07
Total Childhood Exposure		21							**Total Cancer Risk (Children):**	2.2E-06
Adults 21+	0.0001	33	0.4231	9.3E-03	1	3.7E-07	4.6E-02	3.7E-02	1.5E-06	1.8E-06
Total Adult Exposure		33							**Total cancer Risk (Adults):**	1.8E-06

Note: mg/kg/day = milligrams per kilogram per day
NHL= non-Hodgkin's lymphoma
ADAF = age-dependent adjustment factors

Table 11. Excess Cancer Risk for Residents Exposed to Maximum TCE Concentration in Drinking Water from Commercial Well #3 via Reasonable Maximum Ingestion Exposure and Central Tendency Dermal Contact and Inhalation Exposures While Showering

Age Group (years)	Estimated Total Exposure Dose (All Routes) (mg/kg/day)	Age Group Duration (years)	Fraction of 78-year Lifetime	Unadjusted Kidney Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	Kidney Cancer ADAF	ADAF-Adjusted Kidney Cancer Risk	Unadjusted Kidney, NHL & Liver Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	NHL& Liver Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	NHL & Liver Cancer Risk	Total Cancer Risk: ADAF-Adjusted Kidney; Unadjusted NHL & Liver
Birth to <1	0.0001	1	0.0128	9.3E-03	10	9.5E-08	4.6E-02	3.7E-02	3.8E-08	1.3E-07
1 to <2	0.0001	1	0.0128	9.3E-03	10	9.9E-08	4.6E-02	3.7E-02	3.9E-08	1.4E-07
2 to <6	0.0001	4	0.0513	9.3E-03	3	7.6E-08	4.6E-02	3.7E-02	1.0E-07	1.8E-07
6 to <11	0.0001	5	0.0641	9.3E-03	3	9.3E-08	4.6E-02	3.7E-02	1.2E-07	2.2E-07
11 to <16	0.0000	5	0.0641	9.3E-03	3	7.5E-08	4.6E-02	3.7E-02	9.9E-08	1.7E-07
16 to <21	0.0000	5	0.0641	9.3E-03	1	1.9E-08	4.6E-02	3.7E-02	7.5E-08	9.4E-08
Total Childhood Exposure		21							**Total Cancer Risk (Children):**	**9.3E-07**
Adults 21+	0.0000	33	0.4231	9.3E-03	1	1.3E-07	4.6E-02	3.7E-02	5.0E-07	6.2E-07
Total Adult Exposure		33							**Total cancer Risk (Adults):**	**6.2E-07**

Note: mg/kg/day = milligrams per kilogram per day
NHL= non-Hodgkin's lymphoma
ADAF = age-dependent adjustment factors

Table 12. Excess Cancer Risk for Residents Exposed to Maximum TCE Concentration in Drinking Water from Commercial Well #4 via Reasonable Maximum Ingestion Exposure and Central Tendency Dermal Contact and Inhalation Exposures While Showering

Age Group (years)	Estimated Total Exposure Dose (All Routes) mg/kg/day	Age Group Duration (years)	Fraction of 78-year Lifetime	Unadjusted Kidney Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	Kidney Cancer ADAF	ADAF-Adjusted Kidney Cancer Risk	Unadjusted Kidney, NHL & Liver Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	NHL& Liver Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	NHL & Liver Cancer Risk	Total Cancer Risk: ADAF-Adjusted Kidney; Unadjusted NHL & Liver
Birth to <1	0.0021	1	0.0128	9.3E-03	10	2.5E-06	4.6E-02	3.7E-02	9.9E-07	3.5E-06
1 to <2	0.0024	1	0.0128	9.3E-03	10	2.9E-06	4.6E-02	3.7E-02	1.1E-06	4.0E-06
2 to <6	0.0016	4	0.0513	9.3E-03	3	2.3E-06	4.6E-02	3.7E-02	3.0E-06	5.3E-06
6 to <11	0.0015	5	0.0641	9.3E-03	3	2.7E-06	4.6E-02	3.7E-02	3.5E-06	6.2E-06
11 to <16	0.0011	5	0.0641	9.3E-03	3	2.0E-06	4.6E-02	3.7E-02	2.6E-06	4.6E-06
16 to <21	0.0009	5	0.0641	9.3E-03	1	5.5E-07	4.6E-02	3.7E-02	2.2E-06	2.7E-06
Total Childhood Exposure		21							**Total Cancer Risk (Children):**	2.6E-05
Adults 21+	0.0010	33	0.4231	9.3E-03	1	3.8E-06	4.6E-02	3.7E-02	1.5E-05	1.9E-05
Total Adult Exposure		33							**Total Cancer Risk (Adults):**	1.9E-05

