Public Health Assessment

Initial - Public Comment Release

CIRCLE COURT GROUNDWATER PLUME

WILLOW PARK, PARKER COUNTY, TEXAS

EPA FACILITY ID: TXN000606965

Prepared by
Texas Department of State Health Services

JANUARY 11, 2017

COMMENT PERIOD ENDS: FEBRUARY 11, 2017

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

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's Cooperative Agreement Partner 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's Cooperative Agreement Partner 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's Cooperative Agreement Partner. This revised document has now been released for a 30-day public comment period. Subsequent to the public comment period, ATSDR's Cooperative Agreement Partner 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's Cooperative Agreement Partner which, in the agency's opinion, indicates a need to revise or append the conclusions previously issued.

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PUBLIC HEALTH ASSESSMENT

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Prepared by:

Texas Department of State Health Services
Division of Disease Control and Health Protection
Under Cooperative Agreement with the
U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry

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Foreword

The Agency for Toxic Substances and Disease Registry (ATSDR) was established under the mandate of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). This act, also known as the "Superfund" law, authorized the U.S. Environmental Protection Agency (EPA) to conduct clean-up activities at hazardous waste sites. EPA was directed to compile a list of sites considered potentially hazardous to public health. This list is termed the National Priorities List (NPL). Under the Superfund law, ATSDR is charged with assessing the presence and nature of health hazards to communities living near Superfund sites, helping prevent or reduce harmful exposures, and expanding the knowledge base about the health effects that result from exposure to hazardous substances [1].

In 1984, amendments to the Resource Conservation and Recovery Act of 1976 (RCRA) – which provides for the management of hazardous waste storage, treatment, and disposal facilities – authorized ATSDR to conduct Public Health Assessments at these sites when requested by the EPA, states, tribes, or individuals. The 1986 Superfund Amendments and Reauthorization Act broadened ATSDR's responsibilities in the area of Public Health Assessments and directed ATSDR to prepare a Public Health Assessment (PHA) document for each NPL site. In 1990, federal facilities were included on the NPL. ATSDR also conducts PHAs or Public Health Consultations when petitioned by concerned community members, physicians, state or federal agencies, or tribal governments [1].

The aim of these evaluations is to determine if people are being exposed to hazardous substances and, if so, whether that exposure is potentially harmful and should be eliminated or reduced. PHAs are carried out by environmental health scientists from ATSDR and from the states with which ATSDR has cooperative agreements. Because each NPL site has a unique set of circumstances surrounding it, the PHA process allows flexibility in document format when ATSDR and cooperative agreement scientists present their findings about the public health impact of the site. The flexible format allows health assessors to convey important public health messages to affected populations in a clear and expeditious way, tailored to fit the specific circumstances of the site.

Comments

If you have any questions, comments, or unanswered concerns after reading this report, we encourage you to send them to us. Letters should be addressed as follows:

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Summary

Introduction	The Circle Court Groundwater Plume site is located within the city of Willow Park in Parker County, Texas, and consists of a trichloroethylene (also known as trichloroethene or TCE) groundwater plume in the Trinity Aquifer. The Texas Commission on Environmental Quality (TCEQ) discovered the site in October 2001 during routine monitoring of the city of Willow Park public water system (PWS). A source of contamination has not been identified. From June 2006 to July 2014, the TCEQ and the United States Environmental Protection Agency (EPA) collected water samples from private and public drinking water wells to determine the nature and extent of the contamination. Of the 37 wells sampled, TCE was detected in 5 drinking water wells above the EPA's maximum contaminant level (MCL), including the city of Willow Park PWS Well 20 and four private wells, designated as GW-10/PW-42, GW-11/GW-33/PW-13, GW-41/PW-25, and GW-48/PW-80. The Circle Court Groundwater Plume site was proposed to the National Priorities List (NPL) on March 15, 2012, and was listed as final on the NPL on September 18, 2012.
Conclusions	The Texas Department of State Health Services (DSHS) and the Agency for Toxic Substances and Disease Registry (ATSDR) reached three conclusions in this health assessment:
Conclusion 1	Adverse health effects may have occurred from past exposure to TCE in private wells GW-41/PW-25 and GW-11/GW-33/PW-13. However, there are no current or future exposures to the water from these wells.
Basis for Conclusion	Estimated past exposure doses indicate a health concern for pregnant women due to the possibility of fetal heart malformations, as well as a health concern for past exposure for children and adults due to the possibility of adverse effects to the immune system. There was also some risk of cancer associated with drinking water from these wells based on exposure to TCE. There is no current or future exposure to TCE from either of these water wells because homes are either connected to a PWS or the wells are no longer in use.

Conclusion 2	Adverse health effects may have occurred from past exposure to TCE, arsenic, and lead from private well GW-10/PW-42. However, there are no current or future exposures to the water from this well.
Basis for Conclusion	Estimated exposure doses indicate a health concern for past exposure to TCE for pregnant women due to the possibility of fetal heart malformations, as well as a health concern for past exposure for children and adults due to the possibility of adverse effects to the immune system. There was also some risk of cancer associated with drinking water from this well based on exposure to TCE and arsenic. In addition, lead was detected in this well. Lead has no beneficial effect in the body and could have posed a health risk, especially for small children. There is no current or future exposure to contaminants because the well has been disconnected and residents are using a new well. Contaminants have not been detected in the new well.
Conclusion 3	Adverse health effects are not likely to have occurred from past exposure to TCE in private well GW-48/PW-80 and public water supply (PWS) Well 20. Current and future exposures to TCE are also not expected.
Basis for Conclusion	A detailed analysis of estimated exposure doses and estimated cancer risks for these wells indicates that adverse health effects are not likely to have occurred. In addition, private well GW-48/PW-80 is currently equipped with a granular activated carbon (GAC) filtration system and PWS Well 20 is no longer in use. Therefore, there is no current or future exposure to TCE from these drinking water sources.
Next Steps	• This document will be made available to the community and local government officials for public comment. Comments received during the public comment period will be addressed by DSHS and ATSDR and incorporated into the final document. • The final version of this document will be made available to community members, city officials, TCEQ, EPA, and other interested parties. • DSHS will continue to work with EPA and TCEQ in addressing community health concerns. • Individuals concerned about their past exposures to TCE and other contaminants are advised to speak with their personal physician about their health concerns.
For More Information	If you have concerns about your health, it is recommended you contact your health care provider. You may also call the Texas Department of State Health Services, Environmental & Injury Epidemiology & Toxicology Unit, at (800) 588-1248.

Purpose and Health Issues

This public health assessment (PHA) was prepared for the Circle Court Groundwater Plume site in accordance with the interagency cooperative agreement between the Agency for Toxic Substances and Disease Registry (ATSDR) and the Texas Department of State Health Services (DSHS). In preparing this PHA, no independent samples were collected and/or analyzed. The DSHS and ATSDR used sample data previously collected by the Texas Commission on Environmental Quality (TCEQ) and the Environmental Protection Agency (EPA). The primary contaminant of concern associated with the Circle Court Groundwater Plume site is trichloroethylene (also known as trichloroethene or TCE). Additional contaminants detected during sampling were also evaluated, as necessary. The primary route of exposure evaluated in this PHA is the consumption of TCE-contaminated groundwater; however, exposure through inhalation and dermal contact while showering and bathing were also considered. This PHA presents conclusions about whether a health threat is or was present for the identified routes of exposure.

A list of acronyms and abbreviations used in this report is included in Appendix A. Information about how environmental data are reviewed and the exposure dose estimates and parameters are included in Appendix B. Background information about TCE is included in Appendix C.

Limitations

This PHA has several limitations which include: (1) the source of groundwater contamination is unknown and the extent of groundwater contamination has not been determined; (2) the exposure period to contaminants in drinking water is not known; (3) health-protective assumptions, such as using the maximum concentration, were used to estimate exposure doses; and (4) there is limited groundwater sampling of some of the public and private water wells.

Background

Site Description and History

The Circle Court Groundwater Plume site consists of a TCE groundwater plume located in the Trinity Aquifer (Figure 1). The site was discovered in late 2001, during routine monitoring of the city of Willow Park public water system (PWS). The source of contamination has not been identified [2]. The city of Willow Park PWS consists of 1,734 connections and provides water to approximately 4,410 residents of Willow Park, Parker County, Texas [3].

TCE was first detected in the water system during routine sample collection from a point of entry (POE) 010 on October 29, 2001 and POE11 on March 19, 2002 [4]. The level of TCE was below the EPA's maximum contaminant level (MCL) of 5 micrograms per liter (µg/L). The two points of entry are connected by a valve that is open under normal operating conditions [4].

On March 23, 2006, TCE was detected above the MCL at 6.03 µg/L in POE011 [4]. The Willow Springs Oaks Pump Station (Well 20) is the only well that provides drinking water to the system through POE011. The city of Willow Park PWS voluntarily took Well 20 out of service on April 1, 2006. On May 4, 2006, a water sample collected directly from Well 20 (inactive) revealed a TCE level of 33.9 µg/L [4]. A granular activated carbon (GAC) filter was installed on Well 20 on

June 19, 2006 [4]. In 2015, the city replaced Well 20 with a new well. Well 20 is no longer being used [5]. TCE has not been detected in the replacement well [6].

Figure 1. Circle Court Groundwater Plume site map.

In June 2006, the TCEQ sampled nine private wells near Well 20 for volatile organic compounds (VOCs) to determine the nature and extent of groundwater contamination. TCE above the MCL was detected in one privately owned well that was not being used for drinking water [7]. In March and June 2010, TCEQ expanded the scope of its investigation and sampled 28 additional groundwater wells and collected soil samples from potential source areas, residential areas, and background locations. Water and soil samples were analyzed for VOCs, semivolatile organic compounds (SVOCs), and metals [8, 9].

