Health Consultation

NORTH EAST 2ND STREET SITE
(FORMERLY KNOWN AS ATTEBURY GRAIN STORAGE FACILITY)
HAPPY, SWISHER COUNTY, TEXAS 79042

EPA FACILITY ID: TXN000606760

March 16, 2022

Prepared by the
Texas Department of State Health Services

Prepared under a Cooperative Agreement with the
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Office of Capacity Development and Applied Prevention Science
Atlanta, Georgia, 30333

Health Consultation: A Note of Explanation

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

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

You may contact ATSDR toll free at
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The Texas Department of State Health Services (DSHS) prepared this Health Consultation for the North East 2nd Street site, located in Happy, Swisher County, Texas. This publication was made possible by a cooperative agreement (program #TS20-2001) with the federal Agency for Toxic Substances and Disease Registry (ATSDR). DSHS evaluated data of known quality using approved methods, policies, and procedures existing at the date of publication. ATSDR reviewed this document and concurs with its findings based on the information presented by the DSHS.

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Summary

Introduction

The North East 2nd Street site (formerly known as Attebury Grain storage facility) is located in Happy, Swisher County, Texas. In August 2009, the Environmental Protection Agency (EPA) listed the site on its National Priority List (NPL) because of carbon tetrachloride (CTC) contamination in municipal and private residential water supplies.

CTC was first identified in one of the Happy Municipal Water System wells (City Well #3) in 1991 as part of routine monitoring. Based on the CTC contamination, the Happy Municipal Water System stopped using the well that obtained water from the Ogallala Aquifer in 1991 and began to use water from the Dockum Aquifer, which lies beneath the Ogallala. CTC and other site-related contaminants [1,2-dibromoethane (EDB) and 1,2-dichloroethane (1,2-DCA)] have not been detected in the Happy Municipal Water System supply wells obtaining groundwater from Dockum Aquifer. Therefore, the Happy Municipal Water System currently is safe for residential uses, including drinking, and all residential properties are currently connected to it.

The Agency for Toxic Substances and Disease Registry (ATSDR) was established by Congress in 1980 under the Comprehensive Environmental Response, Compensation, and Liability Act, also known as the Superfund law. ATSDR is required by law to conduct public health assessment activities at each site proposed for or listed on the NPL. The Texas Department of State Health Services (DSHS) has a cooperative agreement with ATSDR to perform public health assessment activities for all listed NPL sites in the state of Texas. This health consultation (HC) will provide information that is needed to help protect people’s health.

DSHS assessed available data from 18 groundwater samples collected from private residential wells from 2006 to 2016, one groundwater sample collected from City Well #3 from 1991 and active soil gas samples from 2018. A major limitation affecting data analyses is that not all contaminants were tested nor detected in each well consistently over the sampling events. Other limitations are listed in this HC in the section on limitations.

Based on available data, DSHS reached the following eight conclusions:

Conclusions

Conclusion 1

Some residents who used private residential well water prior to their homes being connected to the Happy Municipal Water System may have an increased risk of developing cancer.

Basis for conclusion

One or more contaminants were detected in 15 private residential wells at levels that could increase the risk of developing cancer following long-term exposure. Arsenic, benzene, carbon tetrachloride, hexavalent chromium, and 1,2-dichloroethane were found in well water during multiple groundwater sampling events conducted from 2006 to 2016. DSHS estimated cancer risks using health protective exposure assumptions, including a high or reasonable maximum exposure. At some properties, cancer risks for children or adults were estimated to exceed one additional cancer case in a population of 10,000 exposed people. However, there is uncertainty with the cancer risk estimates because of the limited samples collected and the assumption of long-term exposure over several decades.

Conclusion 2

Some residents who used private residential well water prior to their homes being connected to the Happy Municipal Water System may have experienced certain noncancer health effects.

Basis for conclusion

During multiple groundwater sampling events conducted from 2006 to 2016, benzene was detected in groundwater in three private residential water wells (GW-17, GW-23, and GW-36) and cadmium was detected in one private residential water well (GW-01) at levels that could cause noncancer adverse health effects. DSHS estimated noncancer health effects using health protective exposure assumptions, including a high or reasonable maximum exposure. Residents who were exposed to benzene for long periods may experience harmful effects in the tissues that form blood cells, including decreases in white blood cells and platelets in the blood. Residents who were exposed to cadmium for long periods may experience early signs of kidney damage, such as increased urinary levels of protein (tubular proteinuria). However, there is uncertainty with this conclusion because of the limited samples collected and the assumption of long-term exposure over several years.

Conclusion 3

People who consume water contaminated with lead from certain wells may be at risk for harmful health effects associated with this metal.

Basis for conclusion

Lead was detected in a water sample collected from a residential private well (GW-01) above the EPA action level of 15 micrograms per liter (μg/L). Although lead can affect almost every organ and system in the body, the main target for lead's harmful effects is the nervous system. Children are more vulnerable to lead exposure than adults because their nervous system is still developing. Exposure to lead in drinking water can increase a child's blood lead level. Elevated blood lead levels in children are associated with neurological, behavioral, and development effects, such as problems with attention, memory, and learning. Because there is no safe blood lead level, ATSDR and DSHS recommend reducing or removing lead exposure whenever possible.

Conclusion 4

Children who drank well water with high fluoride levels prior to their homes being connected to the Happy Municipal Water System may have experienced cosmetic effects to their teeth.

Basis for conclusion

When used appropriately, fluoride is effective in preventing and controlling dental caries. However, drinking excessive fluoride (1 mg/L or higher) during the time teeth are being formed can cause discoloration of teeth or fluorosis (ATSDR 2003). Fluoride was detected in eight residential wells (GW-09C, GW-10, GW-15, GW-21, GW-22, GW-23, GW-41, GW-50) at levels above 1 mg/L. Children drinking water from these wells over long periods may be at increased risk of developing mild dental fluorosis. Fluoride levels in these wells were below those known to cause bone fractures. Therefore, serious harmful effects in residents of these households are unlikely.

Conclusion 5

People who used the Happy Municipal Water System after 1991 have not been exposed to site-related contaminants at levels that are harmful to people's health.

<u>Basis for conclusion</u>

Site-related contaminants have not been detected in water from the Happy Municipal Water System since 1991. All the residences are now connected to the Happy Municipal Water System, which is safe to use for domestic purposes. Therefore, people using the water for cooking, drinking, and other residential uses, such as bathing, are not currently being exposed to site-related contaminants in the groundwater.

Conclusion 6

A few people who used the Happy Municipal Water System before 1991 may have been exposed to site-related contaminants at levels that are harmful to people's health.

<u>Basis for conclusion</u>

Carbon tetrachloride was detected in City Well #3 in one sample collected in 1991. DSHS estimated the noncancer and cancer risk for past exposure (prior to 1991) of carbon tetrachloride assuming people were exposed to this level for long periods. Although noncancer effects are unlikely, long-term exposure may cause a low increased risk of developing cancer. However, there is uncertainty to this conclusion. It is based on the results of one sample collected from one municipal well and assumes long-term exposure to carbon tetrachloride at this level for several decades. In addition, around 1991 City Well #3 contributed only 2 percent of the water to the distribution system of the Happy Municipal Water System and served approximately 12 people (USEPA 2009b).

Conclusion 7

Water containing volatile organic compounds and heavy metals from private residential wells is not expected to harm people's health when used for irrigation, gardening, and recreational activities.

<u>Basis for conclusion</u>

DSHS could not assess the pathway of ingestion of contaminants from home-grown garden vegetables because crop and food samples have not been collected. DSHS does not know if people are currently eating crops irrigated with contaminated groundwater. However, heavy metal concentrations in these private residential wells are below the recommended maximum concentrations of trace elements in irrigation waters established by the U.S. Department of Agriculture (USDA 2011). In addition, rural communities are not expected to consume more than 20 percent of their home-grown food/produce, making the total amount ingested very small (USEPA 2018a).

Additionally, people could have been exposed by incidentally ingesting water and through dermal contact with the water during recreational activities. However, exposure would likely be minimal. Inhalation of contaminants through vaporization in outdoor air is not likely since volatile organic compounds evaporate from water relatively quickly and readily disperse in outdoor air. In addition, heavy metals do not easily volatize and are not readily absorbed through the skin.

Conclusion 8

DSHS does not have enough information to determine if past, present, or future inhalation of carbon tetrachloride and benzene resulting from vapor intrusion could harm people's health.

Basis for conclusion

Because carbon tetrachloride and benzene were detected in the groundwater and may be present in the shallow groundwater table, volatile contaminants could potentially migrate through soil in the form of vapor and enter the indoor air of homes and workplaces. This process is called vapor intrusion and could lead to inhalation of contaminants in indoor air. DSHS could not assess this exposure pathway because no indoor air samples have been collected. Also, subsurface soil and soil gas sampling has been limited.

Recommendations

- Residents in the area should continue to use the Happy Municipal Water System for all purposes, such as drinking, cooking, washing dishes, bathing, gardening, and recreating.
- Residents should not use water from their private residential wells that are impacted by the contaminated groundwater for indoor purposes.
- Residents are encouraged to use Texas Commission on Environmental Quality (TCEQ)[1] and the Texas Department of Licensing and Regulation (TDLR)[2] established methods to abandon their private wells and follow the Texas Well Owner Network[3] suggestions.
- Residents with lead in their drinking water above 15 μg/L should take immediate steps to eliminate or reduce their exposures by either installing lead-specific treatment or by using an alternative drinking water source.