Note: mg/kg/day = milligrams per kilogram per day
NHL= non-Hodgkin's lymphoma
ADAF = age-dependent adjustment factors

Table 13. Excess Cancer Risk for Residents Exposed to Maximum TCE Concentration in Drinking Water from Commercial Well #5 via Reasonable Maximum Ingestion Exposure and Central Tendency Dermal Contact and Inhalation Exposures While Showering

Age Group (years)	Estimated Total Exposure Dose (All Routes) mg/kg/day	Age Group Duration (years)	Fraction of 78-year Lifetime	Unadjusted Kidney Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	Kidney Cancer ADAF	ADAF-Adjusted Kidney Cancer Risk	Unadjusted Kidney, NHL & Liver Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	NHL& Liver Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	NHL & Liver Cancer Risk	Total Cancer Risk: ADAF-Adjusted Kidney; Unadjusted NHL & Liver
Birth to <1	0.0002	1	0.0128	9.3E-03	10	2.5E-07	4.6E-02	3.7E-02	9.9E-08	3.5E-07
1 to <2	0.0002	1	0.0128	9.3E-03	10	2.9E-07	4.6E-02	3.7E-02	1.1E-07	4.0E-07
2 to <6	0.0002	4	0.0513	9.3E-03	3	2.3E-07	4.6E-02	3.7E-02	3.0E-07	5.3E-07
6 to <11	0.0001	5	0.0641	9.3E-03	3	2.5E-07	4.6E-02	3.7E-02	3.3E-07	5.8E-07
11 to <16	0.0001	5	0.0641	9.3E-03	3	2.0E-07	4.6E-02	3.7E-02	2.6E-07	4.6E-07
16 to <21	0.0001	5	0.0641	9.3E-03	1	3.6E-08	4.6E-02	3.7E-02	1.4E-07	1.8E-07
Total Childhood Exposure		21							**Total Cancer Risk (Children):**	2.5E-06
Adults 21+	0.0001	33	0.4231	9.3E-03	1	2.4E-07	4.6E-02	3.7E-02	9.5E-07	1.2E-06
Total Adult Exposure		33							**Total Cancer Risk (Adults):**	1.2E-06

Note: mg/kg/day = milligrams per kilogram per day
NHL= non-Hodgkin's lymphoma
ADAF = age-dependent adjustment factors

Table 14. Excess Cancer Risk for Residents Exposed to Maximum TCE Concentration in Drinking Water from Municipal Well #12 via Reasonable Maximum Ingestion Exposure and Central Tendency Dermal Contact and Inhalation Exposures While Showering

Age Group (years)	Estimated Total Exposure Dose (All Routes) (mg/kg/day)	Age Group Duration (years)	Fraction of 78-year Lifetime	Unadjusted Kidney Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	Kidney Cancer ADAF	ADAF-Adjusted Kidney Cancer Risk	Unadjusted Kidney, NHL & Liver Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	NHL& Liver Lifetime Cancer Slope Factor $(mg/kg/day)^{-1}$	NHL & Liver Cancer Risk	Total Cancer Risk: ADAF-Adjusted Kidney; Unadjusted NHL & Liver
Birth to <1	0.0001	1	0.0128	9.3E-03	10	9.5E-08	4.6E-02	3.7E-02	3.8E-08	1.3E-07
1 to <2	0.0001	1	0.0128	9.3E-03	10	9.9E-08	4.6E-02	3.7E-02	3.9E-08	1.4E-07
2 to <6	0.0001	4	0.0513	9.3E-03	3	7.6E-08	4.6E-02	3.7E-02	1.0E-07	1.8E-07
6 to <11	0.0001	5	0.0641	9.3E-03	3	9.3E-08	4.6E-02	3.7E-02	1.2E-07	2.2E-07
11 to <16	0.0000	5	0.0641	9.3E-03	3	7.5E-08	4.6E-02	3.7E-02	9.9E-08	1.7E-07
16 to <21	0.0000	5	0.0641	9.3E-03	1	1.9E-08	4.6E-02	3.7E-02	7.5E-08	9.4E-08
Total Childhood Exposure		21							**Total Cancer Risk (Children):**	9.3E-07
Adults 21+	0.0000	33	0.4231	9.3E-03	1	1.3E-07	4.6E-02	3.7E-02	5.0E-07	6.2E-07
Total Adult Exposure		33							**Total cancer Risk (Adults):**	6.2E-07

Note: mg/kg/day = milligrams per kilogram per day
NHL= non-Hodgkin's lymphoma
ADAF = age-dependent adjustment factors

Appendix H: Health Effects Evaluation

Health Effects Evaluation

In this section of the public health assessment, ATSDR evaluates public health implications of TCE exposure in the drinking water from the five wells in Table 9, with total TCE doses greater than the ATSDR MRL for TCE. This in-depth health effects evaluation includes a discussion of the current scientific information on TCE's disease-causing potential. The discussion also evaluates potential health effects of TCE exposure based on comparison of total TCE doses from both high-end exposure scenarios (see Table 1 and Table 3 in Appendix F) and typical exposure scenarios (See Table 2 in Appendix F) to TCE doses in studies that have been shown to cause harmful health effects. This section offers a perspective on the plausibility of harmful health outcomes from exposure to TCE at each well.