Sample results from March and June 2010 indicated the TCE groundwater plume follows a 0.50-mile stretch parallel to Russell Road, with the highest concentration of TCE found in a private well along Russell Road. Of the 28 wells sampled, 2 private wells (GW-41/PW-25 and GW-10/PW-420) and a PWS well (Well 20) had levels of TCE that exceeded the MCL. Granular activated carbon filtration (GAC) systems were installed at all private wells with TCE levels above the MCL; however, the filtration systems were later removed. At one location (GW-10/PW-25), the GAC system was removed at the homeowner's request, while at the other location (GW-41/PW-42), the residence was connected to the city water supply [10]. At the PWS, Well 20 was replaced with another well and is no longer being used [6]. The Circle Court Groundwater Plume site was proposed to the National Priorities List (NPL) on March 15, 2012, and was listed as final on the NPL on September 18, 2012 [11, 12].

In July 2012, a resident notified the TCEQ, DSHS, and EPA of a 55-gallon chemical drum found on their property with a label indicating it contained TCE. The EPA identified a TCE liquid in the drum and removed it from the property for off-site disposal [13]. In November 2012, passive soil gas sampling was conducted in the area where the drum was located to determine if TCE was present in the soil. The 77 soil gas samples were analyzed for TCE and its breakdown products (vinyl chloride and cis-1,2-dichloroethene [cis-1,2-DCE]) [14].

In May 2013 the TCEQ identified an additional private well not been previously sampled and tested it for VOCs, SVOCs, and metals [15]. Constituents, including TCE, were not detected in this well.

In June and July 2014, the EPA sampled 21 wells, including private and commercial drinking and non-drinking water wells. These samples were analyzed for VOCs [16, 17]. Three drinking water wells had levels of TCE above the MCL. One well (GW-10/PW-42) had a TCE level over ten times higher than previous levels in 2006 and 2010. The homeowner reportedly disconnected this well from the residence and is now using an irrigation well for drinking water [18]. The irrigation well was sampled in 2014 and TCE was not detected [16, 18]. Filtration systems were installed at the other two drinking water wells (GW-11/GW-33/PW-13 and GW-48/PW-80) [19]. Private water wells, GW-10/PW-42 and GW-11/GW-33/PW-13, are located along Russell Road in the same general area as water well GW-41/PW-25; however, water well GW-48/PW-80 is located approximately 0.30 miles east on Annetta Road.

In July 2014, six monitoring wells, not used for drinking water purposes, were installed and sampled for VOCs at different groundwater depths [17]. TCE was detected in shallow

groundwater zones at levels ranging from 8.2 µg/L to 53.7 µg/L, while TCE levels ranging from 1.4 µg/L to 1.7 µg/L were detected in the deeper groundwater zone [17].

Site Visits and Public Health Activities

DSHS staff conducted an initial site visit on May 22, 2012, and observed Well 20 and the surrounding residential area. On July 9 through 13, 2012, DSHS and ATSDR staff conducted door-to-door community outreach activities. During these activities, staff spoke with over 100 residents about the NPL site, distributed 200 flyers containing information about the groundwater contamination, and obtained information from residents about their private wells and concerns about the site. Staff also conducted site visits with EPA, TCEQ, and ATSDR staff to obtain additional site information. On August 9, 2012, DSHS staff attended an EPA community meeting for the site. Information about the health assessment process and DSHS' role at NPL sites was presented to local officials and community members. Staff distributed TCE and groundwater fact sheets and answered questions. Since 2012, there have not been any community meetings for the site, but collaborative efforts are ongoing. DSHS received groundwater sampling results collected from private water wells by TCEQ and EPA in 2013 and 2014, and were notified of PWS Well 20 being discontinued in 2016.

Demographics

The 2010 United States Census reported the total population for Parker County and the city of Willow Park as 116,927 [20] and 3,982 [21], respectively. The Census reported 2,228 people residing in 847 housing units within a 1-mile radius of the site. At the time of the census, 172 children under the age of six and 372 women of child-bearing age (15 to 44 years old) resided in this area (Figure 2).

Figure 2. Demographic information for the Circle Court Groundwater Plume site.

Circle Court Groundwater

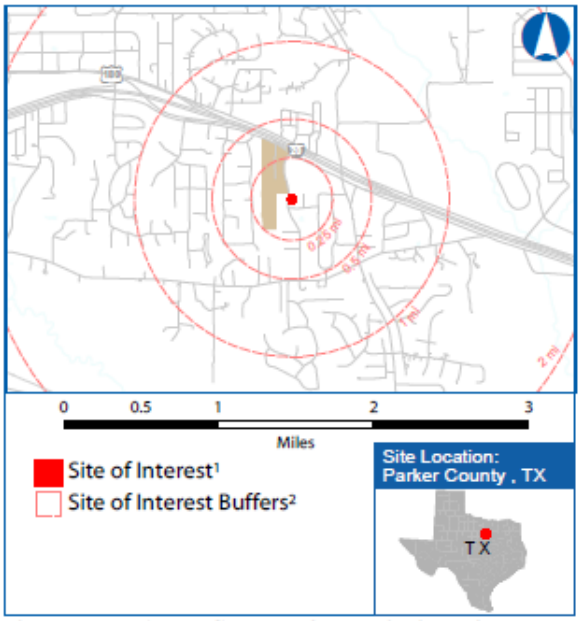
Willow Park, Parker County, TX

GENERAL SITE PROFILE

EPA FACILITY ID TXN000606965

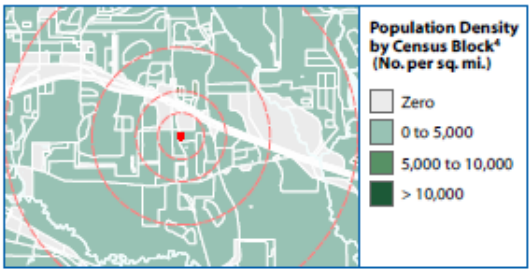
INTRODUCTORY MAP SERIES

Site Vicinity Map

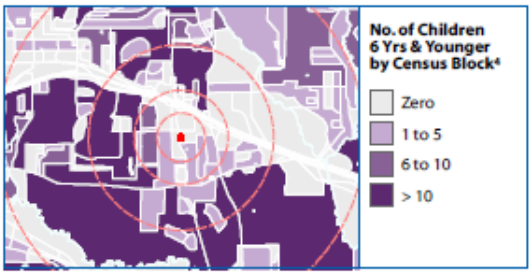


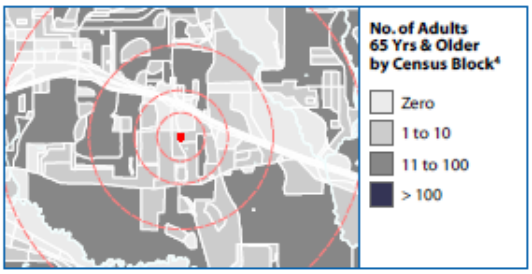
The **General Site Profile Map** depicts the hazardous waste site of interest, along with community demographic and housing statistics.

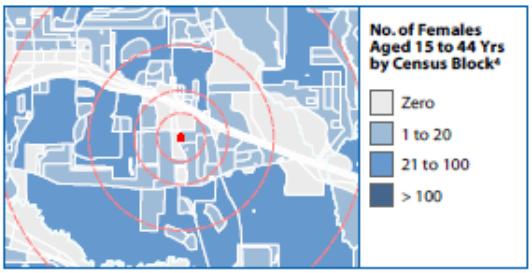
General Population Density



Sensitive Populations







Demographic Statistics[4,5]

Within 1 mile buffer of site boundary

Measure	2000	2010	Change
Total Population	1,881	2,228	+18%
White Alone	1,778	2,005	+12%
Black Alone	12	22	+83%
Am. Indian & Alaska Native Alone	13	26	+100%
Asian Alone	7	7	+0%
Native Hawaiian & Other Pacific Islander Alone	0	2	N/A
Some Other Race Alone	62	141	+127%
Two or More Races	10	27	+170%
Hispanic or Latino[6]	119	269	+126%
Children Aged 6 and Younger	184	172	-6%
Adults Aged 65 and Older	197	290	+47%
Females Aged 15 to 44	358	372	+3%
Housing Units	680	847	+24%
Housing Units Pre 1950	7	10	+42%

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 Texas North Central FIPS 4202 Feet.

PRJ 04235 JKA0 12/14/15

GRASP

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

ATSDR

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Land and Natural Resource Use

Well 20 is located in Willow Park, Parker County, Texas (Figure 1). Willow Park is approximately 6 miles east of Weatherford and 20 miles west of Fort Worth. The site is located about 0.28 miles south of Interstate-20 and 0.3 miles west of Farm-to-Market Road 5 (Annetta Road) [4].

The site is located in a mostly rural area and single-family residences surround the site to the south, west, and east (Figure 1). North of the site is a 15-acre vacant and wooded lot, and a former truck stop/diner is adjacent to the vacant lot, approximately 0.15 miles north of the site. The Parker County Airport is located to the west of the site; the main building of the airport is 0.32 miles northwest of the site and the nearest point of the airport runway is 0.22 miles west of the site. A small engine repair shop is located 0.28 miles northwest of the site, near the airport. A dry cleaner facility and a gas station are in a strip mall shopping center 0.21 miles east-northeast of the site [4]. An active natural gas well pad is located 0.12 miles southwest of the site [9].

The site is located on the Brackett and Maloterre soils, in the Western Cross Timbers region of Texas, on the western margin of the Grand Prairie, on the Walnut Clay Formation. The Walnut Clay Formation overlies the Trinity group, which is a water-bearing formation. The Trinity group is divided into the Antlers, Glen Rose, Paluxy, and Twin Mountains Formations. Well 20 was drilled in 1965 to a depth of 180 feet into the Paluxy Formation [4] and is screened from 120 to 160 feet below ground surface [7]. Groundwater flows to the east and southeast [9].

Within 4 miles of the site there are wells used for PWS, private, irrigation, commercial, livestock, and other miscellaneous purposes. As of July 2011, there were records for 55 PWS wells and 554 private wells within 4 miles of the site [7].