[1] TCEQ: https://www.tceq.texas.gov/assets/public/comm_exec/pubs/rg/rg-347.pdf
[2] TDLR: https://www.tdlr.texas.gov/
[3] Texas Well Owner Network: http://twon.tamu.edu/

- EPA is encouraged to conduct a private well survey for current recreational and irrigation uses, as well as provide education to community members about the site and proper methods to abandon their private wells.
- EPA is encouraged to evaluate the potential for vapor intrusion of the carbon tetrachloride groundwater plume in the Ogallala Aquifer centered near 201 North Gordon Street.

Next Steps

- DSHS will provide a final version of this document to community members, city officials, the TCEQ, the EPA, and other interested parties.
- DSHS will provide community education regarding human health concerns in Happy, TX during community events.
- DSHS will continue to work with ATSDR, EPA, and TCEQ to evaluate additional data as they become available.

For More Information

For more information about this health consultation, contact the Texas Department of State Health Services, Environmental Surveillance and Toxicology Branch at (888) 681-0927.

Background and Statement of Issues

The Agency for Toxic Substances and Disease Registry (ATSDR) was established by Congress in 1980 under the Comprehensive Environmental Response, Compensation, and Liability Act, also known as the Superfund law. ATSDR is required by law to conduct public health assessment activities at each site proposed for or listed on the EPA National Priorities List (NPL). The Texas Department of State Health Services (DSHS) has a cooperative agreement with ATSDR to perform human health risk assessment activities for all listed NPL sites in the state of Texas. This health consultation will provide information that is needed to help protect people's health.

Site Description

DSHS evaluated the public health significance of groundwater contamination with carbon tetrachloride (CTC) at the North East 2nd Street Superfund site in Happy, Swisher County, Texas. The site (originally listed as the Attebury Grain Storage Facility) is a contaminated groundwater plume in the Ogallala Aquifer centered near 201 North Gordon Street (Figure 2)**.** In August 2009, the U.S. Environmental Protection Agency (EPA) listed the site on its NPL because of carbon tetrachloride (CTC) contamination in municipal and private residential water supplies (USEPA 2009a). It has also been determined from past investigations, that an additional and separate groundwater plume that's not part of NE 2nd Street site exists southeast of the grain storage facility. This plume is being investigated by the Texas Commission on Environmental Quality (TCEQ) Remediation Division.

Site History

CTC was first identified in one of Happy Municipal Water System wells (City Well #3) in 1991 as part of routine monitoring (TWC 1991a). Based on the CTC contamination, the Happy Municipal Water System stopped using that well, which draws water from the Ogallala Aquifer, in 1991. The city began to use water from the Dockum Aquifer, which lies beneath the Ogallala. CTC and other site-related contaminants [1,2-dibromoethane (EDB) and 1,2-dichloroethane (1,2-DCA)] have not been detected in municipal water supply wells obtaining groundwater from the Dockum Aquifer. Therefore, the Happy Municipal Water System is safe for residential uses, including drinking, and currently, all residential properties are connected to the municipal water system (Scott Downing, City Secretary, Happy, Texas 2019, personal communication). However, some residential properties that are connected to the Happy Municipal Water System still have active private residential wells that are supplied from the Ogallala Aquifer. DSHS conducted a private well survey in 2013 to determine if people used their private residential wells. DSHS found that although residents were not using private water wells for drinking, some were using the water for swimming pools and irrigation.

The presence of CTC was attributed to use of this chemical to extinguish a fire when a grain storage facility (elevator and bins) burned down in 1962. Also, CTC was commonly used as a grain fumigant before the 1970's. As a grain fumigant, CTC was used alone or mixed with other substances, EDB and 1,2-DCA (TWC 1991b).

From 2006 to 2019, the EPA and TCEQ investigated the lateral and vertical extent of groundwater contamination by collecting water samples from private residential water wells and monitoring wells. Results indicated a groundwater contamination plume approximately a half mile wide and half mile long in the shallow portions (50 to 300 feet below ground surface) of the Ogallala Aquifer (Figure 3). CTC and other site-related contaminants were detected above the EPA's drinking water standards (maximum contaminant levels – MCLs) in private residential wells located east and southeast of the facility. These wells obtain water from the Ogallala Aquifer (USEPA 2009b).

During the site investigations, TCEQ identified benzene in private residential wells at concentrations above the MCL. Based on additional well sampling, EPA and TCEQ determined the benzene contamination to be a separate groundwater plume from the CTC plume and not part of the NPL site. Possible sources of the benzene groundwater contamination include releases from gasoline service stations located along Highway 87. In 2015, the TCEQ Remediation Division, who oversees the assessment and cleanup of leaking petroleum storage tanks, was notified of the separate benzene plume. Assessment of the contaminated groundwater, as appropriate, is ongoing under that program (TCEQ 2015).

Discussion

Environmental Data Used

The EPA and TCEQ collected groundwater samples from 18 private residential wells from 2006 to 2019 and tested for 18 contaminants including volatile organic compounds (VOCs), heavy metals, and general inorganic parameters. DSHS reviewed the available environmental data, and quality assurance/quality control procedures appear adequate regarding data collection and reporting. DSHS evaluated groundwater data collected from private residential wells from 2006 until 2016 when residential properties were connected to the Happy Municipal Water System. Residential households connected to the Happy Municipal Water System at different times. While eighteen contaminants were analyzed for, not all contaminants were tested nor detected in each well consistently over the sampling events. In the case of a private residential well, GW-09, DSHS analyzed samples taken before filtration (GW-09A) and after filtration (GW-09C). In addition, DSHS evaluated CTC in a sample collected in 1991 from a public supply well (City Well #3) of the Happy Municipal Water System.

Exposure Evaluation

Chemical contamination in the environment can only harm a person's health if there is contact with (exposure to) the chemical and if the amount of the chemical the person comes into contact with is high enough to cause harm. Whether people can come into contact with a chemical depends on several factors, including:

- the source of contamination (where the chemical comes from)
- how the chemical is transported through environmental media (*e.g.,* movement through the air)
- a point of exposure (*e.g.,* outdoor air)
- a route of human exposure (*e.g.,* breathing in the outdoor air)
- an exposed population (*e.g.,* people living and working in the area with contaminated air)

Contact with a chemical will only happen if there is a completed exposure pathway. All five of these factors must be present for an exposure pathway to be completed. DSHS evaluated relevant exposure pathways to determine if any were completed based on the available data.

Exposure Pathway Analysis

DSHS identified likely site-specific exposure pathways. The following exposure pathway analysis identifies the different ways people could be or might have been exposed to the contaminants in groundwater from private residential wells in the past, present, and future.

Since 2006, residential properties with private residential wells in the area of the groundwater contamination were eventually connected to the Happy Municipal Water System. The Happy Municipal Water System is supplied by groundwater from the Dockum Aquifer and has not been impacted by the groundwater contamination (Scott Downing, City Secretary, Happy, Texas 2019, personal communication). DSHS assumes that these residents are using this municipal water for drinking and cooking, and therefore are consuming water that meets federal regulatory standards.

Completed Exposure Pathways

<u>In the past, ingestion of water and inhalation of indoor vapors while showering and other household water usage from contaminated Happy Municipal Water System or private residential well water.</u>

Happy Municipal Water System

Past ingestion of drinking water, cooking with contaminated water, and inhalation of indoor vapors from household water use, such as showering, washing hands, and using the dishwasher, from the Happy Municipal Water System represents a completed exposure pathway

(Table 1). People might have been exposed to contaminated groundwater from the Happy Municipal Water System prior to 1991. CTC was first identified in one of Happy Municipal Water System's supply wells (City Well #3) in 1991. Based on the CTC contamination, Happy Municipal Water System stopped using water from the Ogallala Aquifer in 1991 and began to only use water from the Dockum Aquifer. The Dockum Aquifer has not been impacted by the groundwater contamination and residents using water from the Happy Municipal Water System were no longer exposed to contaminated groundwater after 1991. It's unknown how long residents used contaminated water for drinking and bathing.

Private Residential Wells

Ingestion of drinking water, cooking with contaminated water, and inhalation of indoor vapors from household water use, such as showering, washing hands, and using the dishwasher, represent completed exposure pathways in the past (Table 1). Once households with private residential wells connected to the Happy Municipal Water System, they were no longer exposed to the contaminated groundwater. The timeframes when these households were connected varies from 2006 to 2016 (Scott Downing, City Secretary, Happy, Texas 2019, personal communication); therefore, some residents might have been exposed for 15 to 25 years.

Potential Exposure Pathways

Recreational use of private residential well water such as swimming in pools and playing in sprinklers

Recreational uses represent a potential exposure pathway in the past, present, and future (Table 1). VOCs and heavy metals have been detected in several private residential wells in samples collected from 2006 to 2019. Residents may have come in contact with contaminated groundwater if they used their private residential well water to fill up pools and play with sprinklers and water hoses. Children and adults could have been exposed by incidentally ingesting water and through dermal contact with the water during these recreational activities. However, exposure would likely be minimal. Inhalation of contaminants through vaporization in outdoor air is not likely since VOCs readily evaporate from water and disperse quickly in outdoor air. In addition, heavy metals do not easily volatize and are not readily absorbed through the skin.