The likelihood that adverse health outcomes will actually occur depends on the concentration of the chemical, site-specific exposure conditions, individual differences, and factors that affect the route, magnitude, and duration of actual exposure. ATSDR considers multiple chemical factors, including physical properties, form, and bioavailability. ATSDR considers characteristics of the exposed population—age, sex, genetics, lifestyle, nutritional and health status—that influence how people absorb, distribute, metabolize, and excrete contaminants. Where appropriate, we have included these characteristics in the site-specific TCE exposure discussions.

ATSDR uses current scientific information available on TCE. This information includes results of medical, toxicologic, and epidemiologic studies, and data collected in disease registries. ATSDR reviews the weight-of-evidence of toxicologic and epidemiologic data and health effects variables to obtain information about TCE toxicity. The weight-of-evidence is the extent to which available scientific information supports the hypothesis that a specific dose of a substance causes an adverse effect in humans. In this way, we more completely understand the public health implications of exposure. We use this information to determine the likelihood of health effects that might result from exposure by understanding a chemical's disease-causing potential. We also use the information to compare high-end and realistic exposure dose estimates with doses shown to cause health effects. This process enables us to weigh available evidence in light of known uncertainties and offer perspective on the plausibility of harmful health outcomes under site-specific conditions. The science of environmental health is still developing; sometimes, scientific information on the health effects of certain substances is not available. In this case, we recommend further needed public health actions, such as substance-specific applied research, to fill important data needs.

Results of Public Health Implication—Comparison of TCE Doses to Health Effect Levels

Residential Well A and Residential Well B

Residents using drinking water from residential wells A and B are currently not being exposed to TCE. GAC filters were installed on residential wells A and B in 1990 to remove TCE from the drinking water prior to its use in the home. Water samples collected from residential wells A and B after the GAC filter did not contain TCE. Therefore, exposure to TCE is currently not occurring from using residential well A and B water for domestic purposes, and health effects are not expected from the current exposure situation.

If the GAC filters are removed or not properly maintained, residents could be exposed to elevated levels of TCE from ingestion, inhalation, and absorption putting them at risk for health effects associated with TCE exposure (i.e., fetal heart malformation and immune system effects). As shown in Table 1, water samples collected from residential well A and residential well B before the GAC filter contained maximum TCE levels of 15 ppb and 8.3 ppb and average TCE levels of 10.3 ppb and 6.3 ppb, respectively (See Table 1 and Figure 1). These TCE levels in the water are all greater than the EPA MCL (5 ppb).

Once again, residential wells A and B currently have GAC filters that remove TCE from the drinking water prior to the water being used in the home for domestic purposes. Therefore, as long as exposure to TCE is not occurring, health effects are not expected from the current situation. However, continued use of the GAC filter and continued monitoring of pre- and post-filter drinking water from residential well A and B are recommended to prevent potential adverse health effects. In addition, residents should be informed of potential health effects from exposure to unfiltered drinking water.

Residential Well G

The residents using the water from residential well G may be exposed to TCE in the drinking water from ingestion, inhalation, and absorption. As shown in Table 1 and Figure 1, one water sample collected in 2011 from residential well G contained TCE at a level (4.2 ppb) less than the EPA MCL (5 ppb). The drinking water from this residential well was not sampled in 2015 or 2016, and the well does not have a GAC filter.

Developmental Heart Malformations

The estimated total TCE doses for the high-end and typical exposure scenarios for pregnant women are well below than the health effects level (HED_{99} of 5.1×10^{-3} mg/kg/day) derived to correspond with a 1% response rate for fetal heart malformations from TCE exposure (See Table 3 in Appendix E). Based on the one TCE concentration detected in the one drinking water sample from residential well G, ingestion, inhalation, and absorption exposure to TCE in drinking water from residential G well is not expected to harm the health of a fetus.

Immunological Effects

The estimated total TCE doses for the high-end and typical exposure scenarios for children chronically exposed to TCE in water from residential wells G are well below the health effect dose (HED_{99} = 4.8 x 10^{-2} mg/kg/day) for immune system effects and are not at levels expected to harm the health of adults or children. (See Table 1 and Table 2 in Appendix F).