Discussion

Environmental Data Used

Data evaluated in this health assessment were collected by the TCEQ and EPA during site assessment activities and include:

- Sampling results for VOCs for nine private wells in the vicinity of Well 20 (June 2006) [6]
- Sampling results for VOCs, SVOCs, and metals from 13 private and PWS wells (March 2010) [7]
- Sampling results for VOCs and metals from 15 private and PWS wells (June 2010) [8]
- Sampling results for VOCs, SVOCs, and metals from one private well (May 2013) [15]
- Sampling results for VOCs from 21 private wells (June and July 2014) [16, 17]

The specific wells that were sampled varied with each sampling event in that some wells were sampled multiple times while others were only sampled once.

Surface soil and monitoring well samples were collected to help determine the nature and extent of contamination. These samples were not evaluated in this health assessment. Soil gas samples were collected and are addressed qualitatively.

Data reviewed in this report were collected by the TCEQ and EPA using standard procedures and were reviewed by the TCEQ and/or EPA for quality assurance/quality control. Thus, DSHS and ATSDR assumed adequate quality assurance/quality control procedures were followed with regard to data collection, chain of custody, laboratory procedures, and data reporting.

Screening Analysis

Environmental data were first evaluated by comparing the maximum result for each chemical to health protective comparison values (CVs), which are media-specific levels below which no adverse health effects are expected to occur. Exceeding screening values do not necessarily mean that a contaminant will cause adverse health effects; it only indicates that the contaminant should be evaluated further.

In June 2006, March and June 2010, May 2013, and June and July 2014, the TCEQ or EPA collected and analyzed water samples from 37 wells near Well 20, including 23 private drinking water wells, 6 private non-drinking water wells, 1 commercial drinking water well, 1 commercial non-drinking water well, and 6 PWS drinking water wells [6-8, 15-17]. Some wells were sampled multiple times. Sampling results for private and PWS drinking water wells are summarized in Tables 1 and 2, respectively. Results from contaminants exceeding CVs or contaminants without established CVs are included. Further evaluation of these contaminants is included in the Public Health Implications section of this document.

Contaminants found in the non-drinking water wells (private, commercial, and monitoring) were not considered in this report because drinking water exposures were not occurring. Additionally, at the time of this report, no contaminants were found above CVs in the commercial drinking water wells sampled.

Table 1. Sampling results from 23 private drinking water wells tested in June 2006, March and June 2010, May 2013, and June and July 2014 [6-8, 15-17].

Contaminant	**Concentration Range (µg/L)**	**Number of Wells with Detectable Levels/ Number of Wells Tested[a]**	**Comparison Value (µg/L)**	**Number of Wells that Exceed Comparison Values**
Arsenic	ND-10.8	1/17	**0.023 – CREG** **3 – child EMEG/RMEG** **10 – MCL** 11 – adult EMEG/RMEG	**1** **1** **1** 0
Di(2-ethylhexyl)phthalate	ND-2.9 LJ[b]	2/7	**2.5 – CREG** 6 – MCL 600 – child EMEG 2,100 adult EMEG	**2** 0 0 0
Lead	ND-25	5/17	15 – Action Level[c]	**1**
Manganese	ND-568	10/17	**500 – child RMEG** 1,800 – adult RMEG	**1** 0
Trichloroethylene	ND-115	6/23	**0.76 – CREG** **5 – MCL** **5 – child EMEG/RMEG** **18 – adult EMEG/RMEG**	**6** **4** **4** **2**

* Please see Appendix B for definitions and more information about comparison values and data evaluation.
µg/L – micrograms per liter
ND – not detected
CREG – cancer risk evaluation guide
EMEG – environmental media evaluation guide
RMEG – reference dose media evaluation guide
MCL – Environmental Protection Agency (EPA) maximum contaminant level
NA – not available

[a] There were a total of 23 private wells, some of which were sampled multiple times. All 23 private wells were tested for volatile organic compounds (VOCs), 17 of the 23 wells were tested for metals, and 7 of the 23 wells were tested for semivolatile organic compounds (SVOCs).

[b] LJ – EPA data qualifier that indicates the result is an estimated value above the detection limit, but below the reporting limit.

[c] EPA action level for lead.

Table 2. Sampling results from six public water supply drinking water wells tested in March and June 2010 [7, 8].

Contaminant	Concentration Range (µg/L)	Number of Wells with Detectable Levels/ Number of Wells Tested[a]	Comparison Value (µg/L)	Number of Wells that Exceed Comparison Values
Arsenic	ND-3.2 LJ[b]	1/6	**0.023 – CREG** **3 – child EMEG/RMEG** 10 – MCL 11 – adult EMEG/RMEG	**1** **1** 0 0
Chromium	ND-9.2 LJ[b]	1/6	**9 – child EMEG[c]** 32 – adult EMEG[c] 100 – MCL	**1** 0 0
Di(2-ethylhexyl)phthalate	ND-6.9	4/5	**2.5 – CREG** **6 – MCL** 600 – child EMEG 2,100 adult EMEG	**2** **1** 0 0
Trichloroethylene	ND-6.5[d]	1/6	**0.76 – CREG** **5 – MCL** **5 – child EMEG/RMEG** 18 – adult EMEG/RMEG	**1** **1** **1** 0

* Please see Appendix B for definitions and more information about comparison values and data evaluation.
µg/L – micrograms per liter
ND – not detected
CREG – cancer risk evaluation guide
EMEG – environmental media evaluation guide
RMEG – reference dose media evaluation guide
MCL – Environmental Protection Agency (EPA) maximum contaminant level

[a] A total of six public water supply wells were tested. All six wells were tested for volatile organic compounds (VOCs) and metals, and five of the six wells were tested for semivolatile organic compounds (SVOCs).

[b] LJ – EPA data qualifier that indicates the result is an estimated value above the detection limit but below the reporting limit.

[c] The child and adult EMEGs for chromium are based on exposure to hexavalent chromium, the most toxic form of chromium.

[d] The only sample with a detectable level was a water sample collected directly from the well prior to the water passing through the equipped granular activated carbon filter and, therefore, does not represent a level at which people might have been exposed. All other results were below the MCL.

Public Health Implications

Exposure Pathways

TCE was detected in 5 drinking water wells above the MCL, including Well 20 and private wells GW-10/PW-42, GW-11/GW-33/PW-13, GW-41/PW-25, and GW-48/PW-80. The potential for past and current exposure to TCE, as well as other contaminants not related to the site but detected above CVs, was evaluated in this health assessment. In the past, people could have been exposed to contaminants at this site through the ingestion of contaminated drinking water, the inhalation of contaminants volatilizing from contaminated water, and from dermal contact with contaminated water during bathing and showering. The installation of the GAC filtration systems or use of an alternative water source eliminates the current exposure pathway.

The results of passive soil vapor sampling did not reveal widespread soil TCE contamination. Vinyl chloride was not found in any of the samples, and TCE and cis-1,2-DCE were only found in soil gas samples collected near a 55-gallon drum containing residual TCE and near a water faucet connected to the private well with high levels of TCE (GW-41) [14]. Additionally, Well 20 is screened 120 to 160 feet below ground surface [7]. Based on the localized soil vapor results and the depth to groundwater, vapor intrusion was determined not to be a likely exposure scenario.

Exposure Dose Estimates

Estimated exposure doses were used to determine the amount of chemical able to get into the body for each of the chemicals exceeding CVs. The maximum concentration detected in public and private wells, and age-specific ingestion rates and body weights were used to calculate an estimated exposure dose in milligrams per kilogram per day (mg/kg/day) (see Appendix B).

Estimating exposure via inhalation or dermal contact from using TCE-contaminated water in the home is difficult, in part, because of differences between individual use patterns. One approach is to assume that exposure via the non-ingestion pathways (inhalation and dermal contact) is comparable to exposure via ingestion [1]. Therefore, in this assessment, the estimated ingestion exposure dose for TCE was doubled to account for all of these pathways (ingestion, inhalation, and dermal exposure).

Hazard quotients (HQs) were calculated to compare estimated exposure doses to health guidelines, which are levels adverse health effects are not expected. If an HQ is less than 1, the estimated exposure dose is below the health guideline and adverse non-cancer health effects are not expected.

If an estimated exposure dose exceeded a health guideline, the dose was then compared to non-carcinogenic health effect levels found in scientific literature. These comparisons are used to determine if adverse health effects are possible and if the exposure presents a health hazard.

For contaminants considered to be carcinogenic, the estimated cancer risk was calculated (see Appendix B).

Because TCE was first detected in the PWS in 2001 and a GAC filter was installed in 2010, residents could have been exposed to TCE for approximately 10 years. However, it is possible TCE existed in groundwater before it was detected in the PWS. As a conservative measure, DSHS assumed that adult residents could have been exposed to TCE in drinking water in Well 20 and GW-41/PW-25 for 33 years (the 95th percentile residential occupancy duration). In addition, the cumulative cancer risk was estimated for children exposed from birth to 21 years. These same exposure durations were used for cancer risk calculations for arsenic and di(2-ethylhexyl)phthalate, because there are no data to determine how long these contaminants might have been in the drinking water.

For several private wells, including GW-10/PW-42, GW-11/GW-33/PW-13, and GW-48/PW-80, TCE was not detected until 2010. Therefore for these wells, DSHS assumed that adult residents were most likely exposed to TCE in drinking water from 2010 to 2014. In addition, the cumulative cancer risk was estimated for children exposed from birth to 4 years. These exposures were averaged over a lifetime of 78 years.

Further evaluation of contaminants exceeding CVs is provided in Tables 3 through 6. In addition, because lead was detected in several private wells, the public health implications of exposure to lead are also discussed below.

Table 3. Ranges of estimated exposure doses and hazard quotients for children (ages 0-21 years) exposed to contaminants exceeding comparison values.