Consumption of food crops irrigated with contaminated private residential well water

Irrigation represents a potential exposure pathway in the past, present, and future (Table 1). Heavy metals were detected in water samples collected from 2006-2019 in several private residential wells. Heavy metals are known to accumulate in food crops (Kumar 2019). Residents may have consumed food/produce that had been irrigated with contaminated groundwater from private residential wells. Produce samples have not been collected; therefore, DSHS was not able to evaluate this exposure pathway. However, heavy metal concentrations in these private residential wells are below the recommended maximum concentrations of trace elements in irrigation waters established by the U.S. Department of Agriculture (USDA 2011). In addition, rural communities are not expected to consume more than 20 percent of their grown food/produce, making the total amount ingested very small (USEPA 2018a).

Vapor intrusion from contaminants in groundwater and soil into the air of residences and commercial buildings

Because VOCs were detected in the groundwater and may be present in the shallow groundwater table, they could potentially migrate through soil in the form of vapor and enter the indoor air of homes and workplaces (ATSDR 2016b). This process is called vapor intrusion and could lead to inhalation of contaminants in indoor air (Figure 1). At this site, vapor intrusion represents a potential exposure pathway in the past, present, and future (Table 1).

Although the CTC plume is located more than 100 feet below ground surface, a distance considered to be sufficiently removed from contaminated areas, active soil gas (collected from 7-10, 47-52 and 95–100-foot intervals below ground surface) and groundwater samples from nearby monitoring wells (collected at depths ranging from 111 to 130 feet below ground surface) revealed several VOCs above ATSDR soil-gas and groundwater-to-soil gas comparison values (CVs). These VOCs included chloroform, CTC, EDB, and hexachlorobutadiene in active soil gas samples taken from seven to 10 feet below ground surface at the residence associated with private residential well GW-09 in October 2018. Additionally, chloroform, CTC, 1,2-dichloroethane, and EDB exceeded groundwater-to-soil CVs in nearby monitoring wells. These results suggest that chemical exposure through inhalation of vapors may occur. However, DSHS could not adequately assess this exposure pathway because of the insufficient number of soil-gas and groundwater samples and lack of indoor air samples collected.

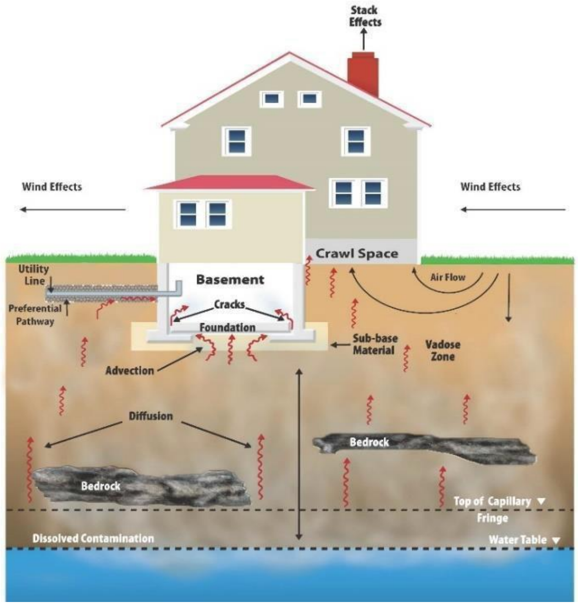

Figure 1. Vapor Intrusion Diagram (ATSDR 2016b).

Eliminated Pathways

In the present and the future, ingestion of water and inhalation of vapors while showering and other household water usage from contaminated Happy Municipal Water System or private residential well water

Happy Municipal Water System

Ingestion of drinking water, cooking with contaminated water, and inhalation of vapors from household water use are eliminated exposure pathways in the present and the future (Table 1). Residents living at properties connected to the Happy Municipal Water System were no longer exposed to contaminated groundwater after 1991.

Private Residential Wells

Ingestion of drinking water, cooking with contaminated water, and inhalation of vapors from household water use are eliminated exposure pathways in the present and the future (Table 1). While contamination currently exists in the groundwater, residential properties are connected to the Happy Municipal Water System and report using it for household purposes. If residents do not use their private residential wells, they are not being exposed to contaminated water through ingestion or inhalation through household water usage.

Table 1. Human Exposure Pathway Evaluation for the North East 2nd Street Superfund site in Happy, Texas.

Medium	Point of Exposure	Route of Exposure	Potentially Exposed Population	Timeframe & Type of Exposure Pathway
Groundwater	Nearby private residential wells (i.e., sprinklers, hoses, filling up pools)	Incidental ingestion and dermal contact	Residents with pools, sprinklers, and hoses	Past: Potential Current: Potential Future: Potential
	Produce from private gardens	Ingestion	Residents irrigating gardens with water from nearby private residential wells	Past: Potential Current: Potential Future: Potential
	Nearby private residential wells (i.e., drinking and cooking)	Ingestion	Users of nearby private well water with contamination	Past: Completed Current: Eliminated Future: Eliminated
	Nearby private residential wells for showers and household water usage in nearby homes	Inhalation of vapor and dermal contact	Users of nearby private residential well water with contamination	Past: Completed Current: Eliminated Future: Eliminated
	Happy Municipal Water System (i.e., drinking and cooking)	Ingestion	Users of nearby private wells with contamination	Past: Completed Current: Eliminated Future: Eliminated
	Happy Municipal Water System for showers and household water usage in nearby homes	Inhalation of vapor and dermal contact	Users of Happy Municipal Water System	Past: Completed Current: Eliminated Future: Eliminated
Indoor air (vapor intrusion from groundwater plume)	Homes and other occupied buildings above the groundwater plume	Inhalation	Residents (all ages) and other building occupants	Past: Potential Present: Potential Future: Potential

Chemical Screening Analysis

Out of the 18 private residential wells tested, all had some contaminants at detectable concentrations. During the screening analysis, DSHS evaluated groundwater samples from private residential wells (collected before the properties were connected to Happy Municipal Water System) by comparing the maximum concentration of each chemical from each well to health-based CVs published by the ATSDR. If a CV was not available, DSHS used either the EPA regional screening level or EPA action level (Table 2 and Appendix A). CVs are the chemical and media specific (i.e., air, water, soil) concentrations of a contaminant that are not likely to harm people's health. Therefore, we do not expect exposure to chemicals with maximum concentrations at or below CVs to cause health effects in people. Because these chemicals are not considered a health hazard, they were not further evaluated.

Results of Chemical Screening

Table 2 depicts the results of chemical screening from contaminants in private residential wells. Arsenic, cadmium, chromium, and zinc were the heavy metals that exceeded their respective CVs. Benzene, bromodichloromethane, bromoform, CTC, dibromochloromethane, EDB, and 1,2-DCA were the VOCs that exceeded their CVs. Fluoride and nitrate are naturally occurring inorganic compounds that exceeded their EPA regional screening level and CV, respectively. Additionally, CTC exceeded its CV in a public supply well for the Happy Municipal Water System.

Lead was detected in three private residential wells. Lead does not have a CV or a regional screening level. Therefore, DSHS compared the lead levels to EPA's action level (15 μg/L) for lead in municipal water systems. Instead of an MCL, EPA regulates lead using a treatment technique that requires systems to control the corrosiveness of their water. If more than 10 percent of tap water samples exceed the lead action level, municipal water systems must take additional steps to reduce levels (EPA 2008). Because lead was detected above the EPA action level in one well (GW-01), it was further evaluated.

Table 2. Maximum concentration of a contaminant detected above its comparison value in private groundwater wells (GW) and a public supply (PW) near the North East 2nd Street Superfund site in Happy, Texas.

	Contaminant	Comparison Value (CV) or EPA screening or action level	Maximum Concentration Detected (mg/L)	ID of Wells with Maximum Concentration Greater than CV or EPA screening or action level*
Metals	Arsenic	0.016 (CREG)	5.87	GW-01, GW-04, GW-09A, GW-09C, GW-10, GW-11, GW-12, GW-13, GW-15, GW-16, GW-17, GW-19, GW-21, GW-22, GW-23, GW-36, GW-41, GW-50
	Cadmium	0.70 (Chronic EMEG child)	7.54	GW-01
	Chromium (VI)**	0.024 (CREG)	9.1	GW-01, GW-04, GW-09A, GW-11, GW-12, GW-13, GW-15, GW-16, GW-17, GW-19, GW-22, GW-23, GW-36
	Lead	15 (EPA action level)***	49.7	GW-01
	Zinc	2,100 (Chronic EMEG child)	6,350	GW-01
Volatile Organic Compounds	Benzene	0.44 (CREG)	67.75	GW-17, GW-22, GW-23, GW-36
	Bromodichloromethane	0.39 (CREG)	1.48	GW-21, GW-39
	Bromoform	0.31 (CREG)	16	GW-21, GW-22, GW-39

	Contaminant	Comparison Value (CV) or EPA screening or action level	Maximum Concentration Detected (mg/L)	ID of Wells with Maximum Concentration Greater than CV or EPA screening or action level*
	Carbon tetrachloride****	0.35 (CREG)	50.62	GW-09A, GW-09C, GW-10, GW-11, GW-12, GW-13, GW-17, GW-19, GW-21, GW-22, GW-23, GW-36, PW: City Well #3
	Dibromochloromethane	0.39 (CREG)	7	GW-21, GW-22, GW-39,
	1,2-Dibromoethane	0.012 (CREG)	0.32	GW-09A, GW-22
	1,2-Dichloroethane	0.27 (CREG)	24.45	GW-09A, GW-09C, GW-10, GW-12, GW-17, GW-22, GW-23, GW-36, GW-51
General Inorganic Parameters	Fluoride	800 (RSL)***	1,970	GW-09C, GW-10, GW-15, GW-21, GW-22, GW-23, GW-41, GW-50
	Nitrate	11,000 (RMEG child)	18,900	GW-09C

* Maximum results for each well listed are provided in Appendix A, Table A1.
** Chromium was compared to CVs for hexavalent chromium.
***EPA regional screening level (RSL) or action level was used in absence of a CV.
****Carbon tetrachloride was detected in Happy Municipal Water System City Well #3 in one sample collected in 1991.
CREG = Cancer Risk Evaluation Guide
RMEG = Reference Dose Media Evaluation Guide
mg/L = milligrams per liter; GW=private residential groundwater well; PW=public water well (Happy Municipal Water System City Well #3).