However, long-term quarterly monitoring of drinking water from a private community well near residential well G indicates that over the years the TCE levels in water samples fluctuate by as much as 4 ppb. Therefore, potential for an increase in TCE level in drinking water could result in a higher total TCE dose to pregnant women. Given the uncertainties in adequately estimating total TCE doses based on one drinking water sample (i.e., fluctuation of TCE levels in the drinking water), residential well G drinking water should be frequently monitored to adequately characterize exposure to TCE and potential health effects. To eliminate TCE exposure and the possibility of any potential health effects from TCE exposure, residents can use a GAC filter.

Garden City Mobile Home Park Well

The available data indicates that people living in the 47 mobile homes using drinking water from the Garden city Mobile Home Park private community water system well for domestic purposes are being exposed to low levels of TCE from ingestion, inhalation, and absorption. As shown in Table 2 and Figure 1, quarterly water samples collected over the years from this community water system well contain a maximum TCE level (5.8 ppb) greater than the EPA MCL of 5 ppb and an average TCE level of 4.5 ppb. This community water system does not have a GAC filter.

Developmental Heart Malformations

Based on the maximum exposure scenario in Table 1 in Appendix F, the estimated total TCE dose (4.0 x 10^{-4} mg/kg/day) for pregnant women is lower than the health effects level (HED_{99} 5.1 x 10^{-3} mg/kg/day) derived to correspond with a 1% response rate for fetal heart malformations from TCE exposure. Therefore, exposure to TCE in the mobile home park well drinking water from ingestion, inhalation, and absorption is not at levels expected to harm the health of a fetus

Immunological Effects

Based on the maximum and typical exposure scenarios in Table 1 and Table 2 in Appendix F, total TCE doses for young children are much lower than the effect level (HED_{99}) for effect on the immune system from TCE exposure. Therefore, chronic exposure to TCE in the mobile home park well water from ingestion, inhalation, and absorption is not at levels expected to harm the health of adults, children, or fetuses. However, the mobile home park community water system well water should continue to be monitored on a quarterly basis because of fluctuating TCE levels in drinking water. Residents should be notified if the TCE levels in the drinking water exceed the EPA MCL of 5 ppb and informed of any potential health effects from exposure to the increase in the TCE level. Residents should be informed about alternatives to reduce or eliminate TCE exposure by using a GAC filter system.

Commercial Well #4

People working in the office currently using the water from commercial well #4 have limited exposure to TCE in the drinking water. As shown in Table 3 and Figure 1, water samples collected from commercial well #4 contain a maximum TCE level (15 ppb) and average TCE level (11.4 ppb) greater than the EPA MCL (5 ppb). The water from this well is used in the office to make coffee, wash hands, and supply water to the toilet. Exposure could occur from ingestion (drinking coffee), dermal absorption (washing hands), and inhalation (breathing TCE evaporating from the making coffee, washing hands, and use of toilet). A worker ingesting six cups of coffee a day using water with maximum TCE level would receive an estimated TCE dose of 2.0×10^{-4} mg/kg/day. Therefore, worker exposure to TCE in the water should result in estimated total TCE doses below the ATSDR MRL screening guideline and is not at levels expected to harm the health of adults or children in the office.

Office workers should be informed of potential health effects. If office workers will consume large quantities (2 to 3 liters a day) of well water, a GAC filter or alternative source of water is recommended to prevent potential adverse health effects. The water from commercial well #4 should be continue to be monitored.

Wells Not Sampled and Wells Sampled Only Once (Residential Wells D, and F; Commercial Well 5)

Drinking water TCE data are not available for some private residential and commercial Garden City wells, so the drinking water from these private wells has not been sampled and analyzed for VOCs. Without monitoring results, ATSDR cannot characterize TCE exposure and determine if TCE or other VOCs at levels that pose a public health hazard. Any well in the general vicinity of the Garden City TCE groundwater plume has the potential to contain elevated levels of TCE and other VOCs in the drinking water. Private wells used for domestic and commercial purposes in the vicinity of the TCE groundwater plume should be monitored for VOCs. Residents should be informed of potential health effects of exposure to levels of TCE in drinking water. Depending on TCE levels, a GAC filter should be installed and maintained or the residence should be connected to the Columbus municipal water utility to prevent exposure to TCE and other VOCs in drinking water.

ATSDR cannot adequately characterize the public health hazard of exposure to TCE in drinking water from the wells near the TCE groundwater plume that were sampled only once (residential wells D and F, and commercial well #5). Too few water samples from each well were collected and analyzed for VOCs.

The level of TCE in one drinking water sample from three of these wells resulted in the estimated total TCE doses below the ATSDR MRL. However, TCE levels within a well can vary over time. Wells with previously detected low TCE levels may currently or in the future contain elevated TCE levels. These wells should be resampled to determine the current conditions of the drinking water.