Contaminant (*well type*)	**Maximum Concentration (µg/L)[a]**	**Estimated Exposure Doses for Children (mg/kg/day)**	**Health Guideline (mg/kg/day)**	**Hazard Quotients for Children**	**Non-Cancer Risk Conclusion for Children**
Arsenic (*private well GW-10/PW-42*)	10.8	0.0004-0.002	0.0003 – MRL/RfD	1.2-5.1	Evaluated further
Arsenic (*PWS well*)	3.2 LJ[b]	0.0001-0.0005	0.0003 – MRL/RfD	0.4-1.5[c]	Evaluated further
Chromium (*PWS well*)	9.2 LJ[b]	0.0003-0.001	0.0009 – MRL	0.3-1.5[c]	Evaluated further
Di(2-ethylhexyl)phthalate (*private well GW-07/PW-41*)	2.9 LJ[b]	0.0001-0.0004	0.06 – MRL	0.002-0.007	Health effects are not expected
Di(2-ethylhexyl)phthalate (*PWS well*)	6.9	0.0002-0.001	0.06 – MRL	0.004-0.02	Health effects are not expected
Manganese (*private well GW-10/PW-42*)	568	0.02-0.08	0.05 – RfD	0.4-1.6[c]	Evaluated further
Trichloroethylene (*private well GW-10/PW-42*)	115	0.008-0.03	0.0005 – MRL/RfD	15.7-65.6	Evaluated further
Trichloroethylene (*PWS well*)	6.03[d]	0.0004-0.002	0.0005 – MRL/RfD	0.8-3.4	Evaluated further

* Please see Appendix B for definitions and information about comparison values and data evaluation.
µg/L – micrograms per liter
mg/kg/day – milligrams per kilogram per day
MRL – minimal risk level
RfD – reference dose
PWS – public water supply

[a] The maximum concentration of each contaminant was used to determine the estimated exposure dose and hazard quotient.

[b] LJ – EPA data qualifier that indicates the result is an estimated value above the detection limit but below the reporting limit.

[c] The only hazard quotient to exceed 1 was for the youngest age group (birth to less than 1 year). The estimated exposure dose for this age group assumes infants drink 1.113 liters (approximately 38 ounces) of tap water (not bottled water) daily. Infants that breastfeed or that drink formula made from bottled water are not exposed at this level. For all other age groups, the hazard quotients were less than 1 and non-cancer health effects are not expected.

[d] The highest concentration (6.03 µg/L) of TCE was detected in the PWS prior to the installation of the GAC filter.

Table 4. Estimated exposure doses and hazard quotients for adults exposed to contaminants exceeding comparison values.

Contaminant (*well type*)	**Maximum Concentration (µg/L)[a]**	**Estimated Exposure Dose for Adults (mg/kg/day)**	**Health Guideline (mg/kg/day)**	**Hazard Quotient for Adults**	**Non-Cancer Risk Conclusion for Adults**
Arsenic (*private well GW-10/PW-42*)	10.8	0.0004	0.0003 – MRL/RfD	1.4	Evaluated further
Arsenic (*PWS well*)	3.2 LJ[b]	0.0001	0.0003 – MRL/RfD	0.4	Health effects are not expected
Chromium (*PWS well*)	9.2 LJ[b]	0.0004	0.0009 – MRL	0.4	Health effects are not expected
Di(2-ethylhexyl)phthalate (*private well GW-07/PW-41*)	2.9 LJ[b]	0.0001	0.06 – MRL	0.002	Health effects are not expected
Di(2-ethylhexyl)phthalate (*PWS well*)	6.9	0.0003	0.06 – MRL	0.004	Health effects are not expected
Manganese (*private well GW-10/PW-42*)	568	0.02	0.05 – RfD	0.4	Health effects are not expected
Trichloroethylene (*private well GW-10/PW-42*)	115	0.009	0.0005 – MRL/RfD	17.8	Evaluated further
Trichloroethylene (*PWS well*)	6.03[c]	0.0005	0.0005 – MRL/RfD	0.9	Health effects are not expected

* Please see Appendix B for definitions and information about comparison values and data evaluation.
µg/L – micrograms per liter
mg/kg/day – milligrams per kilogram per day
MRL – minimal risk level
RfD – reference dose
PWS – public water supply

[a] The maximum concentration of each contaminant was used to determine the estimated exposure dose and hazard quotient.

[b] LJ – EPA data qualifier that indicates the result is an estimated value above the detection limit but below the reporting limit.

[c] The highest concentration (6.03 µg/L) of TCE was detected in the PWS prior to the installation of the GAC filter.

Table 5. Cumulative cancer risk estimates for children exposed to carcinogens[a].

Contaminant (*well type*)	**Maximum Concentration (µg/L)[b]**	**Cancer Slope Factor ([mg/kg/day]$^{-1}$)**	**Estimated Cancer Risk**
Arsenic (*private well GW-10/PW-42*)	10.8	1.50	2.1×10^{-4}
Arsenic (*PWS well*)	3.2 LJ[c]	1.50	6.2×10^{-5}
Di(2-ethylhexyl)phthalate (*private well GW-07/PW-41*)	2.9 LJ[c]	1.40×10^{-2}	5.3×10^{-7}
Di(2-ethylhexyl)phthalate (*PWS well*)	6.9	1.40×10^{-2}	1.3×10^{-6}
Trichloroethylene (*private well GW-10/PW-42*)	115	4.6×10^{-2}	1.1×10^{-4}
Trichloroethylene (*PWS well*)	6.03[d]	4.6×10^{-2}	1.2×10^{-5}

* Please see Appendix B for definitions and information about comparison values and data evaluation.
µg/L – micrograms per liter
mg/kg/day – milligrams per kilogram per day
PWS – public water supply

[a] The cancer risks for oral exposure to chromium and manganese were not evaluated because they are not considered carcinogenic via the oral route of exposure.

[b] The maximum concentration of each contaminant was used to determine the estimated cancer risk.

[c] LJ – EPA data qualifier that indicates the result is an estimated value above the detection limit but below the reporting limit.

[d] The highest concentration (6.03 µg/L) of TCE was detected in the PWS prior to the installation of the GAC filter.

Table 6. Cancer risk estimates for adults exposed to carcinogens[a].

Contaminant (*well type*)	**Maximum Concentration (µg/L)[b]**	**Cancer Slope Factor ([mg/kg/day]$^{-1}$)**	**Estimated Cancer Risk**
Arsenic (*private well GW-10/PW-42*)	10.8	1.50	2.6×10^{-4}
Arsenic (*PWS well*)	3.2 LJ[c]	1.50	7.8×10^{-5}
Di(2-ethylhexyl)phthalate (*private well GW-07/PW-41*)	2.9 LJ[c]	1.40×10^{-2}	6.6×10^{-7}
Di(2-ethylhexyl)phthalate (*PWS well*)	6.9	1.40×10^{-2}	1.6×10^{-6}
Trichloroethylene (*private well GW-10/PW-42*)	115	4.6×10^{-2}	2.1×10^{-5}
Trichloroethylene (*PWS well*)	6.03[d]	4.6×10^{-2}	9.0×10^{-6}

* Please see Appendix B for definitions and information about comparison values and data evaluation.
µg/L – micrograms per liter
mg/kg/day – milligrams per kilogram per day
PWS – public water supply

[a] The cancer risks for oral exposure to chromium and manganese were not evaluated because they are not considered carcinogenic via the oral route of exposure.

[b] The maximum concentration of each contaminant was used to determine the estimated cancer risk.

[c] LJ – EPA data qualifier that indicates the result is an estimated value that is above the detection limit but below the reporting limit.

[d] The highest concentration (6.03 µg/L) of TCE was detected in the PWS prior to the installation of the GAC filter.

TCE in the PWS (Well 20)

In 2006, a GAC system was installed on Well 20, and in 2015 the well was replaced and is no longer in use [10]. Thus, residents receiving treated water through the PWS have not been exposed to elevated levels of TCE since 2006. Recent review of PWS monitoring results in 2016 indicates no detection of TCE since 2006. Because it is possible that people may have been exposed to TCE historically, past exposure to TCE was evaluated.

The maximum concentration of TCE detected in the PWS was 6.03 µg/L. Assuming exposure to TCE at the maximum concentration, the estimated daily dose of TCE for adults drinking and using water from the PWS (0.0005 mg/kg/day) is the same as the minimal risk level (MRL) for TCE (Table 4). The estimated daily doses for children ages 0 to 21 years ranged from 0.0004 mg/kg/day to 0.002 mg/kg/day (Table 3), and estimated exposure doses for most age groups were similar to the MRL. The MRL is based on three critical studies in which adverse effects on the immune system and fetal heart malformations were noted in mice and rats exposed to TCE in drinking water. Decreased thymus weights and decreased immune response were noted in mice exposed to 0.048 mg/kg/day TCE and 0.37 mg/kg/day TCE, respectively. Fetal heart malformations were noted in rats exposed in utero to 0.0051 mg/kg/day TCE [22]. The estimated daily dose for adults exposed to TCE is approximately 10 times lower than the level at which fetal heart malformations were observed in rats. The estimated daily doses for children and adults were much lower (approximately 28 to over 100 times lower) than the level at which effects on the immune system were noted in mice. While estimated exposure doses exceed the MRL for several age groups, they are below the level at which adverse health effects have been observed and past exposure to TCE in the PWS is not likely to cause adverse non-cancer health effects.

The cumulative cancer risk estimate for children (ages 0-21 years) and adults exposed to TCE by all pathways combined (ingestion, inhalation, and dermal contact) was calculated to be 1.2×10^{-5} and 9.0×10^{-6}, respectively (Tables 5 and 6). This represents a low and no apparent increased risk for cancer, respectively.

TCE and Metals in Private Well GW-10/PW-42

The highest concentration of TCE detected in private wells (115 µg/L) was found in GW-10/PW-42 during the June 2014 sampling event. This level was 12 and 25 times greater than the levels found in 2010 (10 µg/L) and 2006 (4.67 µg/L), respectively. Arsenic above the CV and lead were also detected. As the filtration system on GW-10/PW-42 was removed at the homeowner's request [9], past and current exposure to TCE and metals at this residence was evaluated. However, following the 2014 sampling event, the homeowner reportedly disconnected this well from the residence and is now using an irrigation well. TCE was not detected in the irrigation well [16, 19].