Several metals were detected in private residential wells. It is likely that these metals are naturally occurring. Table 3 compares these concentrations to average concentrations in the Ogallala Aquifer (TWDB 2016). These concentrations appear to be similar, however; additional evaluation needs to be conducted to determine if this difference is significant. EPA has determined that metals are not part of the site investigation (USEPA 2019a). Arsenic, cadmium, chromium, and fluoride exceed

CVs or EPA regional screening or action levels (Table A1). Because exposure to metals can be harmful, they were further evaluated.

Table 3. Average contaminant concentrations in groundwater from the Ogallala aquifer and private residential wells near the North East 2nd Street Superfund site in Happy, Texas.

Contaminant	Concentrations in Ogallala Aquifer*	Concentrations in Private Residential Wells**
Arsenic	5.9	3.8
Cadmium	1.1	0.1
Chromium (total)	2.3	5.8
Fluoride	2,797.6	1,474.6
Zinc	42.2	52.8

All concentrations are in micrograms per liter (µg/L).
*sampling occurred from 2000-2016; **sampling occurred from 2006-2019

Health Effects Evaluation

The selected contaminants of concern shown in Table 2 were further evaluated by calculating exposure point concentrations (EPCs) and exposure doses based on site-specific exposure conditions. An EPC is an estimate of the concentration of a contaminant at the point of human exposure and was determined for each contaminant in each well. The maximum concentration was used as the EPC if less than eight samples were collected or more than four sample results had concentrations below the method detection limit (MDL). The 95 percent Upper Confidence Limit (95% UCL) of the mean was used as the EPC if eight or more samples were collected and more than four sample results were detected above the MDL. DSHS calculated the 95% UCL using EPA's ProUCL software.

An exposure dose is an estimate of the contaminant amount that gets into a person's body over a specific period. To evaluate residents' past exposures to the contaminants of concern in drinking water, DSHS calculated exposure doses and estimated noncancer and cancer risks. No site-specific exposure information was available, so DSHS calculated the exposure doses using health protective exposure assumptions for two exposure scenarios, including a typical or central tendency exposure (CTE) and a high or reasonable maximum exposure (RME) as recommended by ATSDR (Appendix B). The RME is referring to individuals who are at the upper end of the exposure distribution (about the 95 percent). The RME assesses exposures that are higher than average but still within a realistic exposure range. In this case, this would refer to individuals who have a very high-water consumption rate. The CTE is referring to individuals who have an average or typical water consumption rate. The equations to calculate exposure doses and exposure assumptions are in Appendix B.

For noncancer health effects, the calculated total exposure doses were compared to health guidelines, such as ATSDR's minimum risk level (MRL) and EPA's reference dose (RfD), to determine if there is a concern for noncancer health effects. To facilitate this comparison, the estimated dose from drinking well water was divided by the health-based guideline to calculate a hazard quotient (HQ). HQs greater than one required further evaluation because the health-based guideline for that contaminant has been exceeded, while HQs less than one are no longer evaluated. MRLs and RfDs are based on animal laboratory or human studies that document no observed or lowest observed adverse effects levels (NOAELs or LOAELs). If an estimated total exposure dose is below the MRL or RfD, adverse noncancer health effects are not expected to occur. If an estimated dose is higher than the MRL or RfD, it does not necessarily mean the exposure will harm people's health; it means that an in-depth evaluation is needed to determine if noncancer health effects are likely. This is done by comparing the dose to known noncancer health effect levels found in the scientific literature.

For cancer health effects associated with exposure to VOCs, DSHS calculated cancer risk by exposure pathway and total cancer risk by adding exposure doses and then multiplying by the oral cancer slope factor (CSF). The calculated ingestion and dermal exposure dose were each multiplied by the oral CSF to calculate ingestion and dermal cancer risk, respectively. Using ATSDR's SHOWER model (ATSDR 2018), the calculated inhalation exposure level was multiplied by the inhalation unit risk (IUR), if available, to calculate inhalation cancer risk (Appendix B). Because metals do not volatilize from shower water, the total cancer risk for metals was determined by multiplying the ingestion exposure dose from drinking water by the oral CSF.

The calculated cancer risk is an excess lifetime cancer risk, which estimates the proportion of a population that may be affected by a carcinogen during an exposure lasting a lifetime (365 days/year for 78 years) (Appendix B). An excess lifetime cancer risk represents the additional risk above the existing background cancer risk. For example, an estimated cancer risk of one per million (or 1E-06) potentially represents one excess cancer case in a population of one million people over a lifetime of continuous exposure. Exposure to contaminants with a potential cancer risk of more than one in 10,000 (or 1E-04) were further evaluated. DSHS considers estimated cancer risk of one in 10,000 or greater to be an increased lifetime risk of developing cancer. In the United States, the background cancer risk (or the probability of developing cancer at some point during a person's lifetime) is about 2 in 5 for both men and women (ACS 2019). Note, the cancer risk estimates in this document are not a measure of the actual cancer cases in a community; rather, they are a tool used by DSHS for making public health recommendations to stop or reduce exposure to cancer-causing chemicals.

Noncancer Health Effects

The calculated HQs for benzene, CTC, cadmium, and fluoride exceeded one, which means the estimated dose or concentration exceeded the noncancer health guideline for that chemical or element. These chemicals were further evaluated for noncancer health effects. The water concentration of chemicals in private and municipal wells are reported in Tables 2 and A1.

Benzene

The health-based guideline used for benzene is the chronic oral MRL of 0.0005 mg/kg/day. This guideline was exceeded in wells GW-17, GW-23, and GW-36 (Table 4), thus requiring further evaluation to determine if residents are at risk of harmful effects. The highest estimated total exposure doses (ingestion RME, inhalation and dermal contact) from drinking and showering in water is 0.031 mg/kg/day for children and 0.0064 mg/kg/day for adults. These doses are above the MRL of 0.005 mg/kg/day.

The MRL for benzene is based on an occupational inhalation study where workers experienced long-term exposure to low levels of benzene in air (Lan 2004). To derive the chronic oral MRL, the workers' inhalation exposure was converted to an equivalent oral dose. Using benchmark dose modeling, ATSDR determined that hematological (blood) effects might occur at a benchmark dose (BMDL)[4] of 0.014 mg/kg/day in some workers. Hematological effects included decreases in B lymphocytes, platelets, and other leucocytes, such as granulocytes and monocytes, in the circulating blood. ATSDR then divided the BMDL of 0.014 mg/kg/day by an uncertainty factor of 30 to account for human variability and uncertainty in route-to-route extrapolation to derive the chronic oral MRL.

The estimated total exposures for children and adults consuming water from wells GW-17, GW-23, and GW-36 approach or exceed 0.014 mg/kg/day. Residents who

[4] The benchmark dose (BMDL) is usually defined as the lower confidence limit on the dose that produced a specific magnitude of change in a specified adverse response.

were exposed to benzene for long periods may experience harmful effects in the tissues that form blood cells, especially the bone marrow.

Carbon tetrachloride

The health-based guideline used for CTC is EPA's RfD of 0.004 mg/kg/day. This guideline was only exceeded in one private residential well, GW-09, in a sample collected in 2006 (Table 4). Because no other sampling data were available, DSHS assumed that residents drinking water from GW-09 were exposed to CTC at this level over many years. The highest estimated total exposure doses (ingestion RME, inhalation and dermal contact) from drinking and showering in water is 0.02 mg/kg/day for children and 0.0048 mg/kg/day for adults. The estimated total exposure doses are above EPA's RfD of 0.004 mg/kg/day.

The RfD for CTC is based on a study that examined liver toxicity in rats after sub-chronic (12 weeks) oral exposure to CTC. Liver toxicity was identified by the development of liver lesions and elevated liver enzymes, particularly sorbitol dehydrogenase (SDH). The study determined that no adverse effects were observed at 1 mg/kg/day and adverse effects were observed at the lowest level of 10 mg/kg/day. EPA used a BMDL based on increased SDH activity following CTC exposure as the point of departure for the derivation of the RfD. EPA further refined the BMDL to have 95 percent confidence that the dose corresponds to an increase in SDH activity that is twice the average for rats not exposed to CTC and to adjust the value to represent a continuous daily dose ($BMDL_{2X\text{-}ADJ}$). The calculated $BMDL_{2X\text{-}ADJ}$ of 3.9 mg/kg/day was then divided by an uncertainty factor of 1,000 to account for differences between and within species, estimation from sub-chronic to chronic exposure, and study deficiencies to obtain the RfD of 0.004 mg/kg/day (USEPA 2010a).