Assuming residents using this well were exposed to the highest level of TCE (115 µg/L), the estimated combined (ingestion, inhalation, and dermal contact) daily doses of TCE for children aged 0 to 21 years (0.008 mg/kg/day to 0.03 mg/kg/day) and adults (0.009 mg/kg/day) exceeded the MRL for TCE (Tables 3 and 4, respectively). The estimated daily dose for adults (0.009 mg/kg/day) exceeds the level at which fetal heart malformations were observed in rats exposed

in utero (0.0051 mg/kg/day TCE). The estimated daily doses for children and adults were lower than, but approaching the level at which effects on the immune system were noted in mice suggesting an increased risk for effects. Although there should not be current exposure to TCE at this residence, a health concern for past exposure for pregnant women due to the possibility of fetal heart malformations is possible, as well as a health concern for past exposure for children and adults due to the possibility of adverse effects on the immune system. It is recommended that people that lived at this residence in the past and have health concerns speak with their personal physician.

The cumulative cancer risk estimate for children (ages 0-4 years; considered to be the most sensitive age group) and adults exposed to TCE at this residence by all pathways combined (ingestion, inhalation, and dermal contact) was calculated to be 1.1×10^{-4} and 2.1×10^{-5}, respectively. This represents a moderate and low increased risk for cancer, respectively.

The arsenic result from this well (10.8 µg/L) was slightly higher than the MCL (10 µg/L); therefore, the risk of exposure to arsenic for residents drinking water from this well is only slightly greater than what is allowed federally for public drinking water systems. The estimated daily dose of arsenic for children aged 0 to 21 years ranged from 0.0004 mg/kg/day to 0.002 mg/kg/day (Table 3), and was 0.0004 mg/kg/day for adults (Table 4). While the estimated daily dose for adults is similar to the MRL for arsenic (0.0003 mg/kg/day), the estimated daily doses for children are up to five times higher than the MRL. This MRL was based on a study in which skin alterations (hyperkeratosis and hyperpigmentation) were noted in humans exposed to 0.014 mg/kg/day arsenic. These alterations were not apparent in humans exposed to 0.0008 mg/kg/day arsenic [23]. The highest estimated daily dose (0.002 mg/kg/day) was for the youngest age group (birth to less than 1 year) and assumes infants drink 1.113 liters (approximately 38 ounces) of tap water (not bottled water) daily. The estimated exposure dose for infants was nine times lower than the level at which health effects have been observed. However, infants that breastfeed or drink formula made from bottled water are not exposed at this level and health effects are not expected. For all other age groups, estimated exposure doses were at least 16 times lower than the level at which health effects have been observed. While estimated exposure doses exceed the MRL for several age groups, exposure to arsenic in this private well is not likely to cause adverse non-cancer health effects.

The cumulative cancer risk estimate for children (ages 0-21 years) and adults exposed to arsenic was calculated to be 2.1×10^{-4} and 2.6×10^{-4}, respectively (Table 5 and 6). This represents a moderate increased risk for cancer.

While drinking water from this private well is not likely to cause adverse non-cancer health effects, exposure to arsenic at this level represents some risk for cancer. However, this is based on health-protective assumptions and limited data (arsenic concentration at one point in time). Information on testing your water and reducing exposure to arsenic can be found at: https://www.epa.gov/ground-water-and-drinking-water.

The highest level of lead found in private wells came from this same private well and was 25 µg/L. This level is above EPA's drinking water action level for treatment of 15 µg/L and above

the maximum contaminant level goal of 0. There is no beneficial effect of lead in the body; therefore, it is important to reduce all exposures to lead, especially for small children and pregnant women.

As shown in Table 3, the exposure dose for the youngest age group (birth to less than 1 year) exposed to manganese in this private well slightly exceeded the EPA RfD, but is not associated with doses that may result in health impacts based on the available studies. It should be noted that this exposure scenario assumes infants drink 1.113 liters (approximately 38 ounces) of tap water (not bottled water) daily from the affected system and infants that breastfeed or that drink formula made from bottled water may have been exposed to much lower levels of manganese in drinking water. . For all other age groups of children and adults, estimated exposure doses for manganese were below the RfD (Tables 3 and 4) and non-cancer health effects are not expected.

All metals were detected at higher concentrations in private well GW-10/PW-42 compared to other wells tested, and the level of TCE appears to be increasing with time. ATSDR and DSHS recommend that private well GW-10/PW-42 continue not be used for drinking water. If this well is considered for drinking water use in the future, it is recommended that a whole-house filtration system capable of removing metals and TCE from the water be installed (and maintained) before the water is used for drinking and other household uses, such as showering.

TCE in Private Well GW-41/PW-25

Although GW-41/PW-25 is currently not used for drinking water, in the past residents used this well for drinking water and may have been exposed to TCE. Past exposure to TCE (prior to 2010 when the GAC filtration system was installed) at this residence was evaluated.

Assuming people at this residence were exposed to 43 µg/L TCE (based on 2010 data), the estimated combined (ingestion, inhalation, and dermal contact) daily doses of TCE for children aged 0 to 21 years (0.003 mg/kg/day to 0.01 mg/kg/day) and adults (0.003 mg/kg/day) exceeded the MRL for TCE. The estimated daily dose for adults exposed to TCE from this private well is approaching the level at which fetal heart malformations were observed in rats exposed in utero. The estimated daily doses for children and adults were lower than, but approaching, the level at which effects on the immune system were noted in mice. Although there is no current exposure to TCE at this residence, a health concern for past exposure for pregnant women due to the possibility of fetal heart malformations is possible, as well as a health concern for past exposure for children and adults due to the possibility of adverse effects on the immune system. It is recommended that people that lived at this residence in the past and have health concerns speak with their personal physician.

The cumulative cancer risk estimate for children (ages 0-21 years) and adults exposed to TCE by all pathways combined (ingestion, inhalation, and dermal contact) was calculated to be 8.4×10^{-5} and 6.5×10^{-5}, respectively, which represents a low increased risk for cancer.

This well was tested again in 2014 and the TCE concentration was 55.9 µg/L. This result supports the conclusion that this well should not be used for drinking water and other household uses, such as showering.

TCE in Private Well GW-11/GW-33/PW-13

Prior to 2014, the levels of TCE in GW-11/GW-33/PW-13 were below the MCL and health-based screening levels. However, in 2014, this well showed a TCE level of 16.8 µg/L, which exceeds both the MCL and the health-based screening level for children (5 µg/L). Although this well is currently equipped with a whole-house filtration system, past exposure to TCE at this residence was evaluated.

Based on the level of TCE in this well in 2014 (16.8 µg/L), the estimated combined (ingestion, inhalation, and dermal contact) daily doses of TCE for children aged 0 to 21 years (0.001 mg/kg/day to 0.005 mg/kg/day) and adults (0.001 mg/kg/day) exceeded the MRL for TCE. The estimated daily dose for adults is approaching the level at which fetal heart malformations were observed in rats exposed in utero. The estimated daily doses for children and adults were nine times lower than, but approaching the level at which effects on the immune system were noted in mice indicating an increased risk for effects. Although there is no current exposure to TCE at this residence, a health concern for past exposure for pregnant women due to the possibility of fetal heart malformations is possible. It is recommended that people that lived at this residence in the past and have health concerns speak with their personal physician.

The cumulative cancer risk estimate for children (ages 0-4 years) and adults exposed to TCE by all pathways combined (ingestion, inhalation, and dermal contact) was calculated to be 1.5×10^{-5} and 3.1×10^{-6}, respectively, which represents a low and no apparent increased risk for cancer, respectively.

TCE in Private Well GW-48/PW-80

While TCE was detected in GW-48/PW-80 in 2010, the level was below the MCL. However, in 2014, the level of TCE (5.2 µg/L) was just above the MCL and the health-based screening level for children. Although this well is currently equipped with a filtration system, past exposure to TCE at this residence was evaluated.

Based on the level of TCE in this well in 2014 (5.2 µg/L), the estimated combined (ingestion, inhalation, and dermal contact) daily doses of TCE for children aged 0 to 21 years ranged from 0.0004 mg/kg/day to 0.001 mg/kg/day. The estimated daily dose for children in the youngest age group (birth to less than 1 year) was three times higher than the MRL, assuming infants drink 1.113 liters (approximately 38 ounces) of tap water (not bottled water) daily. The estimated exposure dose for infants was over 30 times lower than the level at which health effects have been observed. Infants that breastfeed or drink formula made from bottled water are not exposed at this level and health effects are not expected. Estimated exposure doses for adults and all other age groups were either similar to or below the MRL and were well below levels at which health effects have been observed.

The cumulative cancer risk estimate for children (ages 0-4 years) and adults exposed to TCE by all pathways combined (ingestion, inhalation, and dermal contact) was calculated to be 4.8×10^{-6} and 9.5×10^{-7}, respectively, which represents a no apparent increased risk for children and a no significant increased risk for cancer for adults, respectively.

All Other Private and Public Water Wells

Arsenic was detected in one PWS well at 3.2 µg/L. Using this level, the estimated daily dose of arsenic for children aged 0 to 21 years ranged from 0.0001 mg/kg/day to 0.0005 mg/kg/day (Table 3) and was 0.0001 mg/kg/day for adults (Table 4). Only the youngest age group (birth to less than 1 year) drinking tap water had an estimated exposure dose that slightly exceeded the MRL for arsenic (0.0003 mg/kg/day), which does not present a non-cancer health concern. Cancer risk estimates indicate a low increased risk for cancer (Tables 5 and 6).

Lead was not detected in any of the six PWS wells tested, but was detected above the EPA action level in one of the 17 private well samples. There is no beneficial effect of lead in the body; therefore, it is important to reduce all exposures to lead, especially for small children and pregnant women.

As shown in Table 3, exposure doses for chromium in the PWS slightly exceeded the MRL for the youngest age group (birth to less than 1 year), but does not present a concern for non-cancer health effects. For all other age groups, estimated exposure doses for chromium and di(2-ethylhexyl)phthalate in both private and public wells were below their respective MRLs (Tables 3 and 4) and non-cancer health effects are not expected. In addition, as shown in Tables 5 and 6, cancer risk estimates for children and adults exposed to di(2-ethylhexyl)phthalate do not indicate an increased risk for cancer.

Children's Health Considerations

In communities faced with air, water, or soil contamination, children could be at greater risk than adults from certain kinds of exposure to hazardous substances. A child's lower body weight and higher intake rate may result in a greater dose of hazardous substance per unit of body weight. Sufficient exposure levels during critical growth stages can result in permanent damage to the developing body systems of children. Children are dependent on adults for access to housing, for access to medical care, and for risk identification. Consequently, adults need as much information as possible to make informed decisions regarding their children's health.

The likelihood for children to be exposed to the site contaminants at levels of health concern was evaluated. At this site, children could have been exposed to TCE in the past. Exposure scenarios specific to children were used to determine the possible adverse health effects of this exposure. As children have higher exposure doses than adults because of their body weight, conclusions based on children exposed to contaminants are also protective for adults.

An elevated level of lead was found in well water from one residence (private well GW-10/PW-42). All metals were detected at higher concentrations in this private well compared to other wells tested. At the time the well was sampled, there were no children living at this residence. There is no beneficial effect of lead in the body; therefore, it is recommended that the water not be consumed.

Community Health Concerns

As part of the PHA process, the DSHS and ATSDR try to understand community health concerns related to the site. Information and comments from people who live near the site were

actively ascertained during site visits and community meetings. The following are the community health concerns received and responses to those concerns.

Where did the contamination happen, how did it happen, who did it, and when did it happen?
Although the EPA and TCEQ have been investigating potential source areas, as of the writing of this report, the source has not been identified. Until a source is identified, it is not possible to determine where, how, and when the contamination happened. TCE is regularly monitored in PWS and was first detected in the city of Willow Park PWS in 2001.

Why wasn't the community notified about the contamination when it was discovered?
In May 2006, the TCEQ notified residents with private wells located near Well 20 of the TCE contamination found in the PWS. This information was also conveyed to residents in the city of Willow Park Consumer Confidence Report, which is required to be mailed annually to consumers by the PWS.

What can we do now and what type of filtration system should be used?
If you receive water from a PWS, you do not need to do anything. As required by the Safe Drinking Water Act, the PWS will continue to monitor and filter the water as needed to provide safe drinking water.

If you have a private well and your well has been tested for TCE, you do not need to do anything. Data collected from private wells in 2006, 2010, and 2014 did not identify many wells with elevated levels of TCE. Of the wells with elevated levels of TCE, current exposure is not likely because these wells were either equipped with a filtration system, connected to the city's water supply, or no longer in use for drinking water.

If you have a private well that has not been tested for TCE and are concerned about exposure, you can have your well tested for TCE. TCE can be removed from drinking water with a granular activated carbon (GAC) filter. A list of accredited laboratories, the analyses they can perform, and contact information for each laboratory can be found at www.tceq.texas.gov/goto/certified_labs.

Is the water safe to drink and use in the home or for irrigation and swimming pools?
If the water you use throughout the home is from a PWS, you do not need to be concerned about current exposures to TCE. The PWS will continue to monitor and filter the water as needed to provide water that is safe to drink and use throughout the home.

If you have a private well that is equipped with a granular activated carbon (GAC) filtration system, you should be protected from exposure to TCE, assuming the filter is maintained.

TCE is a volatile compound; therefore, when it is used outdoors for irrigation and in swimming pools, TCE in the water will evaporate with the water into the atmosphere and is not likely to cause health problems.

What are the health effects of TCE, including for small children and during pregnancy and cancer treatment?
TCE is a known human carcinogen and exposure to high levels can cause adverse effects on the central nervous system, kidney, liver, immune system, male reproductive system, and heart malformations for the developing embryo/fetus [24]. Information on effects of exposure to TCE is provided in Appendix C. It is recommended that individuals that are concerned about their past exposures to TCE speak with their personal physician about their health concerns. While physicians can provide information about health effects from past exposure, because TCE does not stay in the body, it is not possible to determine how much TCE you might have been exposed to in the past.

Is the natural gas well site the cause?
The source of the groundwater contamination has not yet been identified; however, TCE is not a contaminant normally associated with oil and gas exploration and production activities.

What will the city do?
The City of Willow Park PWS will continue to monitor the water as needed to ensure the water provided by the PWS is safe to drink and use throughout the home.

What will DSHS do?
DSHS will continue to work with EPA and TCEQ in educating the community about potential exposures and addressing community health concerns.

Conclusions

The Texas Department of State Health Services (DSHS) and the Agency for Toxic Substances and Disease Registry (ATSDR) reached three conclusions in this health assessment:

1. Adverse health effects may have occurred from past exposure to TCE in private wells GW-41/PW-25 and GW-11/GW-33/PW-13. However, there are no current or future exposures to the water from these wells. Estimated past exposure doses indicate a health concern for pregnant women due to the possibility of fetal heart malformations, as well as a health concern for past exposure for children and adults due to the possibility of adverse effects to the immune system. There was also some risk of cancer associated with drinking water from these wells based on exposure to TCE. There is no current or future exposure to TCE from either of these water wells because homes are either connected to a PWS or the wells are no longer in use.
2. Adverse health effects may have occurred from past exposure to TCE, arsenic, and lead from private well GW-10/PW-42. However, there are no current or future exposures to the water from this well. Estimated exposure doses indicate a health concern for past exposure to TCE for pregnant women due to the possibility of fetal heart malformations, as well as a health concern for past exposure for children and adults due to the possibility of adverse effects to the immune system. There was also some risk of cancer associated with drinking water from this well based on exposure to TCE and arsenic. In addition, lead was detected in this well. Lead has no beneficial effect in the body and could have posed a health risk, especially for small children. There is no current or future exposure to contaminants because the well has been disconnected and residents are using a new well. Contaminants have not been detected in the new well.
3. Adverse health effects are not likely to have occurred from past exposure to TCE in private wells GW-48/PW-80 and public water supply (PWS) Well 20. Current and future exposures to TCE are also not expected. A detailed analysis of estimated exposure doses and estimated cancer risks for these wells indicates that adverse health effects are not likely to occur. In addition, GW-48/PW-80 is currently equipped with a granular activated carbon (GAC) filtration system and Well 20 is no longer in use. Therefore, there is no current or future exposure to TCE from these drinking water sources.

Recommendations

Based on the review of the data and the concerns expressed by community members, the following recommendations are appropriate and protective of public health:

1. Individuals concerned about their past exposures to TCE and other contaminants are advised to speak with their personal physician about their health concerns.
2. EPA and TCEQ continue to maintain the GAC filtration systems on private wells GW-11/GW-33/PW-13 and GW-48/PW-80.
3. Private wells GW-10/PW-42 and GW-41/PW-25 should not to be used for drinking water and other household purposes unless a whole-house water filtration system is installed and properly maintained.
4. EPA and TCEQ continue efforts to identify the source of the groundwater contamination.

5. EPA and TCEQ continue to monitor and assess affected and potentially affected groundwater in the area of investigation to include private water wells near Well 20 that are being used for drinking and other household purposes.
6. Private well owners interested in testing their drinking water for contaminants may obtain information at: https://www.epa.gov/ground-water-and-drinking-water.

Public Health Action Plan

The public health action plan for the site contains a description of actions that have been or will be taken by DSHS, ATSDR, and other government agencies at the site. The purpose of the public health action plan is to ensure that this public health assessment both identifies public health hazards and provides a plan of action designed to mitigate and prevent harmful human health effects resulting from breathing, drinking, or touching hazardous substances in the environment. Included is a commitment on the part of DSHS and ATSDR to follow up on this plan to ensure that it is implemented.

Actions Completed

1. The city of Willow Park PWS identified TCE in groundwater in 2001 during routine monitoring. Levels were below the MCL.
2. TCE was detected in the city of Willow Park PWS (Well 20) above the MCL in 2006. Well 20 was used with a GAC filtration system until 2015.
3. Public and private drinking and non-drinking water wells in the area were sampled in 2006 and 2010, and GAC filters were installed on drinking water wells with levels of TCE above the MCL.
4. The Circle Court Groundwater Plume site was proposed to the NPL in March 2012, and listed as final on the NPL in September 2012.
5. DSHS conducted an initial site visit in May 2012, and conducted a follow-up site visit and door-to-door community outreach activities in July 2012.
6. EPA hosted a community meeting regarding the site in August 2012.
7. Due to the identification of a drum containing TCE liquid or residue, passive soil gas samples were collected in November 2012.
8. An additional private well that had not been previously sampled was tested by the TCEQ in May 2013.
9. Private wells in the area were sampled in 2014, and GAC filters were installed on drinking water wells with levels of TCE above the MCL.
10. In 2015, Well 20 was replaced with a new water well that was constructed in a deeper groundwater aquifer.

Actions Planned

1. This document will be made available to the community and local government officials for public comment. Comments received during the public comment period will be addressed by DSHS and ATSDR and incorporated into the final version.
2. The final version of this document will be made available to community members, city officials, the TCEQ, and the EPA as well as other interested parties.
3. DSHS will continue to work with EPA and TCEQ in addressing community health concerns.
4. As required by the Safe Drinking Water Act, the city of Willow Park PWS will continue to monitor and maintain the GAC filtration system to remove TCE prior to distribution.
5. EPA, in consultation with TCEQ, will continue efforts to identify the source of the groundwater contamination.
6. EPA, in consultation with TCEQ, will continue to monitor and assess affected and potentially affected groundwater in the area of investigation to include private water wells near Well 20 that are being used for drinking and other household purposes.

Preparers of Report

This Public Health Assessment for the Circle Court Groundwater Plume site was prepared by the Texas Department of State Health Services (DSHS) under a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with the approved agency methods, policies, and procedures existing at the date of publication. Editorial review was completed by the cooperative agreement partner. ATSDR has reviewed this document and concurs with its findings based on the information presented.