The estimated exposures for children and adults consuming water from GW-09 are 195 and 975 times lower, respectively, than the $BMDL_{2X\text{-}ADJ}$ of 3.9 mg/kg/day. Based on this comparison, it is unlikely that children and adults would experience noncancer health effects from showering and drinking water from this private well. Additionally, a filtration system was installed at the GW-09 residence in 2007. This further reduced exposure to CTC and other contaminants from groundwater.

Cadmium

The health-based guideline used for cadmium was ATSDR's MRL of 0.0001 mg/kg/day. This guideline was only exceeded in one well, GW-01, in a sample collected in 2006 (Table A2). Because no other sampling data were available, DSHS assumed that residents drinking water from GW-01 were exposed to cadmium at this level over many years. Residents will not have an inhalation exposure while bathing or showering because cadmium does not evaporate to indoor air. Also, cadmium absorption through the skin is minimal compared to drinking the water. The highest estimated ingestion RME doses from drinking well water was 0.0011 mg/kg/day for children and 0.0003 mg/kg/day for adults. The estimated exposure doses exceed the MRL.

ATSDR derived an MRL of 0.0001 mg/kg/day based on a database that examines the relationship between urinary cadmium levels and adverse health effects, including skeletal defects, kidney dysfunctions and hormonal changes (ATSDR 2012). A urinary cadmium level corresponding to a probability of 10 percent excess risk of kidney effects, such as tubular proteinuria, was determined. The MRL is based on the lower confidence limit of the calculated urinary cadmium level ($UCDL_{10}$) of 0.00033 mg/kg/day. For the detected cadmium concentration in one private water well (GW-01), the calculated exposure doses for children (0.0011 mg/kg/day) and adults (0.0003 mg/kg/day) exceeded the $UCDL_{10}$ used to derive the MRL. Therefore, residents of this household who drink water from GW-01 with cadmium at this level for long periods of time could experience early signs of kidney damage (tubular proteinuria). However, there is uncertainty to this conclusion. It is based on the results of one sample collected from one private well and assumes long-term exposure to cadmium at this level for several decades.

Cadmium occurs naturally in the Ogallala Aquifer. Sampling results from the Ogallala Aquifer in Swisher County collected during 2000 to 2016 show concentrations of cadmium (from 0.65 µg/L to 11 µg/L, with an average concentration of 1.1 µg/L) similar to what was detected in the private residential well GW-01 (maximum concentration of 7.54 µg/L) (Table 3). Based on these results, the cadmium concentrations in this private well during the site investigation are representative of naturally occurring levels.

Fluoride

The health-based guideline used for fluoride was ATSDR's MRL of 0.05 mg/kg/day. This guideline was exceeded in several wells (GW-09C, GW-10, GW-15, GW-21, GW-22, GW-23, GW-41, and GW-50) (Table A2). However, only one sample was collected from each well (Table A1). Because no other sampling data was available, DSHS assumed that residents drinking water from these wells were exposed to fluoride at this level over many years. Residents will not have an inhalation exposure while bathing or showering because fluoride does not evaporate to indoor air. Also, fluoride absorption through the skin is minimal compared to drinking the water. The highest estimated ingestion RME dose from drinking well water is 0.28 mg/kg/day for children and 0.076 mg/kg/day for adults. These doses exceed the MRL of 0.05 mg/kg/day.

The MRL is based on a NOAEL of 0.15 mg/kg/day (3.56 ppm) to protect against increased rates of bone fractures in older adults (ATSDR 2003). The MRL was calculated by dividing the NOAEL by an uncertainty factor of 3 to account for human variability. The estimated ingestion doses for adults from drinking water are well below levels that cause harmful effects. Therefore, harmful effects in residents of these households are unlikely.

The MRL is based on increased rates of bone fractures in older adults and may not be applicable to children. Therefore, the estimated highest exposure dose for children was compared to EPA's RfD of 0.06 mg/kg/day. The RfD is set to protect children against dental fluorosis (discoloration of the tooth enamel) (USEPA 2010b). The RfD is based on a NOAEL of 0.06 mg/kg/day (1 ppm or 1000 µg/L) in drinking water for young adults. The highest estimated exposure dose (0.28 mg/kg/day) for children exceeds the RfD. In addition, the detected fluoride concentrations in private residential wells approach EPA's secondary MCL of 2,000 µg/L, which was established to protect against moderate dental fluorosis in young children (USEPA 2021).

When used appropriately, fluoride is effective in preventing and controlling dental caries. However, drinking or eating excessive fluoride during the time teeth are being formed can cause fluorosis. The changes increase in severity with increasing levels of fluoride. In general, studies show some children who drink water with 1,000 µg/L fluoride may get a few small spots or slight discolorations on their teeth. While other children who drink water with 4,000 µg/L fluoride in it for long periods before their permanent teeth are in place may develop a more severe form of dental fluorosis (ATSDR 2003). The maximum fluoride level detected in residential private wells at the site was 1,970 µg/L. Based on this evaluation, children drinking water from residential private water wells over long periods may be at increased risk of developing mild dental fluorosis.

Fluoride occurs naturally in the Ogallala Aquifer. Sampling results from the Ogallala Aquifer in Swisher County collected during 2000 to 2016 show concentrations of fluoride (from 960 µg/L to 4,820 µg/L, with an average concentration of 2,797 µg/L) similar to what was detected in the private residential wells at the site (maximum concentration of 1,970 µg/L) (Table 3) (TWDB 2016). Based on these results the fluoride concentrations in these private wells during the site investigation are representative of naturally occurring levels.

Lead

Lead was detected in private residential water well GW-01 at 49.7 µg/L. This level exceeds the EPA action level of 15 µg/L. The source of lead in the water sample could have come from lead in groundwater or from internal corrosion of the resident's piping and plumbing system (ATSDR 2020).

Health effects associated with lead exposure mainly include neurological effects such as decreased cognitive function including attention and memory and weakness in fingers, wrists, or ankles in both children and adults (ATSDR 2020). Lead exposure can cause anemia and damage to the kidneys and increase blood pressure, particularly in older people. Children are more vulnerable to lead exposure than adults because their nervous system is still developing. At lower levels of exposure, lead can decrease mental development, especially learning, intelligence and behavior (ATSDR 2020). Because there is no known safe level of lead in the blood, DSHS recommends reducing lead exposure wherever possible.

Table 4. Total exposure doses and hazard quotients from ingestion, inhalation, and dermal contact with contaminated groundwater (carbon tetrachloride or benzene) from private residential wells near the North East 2nd Street Superfund site in Happy, Texas.

Well ID and Contamin-ant	Exposure Group	EPC Value (µg/L) and Type	Ingestion Dose CTE (mg/kg/day)	Ingestion Dose RME (mg/kg/day)	Average Daily Inhalation Dose from Showering* (mg/kg/day)	Average Daily Dermal Dose from Showering*(mg/kg/day)	Total CTE dose from ingestion, inhalation, and dermal	CTE HQ**	Total RME dose from ingestion, inhalation, and dermal	RME** HQ
GW-09A Carbon Tetrachloride	Birth to < 1 year	50.62 (Max.)	3.3E-03	0.0072	-	-	0.0033	0.8	0.0072	2
	1 to < 2 years		1.4E-03	0.0040	0.017	0.00035	0.019	5	0.021	5
	2 to < 6 years		1.1E-03	0.0028	0.011	0.00030	0.012	3	0.014	4
	6 to < 11 years		8.1E-04	0.0022	0.0062	0.00030	0.0070	2	0.0087	4
	11 to < 16 years		5.7E-04	0.0018	0.0038	0.00020	0.0046	1	0.0058	2
	16 to < 21 years		5.4E-04	0.0017	0.0030	0.00020	0.0037	0.9	0.0049	1
	Adult		7.8E-04	0.0020	0.0026	0.00020	0.0036	0.9	0.0048	1
	Pregnant Women		6.0E-04	0.0018	0.0039	0.00020	0.0047	1	0.0059	2
	Lactating Women		1.2E-03	0.0025	0.0039	0.00020	0.0053	1	0.0066	2
GW-17 Benzene	Birth to < 1 year	57.75 (Max.)	0.0037	0.0082	-	-	0.0037	7	0.0082	16
	1 to < 2 years		0.0016	0.0045	0.021	0.00022	0.023	46	0.026	51
	2 to < 6 years		0.0012	0.0032	0.013	0.00019	0.014	29	0.016	33
	6 to < 11 years		0.00093	0.0025	0.0067	0.00020	0.0078	16	0.0094	19

Well ID and Contamin-ant	Exposure Group	EPC Value (µg/L) and Type	Ingestion Dose CTE (mg/kg/ day)	Ingestion Dose RME (mg/kg/ day)	Average Daily Inhalation Dose from Showering* (mg/kg/day)	Average Daily Dermal Dose from Showering*(mg/kg/day)	Total CTE dose from ingestion, inhalation, and dermal	CTE HQ**	Total RME dose from ingestion, inhalation, and dermal	RME** HQ
	11 to < 16 years		0.00065	0.0020	0.0046	0.00010	0.0054	11	0.0067	13
	16 to < 21 years		0.00062	0.0020	0.0036	0.00010	0.0043	9	0.0057	11
	Adult		0.00089	0.0022	0.0032	0.00010	0.0042	8	0.0055	11
	Pregnant Women		0.00069	0.0020	0.0047	0.00010	0.0055	11	0.0068	14
	Lactating Women		0.0013	0.0028	0.0047	0.00010	0.0061	12	0.0076	15
GW-23 Benzene	Birth to < 1 year	15.15 (95% UCL)	9.8E-04	0.0022	-	-	0.0010	2	0.0022	4
	1 to < 2 years		4.1E-04	0.0012	0.0055	0.000057	0.0060	12	0.0068	14
	2 to < 6 years		3.3E-04	0.00090	0.0035	0.000049	0.0039	8	0.0044	9
	6 to < 11 years		2.4E-04	0.00070	0.0018	0.0000	0.0021	4	0.0025	5
	11 to < 16 years		1.7E-04	0.00050	0.0012	0.0000	0.0014	3	0.0018	4
	16 to < 21 years		1.6E-04	0.00050	0.0010	0.0000	0.0011	2	0.0015	3
	Adult		2.3E-04	0.00060	0.0008	0.0000	0.0011	2	0.0014	3
	Pregnant Women		1.8E-04	0.00050	0.0012	0.0000	0.0014	3	0.0018	4
	Lactating Women		3.5E-04	0.00070	0.0012	0.0000	0.0016	3	0.0020	4
GW-36 Benzene	Birth to < 1 year	67.75 (Max.)	4.4E-03	0.0097	-	-	0.0044	9	0.0097	19

Well ID and Contamin-ant	Exposure Group	EPC Value (µg/L) and Type	Ingestion Dose CTE (mg/kg/ day)	Ingestion Dose RME (mg/kg/ day)	Average Daily Inhalation Dose from Showering* (mg/kg/day)	Average Daily Dermal Dose from Showering*(mg/kg/day)	Total CTE dose from ingestion, inhalation, and dermal	CTE HQ**	Total RME dose from ingestion, inhalation, and dermal	RME** HQ
	1 to < 2 years		1.8E-03	0.0053	0.025	0.00026	0.027	54	0.031	61
	2 to < 6 years		1.5E-03	0.0038	0.016	0.00022	0.018	35	0.020	40
	6 to < 11 years		1.1E-03	0.0030	0.0079	0.00020	0.0092	18	0.011	22
	11 to < 16 years		7.6E-04	0.0024	0.0054	0.00020	0.0063	13	0.0080	16
	16 to < 21 years		7.3E-04	0.0023	0.0042	0.00010	0.0051	10	0.0066	13
	Adult		1.0E-03	0.0026	0.0037	0.00010	0.0048	10	0.0064	13
	Pregnant Women		8.1E-04	0.0024	0.0055	0.00010	0.0065	13	0.0080	16
	Lactating Women		1.5E-03	0.0033	0.0055	0.00010	0.0071	14	0.0089	18

EPC = Exposure Point Concentration
µg/L = micrograms chemical per liter water
mg/kg/day = milligram chemical per kilogram body weight per day
CTE = Central Tendency Exposure (average)
RME = Reasonable Maximum Exposure
HQ = Hazard Quotient
MRL = Minimal Risk Level
RfC = Reference Dose Concentration
VOCs = volatile organic compounds.
*Based on 4-person household using the ATSDR SHOWER model
**CTE HQ=total central tendency exposure dose per chronic oral minimal risk level of reference dose concentration. RME HQ=total reasonable maximum exposure dose per chronic oral minimal risk level or reference dose concentration

Cancer Health Effects

DSHS estimated cancer risk for exposure to cancer-causing contaminants detected in groundwater from residential private wells. Cancer risk for VOCs is based on drinking water and inhalation and dermal exposure while showering and bathing. While cancer risk for metals is based only on exposure from drinking water. The cancer risk from exposure to the maximum concentration of VOCs (bromodichloromethane, bromoform, dichromochloromethane, and EDB) was one in 100,000 or less for both adults and children (Table 5). DSHS interprets this to be a low to no increased lifetime risk of developing cancer. The cancer risk for arsenic, benzene, CTC, hexavalent chromium and 1,2-DCA was more than one in 10,000. These contaminants were further evaluated (Table 5).

Arsenic

Arsenic is classified as a human carcinogen. This classification is based on animal and human studies that indicate an increased risk for developing cancers of the skin, lung, bladder, kidney, and prostate from consuming arsenic-containing water at high levels and for long periods of time (ATSDR 2007a).

Based on drinking the water and using the maximum concentration, DSHS estimated a moderate cancer risk (one in 10,000) in private residential wells GW-01, GW-13, GW-15, GW-16, GW-19, GW-22, GW-23, GW-41, and GW-50 (Table 5). However, the maximum concentration of arsenic in each of these wells was below EPA’s MCL of 10 µg/L. Therefore, people that consumed water with these concentrations of arsenic would not have been exposed to more of the contaminant than the general population that consumes water from public water systems in the United States.

Arsenic occurs naturally in the Ogallala Aquifer. Sampling results from the Ogallala Aquifer in Swisher County collected during 2000 to 2016 show concentrations of arsenic (from 2.0 µg/L to 14.7 µg/L, with an average concentration of 5.9 µg/L) similar to what was detected in the private residential wells at the site (maximum concentration of 5.87 µg/L) (TWDB 2016). Based on these results, the arsenic concentrations in private wells during the site investigation are representative of naturally occurring levels.

Benzene

Benzene is classified as a human carcinogen. This classification is based on animal and human studies that indicate an increased risk for developing leukemia from inhalation of benzene (ATSDR 2007b). Combining the cancer risk from drinking and bathing in household water, DSHS estimated the total cancer risk using the maximum concentration of benzene in household water in two private residential wells, GW-17 and GW-36 (Tables 4 and 5). DSHS estimated that past exposure to groundwater from each of these wells would result in up to nine additional cancer cases in a population of 100,000 exposed persons for children and one additional cancer case in a population of 10,000 exposed persons for adults. DSHS interpreted this as a low increased and increased lifetime risk for developing cancer from past exposures for children and adults, respectively. Considerable uncertainty exists in this conclusion, however, because the estimated cancer risk is based on the results of one sample collected from each well and assumes long-term exposure to benzene at this level over decades.

Carbon tetrachloride

CTC is classified by EPA as a probable human carcinogen. This is based on animal studies that show development of liver tumors following long-term CTC exposure. Studies in humans have not been able to determine whether CTC can cause cancer because of exposure to other chemicals at the same time (ATSDR 2005a).

DSHS estimated cancer risk from exposure to CTC from several private residential wells (Table 5). The total cancer risk from private well GW-09A for children and adults was determined to be seven additional cancer cases in a population of 100,000 and one additional cancer case in a population of 10,000, respectively. DSHS considers this to be a low increased and an increased risk of developing cancer over a lifetime for children and adults, respectively. However, water samples from GW-09A were collected prior to chemicals being removed from the water through filtration. The risk of developing cancer for adults and children from exposure to CTC in water collected from GW-09 after filtration was low (below one in 100,000). Additionally, cancer risk from all the other wells (GW-10, GW-11, GW-12, GW-13, GW-17, GW-19, GW-21, GW-22, GW-23, GW-36) was low (below one in 100,000).

DSHS also estimated the cancer risk for past exposure (prior to 1991) of CTC in the Happy Municipal Water System. DSHS estimated that the excess cancer risk for children is two in a population of 100,000 (Table 5). For adults, DSHS estimated the excess cancer risk to be three in a population of 100,000. DSHS interprets this to be a low increased lifetime risk of developing cancer among both children and adults. However, this conclusion is based on the results of one sample collected from one municipal well and assumes long-term exposure to CTC at this level. In addition, around 1991 City Well #3 contributed only 2 percent of the water to the distribution system of the Happy Municipal Water System and served approximately 12 people (USEPA 2009b).

Chromium

Hexavalent chromium has been classified by the National Toxicology Program (NTP) as a known human carcinogen based on human occupational studies where workers exposed by inhalation developed lung cancer. The NTP also reported that sodium dichromate dihydrate, a compound containing hexavalent chromium, was associated with an increase in oral and stomach tumors in laboratory animals following ingestion (NTP 2008). The California Environmental Protection Agency (CalEPA) derived a cancer slope factor of 0.5 $(mg/kg/day)^{-1}$ based on NTP's study. DSHS calculated the total cancer risk using CalEPA oral cancer slope factor of 0.5 $(mg/kg/day)^{-1}$, which considers hexavalent chromium to be a mutagen.

The final release of EPA's Integrated Risk Information System (IRIS) reassessment of the carcinogenic effects of hexavalent chromium through oral ingestion is pending. EPA is evaluating the carcinogenic mode of action of hexavalent chromium. Some scientists hypothesize that ingestion of high concentrations of hexavalent chromium results in hyperplasia of the intestine from excessive oxidative stress, which exceeds the intestine's capacity to reduce hexavalent chromium. Health Canada states that this points to the occurrence of a threshold for hexavalent chromium carcinogenesis (Health Canada 2018). It's uncertain whether EPA will adopt this hypothesis in their reevaluation. Upon completion of the IRIS reassessment, EPA will determine whether the MCL for total chromium needs to be revised (USEPA 2019b).