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Appendix A: Acronyms and Abbreviations

AT	averaging time
ATSDR	Agency for Toxic Substances and Disease Registry
BW	body weight
C	contaminant concentration
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980
cis-1,2-DCE	cis-1,2-dichloroethene
CREG	cancer risk evaluation guide
CSF	cancer slope factor
CV	comparison value
DSHS	Texas Department of State Health Services
ED	exposure duration
EF	exposure factor
EMEG	environmental media evaluation guide
EPA	United States Environmental Protection Agency
GAC	granular activated carbon
HQ	hazard quotient
IR	ingestion rate
IUR	inhalation unit risk
kg	Kilogram
L/day	liters per day
L/kg/day	liters per kilogram per day
LOAEL	lowest observed adverse effect level
MCL	maximum contaminant level
µg/L	micrograms per liter
µg/mg	micrograms per milligram
mg/day	milligrams per day
mg/kg/day	milligrams per kilogram per day
mg/L	milligrams per liter
MRL	minimal risk level
NA	not available
ND	not detected
NOAEL	no observed adverse effect level
NPL	National Priorities List
PCE	Tetrachloroethylene
PHA	Public Health Assessment
POE	point of entry
PWS	public water system
RCRA	Resource Conservation and Recovery Act
RfC	reference concentration
RfD	reference dose
RMEG	reference dose media evaluation guide
SVOC	semivolatile organic compounds
TCE	Trichloroethylene
TCEQ	Texas Commission on Environmental Quality
VOC	volatile organic compounds

Appendix B: Methodology

This appendix details how environmental data collected at a site are evaluated to determine if exposure to contaminants could occur and if that exposure could result in adverse health effects. Past, current, and future exposure scenarios are evaluated to determine if exposure has occurred, is occurring, or could occur in the future. Environmental data are evaluated using a two-step process to determine the potential for adverse health effects to occur from exposure to contaminated media. The first step involves screening the data to determine if levels of contaminants found in environmental media are of potential public health concern. The second step includes evaluating estimated exposure doses compared to levels of exposure that are known to cause adverse health effects. Equations and parameters used to make these determinations, as well as example calculations using site-specific data, are also included.

Exposure Pathways

The presence of chemicals in the environment does not always mean that people who spend time in the area are likely to experience adverse health effects. These effects are only possible when people are exposed to sufficient levels of the contaminant and the chemical enters the body through the lungs, through the gastrointestinal tract, or directly through the skin. Exposure can occur by breathing air containing volatile or dust-borne contaminants, by eating or drinking food or water that contain contaminants (or through hand-to-mouth activities when contaminated soil, dust, sediment, or water is present on the hands), or by coming into direct skin-contact with contaminated soil, dust, sediment, or water resulting in dermal absorption of the chemical.

An exposure pathways analysis is conducted to determine whether people visiting the site or living nearby have been, currently are, or could be exposed (at some time in the future) to contaminants associated with this site. The five elements of an exposure pathway include:

1) the contaminant source (the location where contaminants are being released to various media),
2) the environmental fate and transport of contaminants (how contaminants move through the environment),
3) the exposure point or area (the location where people may come into physical contact with site contaminants),
4) the exposure route (the means by which a contaminant gets into the body at the exposure point or area), and
5) the potentially exposed population (a group of people who may come in physical contact with site contaminants).

Past, current, and future exposure scenarios are evaluated to determine if each exposure pathway is a completed exposure pathway, a potential exposure pathway, or an eliminated exposure pathway. A pathway is complete when all five elements in the pathway are present and exposure has occurred, is occurring, or will occur in the future. Potential pathways are missing information for one or more of the five elements and indicate that exposure could have occurred in the past, could be occurring, or could occur in the future. A pathway is eliminated if one or more of the elements are missing and past, current, or future exposures are unlikely.

For a person to be exposed to site contaminants, at least one exposure scenario must be a completed pathway. Although a complete pathway indicates exposure to site contaminants, it does not indicate that this exposure will lead to adverse health effects. Factors that influence whether that exposure could potentially result in adverse health effects include:

- the toxicological properties of the contaminant (the toxicity or carcinogenicity),
- the manner in which the contaminant enters the body (the route of exposure),
- how often and how long the exposure occurs (the frequency and duration of exposure),
- how much of the contaminant actually gets into the body (the delivered dose),
- once in (or on) the body, how much gets into the bloodstream (the absorbed dose),
- the number of contaminants involved in the exposure (the synergistic or combined effects of multiple contaminants), and
- individual host factors predisposing to susceptibility (characteristics such as age, sex, body weight, genetic background, health status, nutritional status, and lifestyle factors that may influence how an individual absorbs, distributes, metabolizes, and/or excretes the contaminants).

Complete and potential exposure pathways are evaluated to determine the potential for adverse health effects to occur. Based on the past, current, and future exposure scenarios for this site, the following exposure pathways were evaluated:

Pathway Name	Exposure Pathway Elements					Time
	Source	Environmental Medium	Point of Exposure	Route of Exposure	Potentially Exposed Population	
Private drinking water wells	Unknown	Water	Homes connected to private well	Ingestion Inhalation Dermal	Adults and children in residential areas	Past Current
Public water supply wells	Unknown	Water	Homes connected to public water supply	Ingestion Inhalation Dermal	Adults and children in residential areas	Past

Screening Analysis

The following information is provided from the Agency for Toxic Substances and Disease Registry's (ATSDR's) Comparison Value Guidance [25].

Background Information

Comparison values (CVs) are chemical and media-specific concentrations in air, soil, and drinking water that are used by ATSDR health assessors and others to identify environmental contaminants at hazardous waste sites that require further evaluation. CVs incorporate assumptions of daily exposure to the chemical and, in the case of soil and water, a standard amount that someone may likely take into their body each day. CVs are non-site specific. They are based on health guidelines

with uncertainty or safety factors applied to ensure that they are adequately protective of public health.

The comparison of environmental data with ATSDR CVs is one of the first steps in the public health assessment process. The results of this screening step give health assessors an understanding of the priority contaminants at a site. When a contaminant is detected at a concentration less than its respective CVs, exposure is not expected to result in health effects and it is not considered further as part of the public health assessment process. It should be noted that contaminants detected at concentrations that exceed their respective CVs, do not necessarily represent a health threat. Instead, the results of the CV screening identify those contaminants that warrant a more detailed, site-specific evaluation to determine whether health effects are possible. CVs are not intended to be used as environmental clean-up levels.

CVs can be based on either carcinogenic or non-carcinogenic effects. Cancer-based CVs are calculated from the U.S. Environmental Protection Agency's (EPA's) oral cancer slope factor (CSF) or inhalation unit risk (IUR). CVs based on cancerous effects account for a lifetime exposure (70 years) with an estimated excess lifetime cancer risk of 1 extra case per 1 million exposed people. Non-cancer values are calculated from ATSDR's minimal risk levels (MRLs), EPA's reference doses (RfDs), or EPA's reference concentrations (RfCs). When a cancer and non-cancer CV exists for the same chemical, the lower of these values is used in the data comparison for public health protectiveness [1].

Derivation of Comparison Values

Minimal Risk Levels

Minimal risk levels (MRLs) are an estimate of the daily human exposure to a substance that is likely to be without appreciable risk of adverse health effects during a specified duration of exposure. MRLs are based only on non-carcinogenic effects. MRLs are derived for acute (1-14 days), intermediate (15-364 days), and chronic (365 days and longer) durations for the oral and inhalation routes of exposure. Currently, MRLs for dermal exposure are not derived.

Environmental Media Evaluation Guides (Derived from ATSDR MRLs)

Environmental media evaluation guides (EMEGs) represent concentrations of substances in water, soil, and air to which humans may be exposed during a specified period of time (acute, intermediate, or chronic) without experiencing non-cancerous adverse health effects. EMEGs are calculated using MRLs and default exposure assumptions. The default exposure assumptions account for variations in water and soil ingestion between adults and children.

Reference Dose Media Evaluation Guides (Derived from EPA RfDs and RfCs)

ATSDR develops reference dose media evaluation guides (RMEGs) for soil and drinking water using EPA's RfDs and default exposure assumptions. EPA's RfCs serve as RMEGs for air exposures. Like EMEGs, RMEGs represent concentrations of substances (in water, soil, and air) to which humans may be exposed without experiencing non-cancerous, adverse health effects. RfDs and RfCs consider lifetime exposures; therefore, RMEGs apply to chronic exposures.

Cancer Risk Evaluation Guides

Cancer risk evaluation guides (CREGs) are media-specific comparison values that are used to identify concentrations of cancer-causing substances that are unlikely to result in a significant increase of cancer rates in an exposed population. ATSDR develops CREGs using EPA's CSF or IUR, a target risk level (10^{-6}), and default exposure assumptions. The target risk level of 10^{-6} represents an estimated risk of 1 excess cancer cases in an exposed population of 1 million.

Exposure Dose Analysis

Chemicals that exceed their CVs are further evaluated by calculating estimated exposure doses and determining the public health implications of those exposures based on known health effects levels. In addition, cancer risk estimates are determined for those chemicals that exceed their CREG. Conclusions, recommendations, and the public health action plan are based on the results of these analyses.

Estimated Exposure Doses

Estimated exposure doses are calculated to determine the amount of a chemical that could get into the body. These estimated exposure doses are calculated using the chemical concentration and default exposure parameters from ATSDR's Public Health Assessment Guidance Manual [1], EPA's Exposure Factors Handbook [26], and ATSDR's Exposure Dose Guidance [27] when site specific information is unknown.