In absence of site-specific information, DSHS assumed that all chromium detected in well water is hexavalent chromium, the most toxic form of the metal. DSHS estimated cancer risks for the RME exposure scenario (Table 5). Based on the maximum concentration, DSHS estimated cancer risk for children to be one to three additional cases of cancer in a population of 10,000 from exposure to chromium in each well, including GW-04, GW-09A, GW-12, GW-13, GW-15, GW-16, GW-17, GW-19, GW-22, GW-23, and GW-36 (Table 5). DSHS interprets this as an increased lifetime cancer risk for children. However, this result is based on one sample collected from each well and assumes long-term exposure to hexavalent chromium at this level.

1,2-Dichloroethane (1,2-DCA)

EPA has determined that 1,2-DCA is a probable human carcinogen. This is based on animal studies that show development of stomach, mammary gland, liver, lung, and endometrium cancers following long-term exposure (ATSDR 2001). Studies in humans have not been able to determine whether 1,2-DCA can cause cancer (ATSDR 2001).

DSHS estimated cancer risk from exposure to the highest levels of 1,2-DCA detected in one private residential well, GW-36 (Table 5). The total cancer risk from GW-36 for children and adults was determined to be eight additional cancer cases in a population of 100,000 and one additional cancer case in a population of 10,000, respectively. DSHS considers this to be a low increased and an increased risk of developing cancer over a lifetime for children and adults, respectively. However, this result is based on one sample and assumes long-term exposure to 1,2-DCA at this level. The risk of developing cancer for children and adults from exposure to 1,2-DCA in water collected from each of all the other wells (GW-09C, GW-10, GW-12, GW-17, GW-22, GW-23, and GW-51) was low (below eight in 100,000).

Table 5. Excess cancer risk for residents exposed to contaminants in drinking water from residential private wells and water from the Happy Municipal Water System via reasonable maximum ingestion exposure and central tendency dermal contact and inhalation exposures while showering.

Well ID	Contaminant (concentration µg/L)	Exposure Group	Ingestion Cancer Risk RME (unitless)	Inhalation Cancer Risk (unitless)	Dermal Cancer Risk (unitless)	Total Cancer Risk (unitless)
PW	Carbon tetrachloride (14)	Combined child	1E-05	6E-06	1E-06	2E-05
	Carbon tetrachloride (14)	Adult	2E-05	9E-06	1E-06	3E-05
GW-01	Arsenic (4.55)	Combined child	9E-05	-	-	-
	Arsenic (4.55)	Adult	**1E-04**	-	-	-
	Chromium (VI) (1.13)	Combined child	3E-05	-	-	-
	Chromium (VI) (1.13)	Adult	9E-06	-	-	-
GW-04	Arsenic (3.1)	Combined child	6E-05	-	-	-
	Arsenic (3.1)	Adult	8E-05	-	-	-
	Chromium (VI) (5.28)	Combined child	**1E-04**	-	-	-
	Chromium (VI) (5.28)	Adult	4E-05	-	-	-
GW-09A	Arsenic (2.98)	Combined child	6E-05	-	-	-
	Arsenic (2.98)	Adult	8E-05	-	-	-

Well ID	Contaminant (concentration µg/L)	Exposure Group	Ingestion Cancer Risk RME (unitless)	Inhalation Cancer Risk (unitless)	Dermal Cancer Risk (unitless)	Total Cancer Risk (unitless)
	Carbon tetrachloride (50.62)	Combined child	5E-05	2E-05	4E-06	7E-05
	Carbon tetrachloride (50.62)	Adult	6E-05	3E-05	5E-06	**1E-04**
	Chromium (VI) (4.96)	Combined child	**1E-04**	-	-	-
	Chromium (VI) (4.96)	Adult	4E-05	-	-	-
	1,2-Dibromoethane (0.32)	Combined child	8E-06	1E-05	2E-07	2E-05
	1,2-Dibromoethane (0.32)	Adult	1E-05	2E-05	2E-07	3E-05
	1,2-Dichloroethane (2.1)	Combined child	3E-06	4E-06	4E-08	7E-06
	1,2-Dichloroethane (2.1)	Adult	3E-06	6E-06	5E-08	9E-06
GW-09C	Arsenic (2.89)	Combined child	6E-05	-	-	-
	Arsenic (2.89)	Adult	7E-05	-	-	-
	Carbon tetrachloride (15.25)	Combined child	4E-05	6E-06	1E-06	5E-05
	Carbon tetrachloride (15.25)	Adult	2E-05	1E-05	2E-06	3E-05
	1,2-Dichloroethane (1.59)	Combined child	2E-06	3E-06	3E-08	5E-06
	1,2-Dichloroethane (1.59)	Adult	2E-06	5E-06	4E-08	7E-06
GW-10	Arsenic (3.23)	Combined child	6E-05	-	-	-
	Arsenic (3.23)	Adult	8E-05	-	-	-
	Carbon tetrachloride (3.64)	Combined child	2E-06	2E-06	1E-07	4E-06
	Carbon tetrachloride (3.64)	Adult	2E-06	2E-06	2E-07	4E-06
	1,2-Dibromoethane (0.01)	Combined child	3E-07	4E-07	5E-09	7E-07
	1,2-Dibromoethane (0.01)	Adult	3E-07	7E-07	6E-09	1E-06
	1,2-Dichloroethane (2.29)	Combined child	3E-06	4E-06	4E-08	7E-06
	1,2-Dichloroethane (2.29)	Adult	3E-06	7E-06	5E-08	1E-05
GW-11	Arsenic (3.98)	Combined child	8E-05	-	-	-

Well ID	Contaminant (concentration µg/L)	Exposure Group	Ingestion Cancer Risk RME (unitless)	Inhalation Cancer Risk (unitless)	Dermal Cancer Risk (unitless)	Total Cancer Risk (unitless)
	Arsenic (3.98)	Adult	**1E-04**	-	-	-
	Carbon tetrachloride (1.57)	Combined child	1E-06	6E-07	1E-07	2E-06
	Carbon tetrachloride (1.57)	Adult	2E-06	1E-06	2E-07	3E-06
GW-12	Arsenic (2.93)	Combined child	6E-05	-	-	-
	Arsenic (2.93)	Adult	7E-05	-	-	-
	Carbon tetrachloride (1.29)	Combined child	1E-06	5E-07	1E-07	2E-06
	Carbon tetrachloride (1.29)	Adult	2E-06	8E-07	1E-07	3E-06
	Chromium (VI) (6.25)	Combined child	**2E-04**	-	-	-
	Chromium (VI) (6.25)	Adult	5E-05	-	-	-
	1,2-Dichloroethane (0.45)	Combined child	5E-07	8E-07	9E-09	1E-06
	1,2-Dichloroethane (0.45)	Adult	7E-07	1E-06	1E-08	2E-06
GW-13	Arsenic (4.06)	Combined child	8E-05	-	-	-
	Arsenic (4.06)	Adult	**1E-04**	-	-	-
	Carbon tetrachloride (0.63)	Combined child	6E-07	3E-07	5E-08	1E-06
	Carbon tetrachloride (0.63)	Adult	7E-07	4E-07	7E-08	2E-06
	Chromium (VI) (5.37)	Combined child	**2E-04**	-	-	-
	Chromium (VI) (5.37)	Adult	4E-05	-	-	-
GW-15	Arsenic (5.87)	Combined child	**1E-04**	-	-	-
	Arsenic (5.87)	Adult	**2E-04**	-	-	-
	Chromium (VI) (5.61)	Combined child	**2E-04**	-	-	-
	Chromium (VI) (5.61)	Adult	5E-05			
GW-16	Arsenic (5.24)	Combined child	**1E-04**	-	-	-
	Arsenic (5.24)	Adult	**1E-04**	-	-	-

Well ID	Contaminant (concentration µg/L)	Exposure Group	Ingestion Cancer Risk RME (unitless)	Inhalation Cancer Risk (unitless)	Dermal Cancer Risk (unitless)	Total Cancer Risk (unitless)
	Chromium (VI) (4.67)	Combined child	**1E-04**	-	-	-
	Chromium (VI) (4.67)	Adult	4 E-05	-	-	-
GW-17	Arsenic (3.66)	Combined child	7E-05			
	Arsenic (3.66)	Adult	9E-05			
	Benzene (57.75)	Combined child	4E-05	3E-05	2E-06	7E-05
	Benzene (57.75)	Adult	5E-05	5E-05	3E-06	**1E-04**
	Carbon tetrachloride (0.78)	Combined child	7E-07	3E-07	6E-08	1E-06
	Carbon tetrachloride (0.78)	Adult	9E-06	5E-07	8E-08	1E-05
	Chromium (VI) (7.19)	Combined child	**2E-04**	-	-	-
	Chromium (VI) (7.19)	Adult	6E-05	-	-	-
	1,2-Dichloroethane (16.97)	Combined child	2E-05	3E-05	3E-07	5E-05
	1,2-Dichloroethane (16.97)	Adult	3E-05	5E-05	4E-07	8E-05
GW-19	Arsenic (4.21)	Combined child	8E-05	-	-	-
	Arsenic (4.21)	Adult	**1E-04**	-	-	-
	Carbon tetrachloride (0.98)	Combined child	9E-07	4E-07	8E-08	1E-06
	Carbon tetrachloride (0.98)	Adult	1E-06	6E-07	1E-07	2E-06
	Chromium (VI) (4.97)	Combined child	**1E-04**	-	-	-
	Chromium (VI) (4.97)	Adult	4E-05	-	-	-
GW-21	Arsenic (3.54)	Combined child	7E-05	-	-	-
	Arsenic (3.54)	Adult	9E-05	-	-	-
	Bromodichloromethane (1.48)	Combined child	1E-06	4E-06	3E-08	5E-06
	Bromodichloromethane (1.48)	Adult	2E-06	6E-06	4E-08	8E-06
	Bromoform (6.60)	Combined child	7E-07	5E-07	2E-08	1E-06