Drinking Water Estimated Exposure Dose

The estimated exposure dose for drinking water is calculated using the following formula [1]:

$$D = \frac{C \times IR \times EF}{BW}$$

D = exposure dose (mg/kg/day)
C = contaminant concentration (mg/L)
IR = ingestion rate of contaminated water (L/day)
EF = exposure factor (unitless)
BW = body weight (kg)

The contaminant concentration is based on site-specific data (typically the maximum concentration detected or an estimate of the average concentration, such as the 95% upper confidence limit of the mean) and the exposure factor is typically 1 to represent daily exposures. The following age-specific ingestion rates and body weights (based on data presented in the EPA Exposure Factors Handbook [26]) are used with the above formula to calculate age-specific estimated exposure doses for drinking water [27]:

Age Range	Ingestion Rate (L/day)	Body Weight (kg)
Birth to <1 year	1.113	7.8
1 to <2 year	0.893	11.4
2 to <6 year	0.977	17.4
6 to <11 year	1.404	31.8
11 to <16 year	1.976	56.8
16 to <21 year	2.444	71.6
≥21 year	3.092	80

Determining the Public Health Implications for Noncarcinogens

The public health implications associated with exposure to chemicals that are not considered to be carcinogens is determined by comparing estimated exposure doses for each age group above to health guidelines. These health guidelines, such as MRLs and RfDs, are considered to be safe doses at which adverse health effects are not expected. The hazard quotient (HQ) is calculated by dividing the estimated exposure dose by the health guideline.

$$HQ = \frac{D}{MRL\ or\ RfD}$$

HQ = hazard quotient (unitless)
D = exposure dose (mg/kg/day)
MRL = minimal risk level (mg/kg/day)
RfD = reference dose (mg/kg/day)

If an HQ is less than 1, the estimated exposure dose is below the health guideline and adverse non-cancer health effects are not expected. If an estimated exposure dose exceeds a health guideline, the dose is then compared to known health effect levels found in scientific literature, such as the NOAEL and LOAEL upon which the MRL is based. These comparisons are used to determine if adverse health effects are possible and if the exposure presents a health hazard.

Estimated Cancer Risk

For contaminants considered to be carcinogens, the estimated cancer risk is calculated using the following formula:

$$Risk = \frac{D \times CSF \times ED}{AT}$$

D = exposure dose (mg/kg/day)
CSF = EPA's oral cancer slope factor [$(mg/kg/day)^{-1}$]
ED = exposure duration (years)
AT = averaging time (78 years)

This cancer risk is calculated for each age group above. The cancer risks for age groups from birth to less than 21 years are summed to obtain the cumulative cancer risk estimate for children ages 0-

21 years. The cancer risk for adults exposed for 33 years is also determined. These exposures are averaged over a lifetime of 78 years.

Determining Public Health Implications for Carcinogens

The estimated cancer risk is reported as a value such as 1×10^{-6}. This means that in a population of one million people exposed to a carcinogen over a lifetime, there may be one additional cancer case because of this exposure. Similarly, a value of 1×10^{-4} indicates that in a population of 10,000 people exposed to a carcinogen over a lifetime, there may be one additional cancer because of the exposure. It is important to note that this is an estimated risk for cancer for a population with a similar chemical exposure. The true cancer risk for the population is not known but is likely to be lower, and we cannot determine the risk for cancer for an individual. This risk is also an additional or excess cancer risk which is above and beyond the normal or background risk for cancer.

Site Specific Considerations and Example Calculation

Because of data limitations and in the interest of being protective of human health, the maximum concentration of each chemical in milligrams per liter (mg/L) was used to calculate age-specific estimated exposure doses in milligrams per kilogram per day (mg/kg/day).

While exposure to trichloroethylene (TCE) and other volatile compounds through ingestion of water can be estimated based on default assumptions, estimating exposure via inhalation or dermal contact from using TCE-contaminated water in the home is difficult, in part, because of differences between individual use patterns. One approach is to assume that exposure via the non-ingestion pathways is comparable to exposure via ingestion [1]. Therefore, in this assessment, the estimated ingestion exposure dose for TCE was doubled to account for all of these pathways (ingestion, inhalation, and dermal exposure).

For the Circle Court Groundwater Plume site, the estimated exposure dose[1] for children (birth to less than 1 year old) exposed to TCE in the public water supply (PWS) at the maximum concentration of 6.03 micrograms per liter (µg/L) via all pathways combined (ingestion, inhalation, and dermal contact) was calculated as follows:

$$D = 2 \times \left(\frac{0.00603 \text{ mg/L} \times 1.113 \text{ L/day} \times 1}{7.8 \text{ kg}}\right)$$

$$D = 0.002 \text{ mg/kg/day}$$

[1] Estimated exposure doses are typically rounded to one significant digit. The actual estimated exposure dose (not the rounded value) is used for all subsequent calculations and rounded values are presented in the text.

The HQ was calculated using this estimated exposure dose and the MRL for TCE (0.0005 mg/kg/day) as follows:

$$HQ = \frac{0.002 \text{ mg/kg/day}}{0.0005 \text{ mg/kg/day}}$$

$$HQ = 4.0$$

The estimated exposure dose was then compared to the three critical studies that were used to develop the MRL. These studies show adverse effects on the immune system and fetal heart malformations in mice and rats exposed to TCE in drinking water. Decreased thymus weights and decreased immune response were noted in mice exposed to 0.048 mg/kg/day TCE and 0.37 mg/kg/day TCE, respectively. Fetal heart malformations were noted in rats exposed in utero to 0.0051 mg/kg/day TCE [22].

For contaminants such as TCE that have a mutagenic mode of action, age-dependent adjustment factors (ADAF) are applied to the cancer risk to account for early life exposures [28]. However, for TCE, the ADAF is only applied to the kidney portion of the cancer risk [29]. Based on EPA guidance, a cancer risk for each age group is derived [28, 29]. This cancer risk includes an adjusted kidney cancer potency value as well as unadjusted potency values for liver cancer and non-Hodgkin's lymphoma. These risks are summed across age groups to obtain the total risk for the exposure period.

The other carcinogens evaluated do not have a known mutagenic mode of action and therefore the cancer risk for each age group was determined using the formula above. Because there are not historical data to determine how long these contaminants might have been in the drinking water, conservative estimates were used to determine the estimated cancer risk. The cancer risks for each age group from birth to less than 21 years were summed to obtain the cumulative cancer risk estimate for children ages 0-21 years and the cancer risk for adults exposed for 33 years was determined. These exposures were averaged over a lifetime of 78 years.

Appendix C: Trichloroethylene

Trichloroethylene (also known as trichloroethene or TCE), a liquid at room temperature, is a solvent that is primarily used to remove grease from metal parts. It is found in some household products such as typewriter correction fluid, paint removers, adhesives, and spot removers. Because it is a highly used chemical, it is one of the more common man-made compounds found in the environment. It also is a breakdown product of tetrachloroethylene (PCE) [22].

In surface water, TCE easily evaporates and is broken down within days to weeks. In groundwater, this process occurs more slowly because of a slower evaporation rate and the absence of photocatalysis. Very little TCE in soil gets broken down, and TCE in the soil can move into groundwater. Although TCE can be found in some foods, this contamination is thought to originate from the use of contaminated water during food preparation [22]. TCE taken up into plants does not accumulate as most of it volatilizes out of the plant [30, 31].

People are exposed to TCE by breathing air, by drinking or using TCE-contaminated water, or by direct contact with TCE. These exposures generally occur in areas near factories that use TCE, near hazardous waste sites with TCE contamination, or due to use of household products. Workers at facilities that use TCE may be routinely exposed to the chemical. Approximately half of the TCE vapors that are inhaled are absorbed into the bloodstream, while the remaining portion leaves the body in the exhaled air. TCE that is ingested will also make its way into the bloodstream. Once in the blood, TCE may either be eliminated from the body or stored in body tissues such as fat. TCE may be eliminated in the breath or in the urine (in about a day) either as the intact compound or after it has been broken down into other compounds by the liver. Breakdown products of TCE also may be stored in body fat [22].

TCE was once used as an anesthetic for surgery because inhalation of large amounts makes people dizzy or sleepy and could result in a loss of consciousness. Inhalation of moderate levels of TCE may also cause headaches or dizziness. Exposure to high concentrations can damage facial nerves, damage the liver and/or the kidneys, cause changes in heart rate, or even result in death. Dermal exposure to concentrated solutions of TCE can cause skin rashes [22]. These types of effects typically occur at doses significantly higher than environmental levels.

TCE can cause adverse effects on the central nervous system, kidney, liver, immune system, male reproductive system, and the developing embryo/fetus [24]. Recently, the EPA completed a thorough review of the TCE scientific literature on non-cancerous and cancerous health effects. Through this review they developed a reference dose (RfD) for TCE and determined that TCE is a human carcinogen by all routes of exposure [32].

The RfD (0.0005 mg/kg/day), adopted by the ATSDR as a chronic and intermediate duration oral MRL, is based on three critical studies in which adverse effects on the immune system and fetal heart malformations were noted in mice and rats exposed to TCE in drinking water. Decreased thymus weights and decreased immune response were noted in mice exposed to 0.048 mg/kg/day TCE and 0.37 mg/kg/day TCE, respectively. Fetal heart malformations were noted in rats exposed to 0.0051 mg/kg/day TCE [22].

The determination that TCE is carcinogenic to humans is based on studies that show a causal relationship between human exposure to TCE and kidney cancer that cannot be attributed to chance, bias, or confounding factors [32]. There is also strong evidence that exposure to TCE contributes to non-Hodgkin lymphoma, and more limited evidence for liver and biliary tract cancer. Although less convincing, some studies have shown a relationship between exposure to TCE and other cancers such as bladder, esophageal, prostate, cervical, breast, and childhood leukemia [32].

Exposure to TCE can also cause birth defects. There is strong evidence from human and animal studies that exposure to TCE can cause malformations in the fetal heart. In addition, there is limited evidence that TCE exposure can cause other fetal malformations, prenatal losses, decreased growth or birth weight of offspring, and alterations in immune system function [24].

Tests to determine if people have been exposed to TCE are available; however, they are not routinely performed in doctors' offices. TCE can be measured in the breath for up to a day after an exposure. These breath tests can indicate if a person has been exposed to a large or small amount of TCE. Breakdown products of TCE can be measured in the urine up to a week after exposure; however, other chemicals also produce the same breakdown products making it difficult to determine whether the person was exposed to TCE [22].