Well ID	Contaminant (concentration µg/L)	Exposure Group	Ingestion Cancer Risk RME (unitless)	Inhalation Cancer Risk (unitless)	Dermal Cancer Risk (unitless)	Total Cancer Risk (unitless)
	Bromoform (6.60)	Adult	8E-07	8E-07	2E-08	2E-06
	Carbon tetrachloride (0.67)	Combined child	8E-07	8E-07	7E-08	2E-06
	Carbon tetrachloride (0.67)	Adult	1E-06	1E-06	9E-08	2E-06
	Dibromochloromethane (4.00)	Combined child	4E-06		1E-07	4E-06
	Dibromochloromethane (4.00)	Adult	5E-06		1E-07	5E-06
GW-22	Arsenic (4.96)	Combined child	**1E-04**			
	Arsenic (4.96)	Adult	**1E-04**			
	Benzene (0.47)	Combined child	3E-07	2E-07	2E-08	5E-07
	Benzene (0.47)	Adult	4E-07	4E-07	2E-08	8E-07
	Bromoform (4.60)	Combined child	2E-07	4E-07	1E-08	6E-07
	Bromoform (4.60)	Adult	2E-07	6E-07	1E-08	8E-07
	Carbon tetrachloride (2.10)	Combined child	6E-07	7E-07	1E-07	1E-06
	Carbon tetrachloride (2.10)	Adult	8E-07	1E-06	2E-07	2E-06
	Chromium (VI) (4.59)	Combined child	**1E-04**	-	-	-
	Chromium (VI) (4.59)	Adult	4E-05	-	-	-
	Dibromochloromethane (1.58)	Combined child	2E-06	-	4E-08	2E-06
	Dibromochloromethane (1.58)	Adult	2E-06	-	5E-08	2E-06
	1,2-Dibromoethane (0.28)	Combined child	7E-06	1E-05	1E-07	2E-05
	1,2-Dibromoethane (0.28)	Adult	9E-06	2E-05	2E-07	3E-05
	1,2-Dichloroethane (2.11)	Combined child	2E-06	4E-06	4E-08	6E-06
	1,2-Dichloroethane (2.11)	Adult	3E-06	6E-06	5E-08	9E-06
GW-23	Arsenic (4.07)	Combined child	8E-05	-	-	-
	Arsenic (4.07)	Adult	**1E-04**	-	-	-

Well ID	Contaminant (concentration µg/L)	Exposure Group	Ingestion Cancer Risk RME (unitless)	Inhalation Cancer Risk (unitless)	Dermal Cancer Risk (unitless)	Total Cancer Risk (unitless)
	Benzene (42.70)	Combined child	1E-05	8E-06	5E-07	2E-05
	Benzene (42.70)	Adult	1E-05	1E-05	7E-07	2E-05
	Carbon tetrachloride (1.94)	Combined child	1E-06	6E-07	1E-07	2E-06
	Carbon tetrachloride (1.94)	Adult	2E-06	1E-06	2E-07	3E-06
	Chromium (VI) (5.79)	Combined child	**2E-04**	-	-	-
	Chromium (VI) (5.79)	Adult	5E-05	-	-	-
	1,2-Dichloroethane (11.10)	Combined child	1E-05	2E-05	2E-07	3E-05
	1,2-Dichloroethane (11.10)	Adult	1E-05	3E-05	2E-07	4E-05
GW-36	Arsenic (3.43)	Combined child	7E-05	-	-	-
	Arsenic (3.430)	Adult	8E-05	-	-	-
	Benzene (67.75)	Combined child	5E-05	4E-05	2E-06	9E-05
	Benzene (67.75)	Adult	6E-05	6E-05	3E-06	**1E-04**
	Carbon tetrachloride (0.37)	Combined child	3E-07	2E-07	3E-08	5E-07
	Carbon tetrachloride (0.37)	Adult	4E-07	2E-07	4E-08	6E-07
	Chromium (VI) (9.10)	Combined child	**3E-04**	-	-	-
	Chromium (VI) (9.10)	Adult	7E-05	-	-	-
	1,2-Dichloroethane (24.45)	Combined child	3E-05	5E-05	5E-07	8E-05
	1,2-Dichloroethane (24.45)	Adult	4E-05	7E-05	6E-07	**1E-04**
GW-41	Arsenic (5.23)	Combined child	**1E-04**	-	-	-
	Arsenic (5.23)	Adult	**1E-04**	-	-	-
GW-50	Arsenic (5.03)	Combined child	**1E-04**	-	-	-
	Arsenic (5.03)	Adult	**1E-04**	-	-	-
GW-51	1,2-Dichloroethane (0.62)	Combined child	7E-07	1E-06	1E-08	2E-06

Well ID	Contaminant (concentration μg/L)	Exposure Group	Ingestion Cancer Risk RME (unitless)	Inhalation Cancer Risk (unitless)	Dermal Cancer Risk (unitless)	Total Cancer Risk (unitless)
	1,2-Dichloroethane (0.62)	Adult	9E-07	2E-06	2E-08	3E-06

RME = Reasonable Maximum Exposure
PW = public water well (Happy Municipal Water System City Well #3)
Bolded values indicated low increased cancer risks.

Limitations

Several limitations exist when evaluating contaminant levels in private wells, which add some uncertainty to the conclusions in this report. In particular, the conclusions are based on very few to sometimes only one sample from a private well. To evaluate the risk, we assumed that residents were exposed to that concentration for long periods. The limitations follow:

- DSHS does not know if residents are currently using their private residential wells for recreational purposes.
- DSHS does not know if residents are currently using their private residential wells for irrigation.
- DSHS does not have data from food/produce grown in the area.
- Some of the wells have not been sampled since 2006, and conditions may have changed, such as contaminant concentrations in water.
- Well sampling and contaminants tested were not consistent throughout the years.
- DSHS assumed chromium detected in groundwater to be hexavalent chromium.
- DSHS does not have enough data to evaluate vapor intrusion concerns.

Conclusions

Based on available data, DSHS reached the following eight conclusions:

Conclusion 1

Some residents who used private residential well water prior to their homes being connected to the Happy Municipal Water System may have an increased risk of developing cancer.

Basis for conclusion

One or more contaminants were detected in 15 private residential wells at levels that could increase the risk of developing cancer following long-term exposure. Arsenic, benzene, carbon tetrachloride, hexavalent chromium, and 1,2-dichloroethane were found in well water during multiple groundwater sampling events conducted from 2006 to 2016. DSHS estimated cancer risks using health protective exposure assumptions, including a high or reasonable maximum exposure. At some properties, cancer risks for children or adults were estimated to exceed one additional cancer case in a population of 10,000 exposed people. However, there is uncertainty with the cancer risk estimates because of the limited samples collected and the assumption of long-term exposure over several decades.

Conclusion 2

Some residents who used private residential well water prior to their homes being connected to the Happy Municipal Water System may have experienced certain noncancer health effects.

Basis for conclusion

During multiple groundwater sampling events conducted from 2006 to 2016, benzene was detected in groundwater in three private residential water wells (GW-17, GW-23, and GW-36) and cadmium was detected in one private residential water well (GW-01) at levels that could cause noncancer adverse health effects. DSHS estimated noncancer health effects using health protective exposure assumptions, including a high or reasonable maximum exposure. Residents who were exposed to benzene for long periods may experience harmful effects in the tissues that form blood cells, including decreases in white blood cells and platelets in the blood. Residents who were exposed to cadmium for long periods may experience early signs of kidney damage, such as increased urinary levels of protein (tubular proteinuria). However, there is uncertainty with this conclusion because of the limited samples collected and the assumption of long-term exposure over several years.

Conclusion 3

People who consume water contaminated with lead from certain wells may be at risk for harmful health effects associated with this metal.

Basis for conclusion

Lead was detected in a water sample collected from a residential private well (GW-01) above the EPA action level of 15 micrograms per liter (μg/L). Although lead can affect almost every organ and system in the body, the main target for lead's harmful effects is the nervous system. Children are more vulnerable to lead exposure than adults because their nervous system is still developing. Exposure to lead in drinking water can increase a child's blood lead level. Elevated blood lead levels in children are associated with neurological, behavioral, and development effects, such as problems with attention, memory, and learning. Because there is no safe blood lead level, ATSDR and DSHS recommend reducing or removing lead exposure whenever possible.

Conclusion 4

Children who drank well water with high fluoride levels prior to their homes being connected to the Happy Municipal Water System may have experienced cosmetic effects to their teeth.

Basis for conclusion

When used appropriately, fluoride is effective in preventing and controlling dental caries. However, drinking excessive fluoride (1 mg/L or higher) during the time teeth are being formed can cause discoloration of teeth or fluorosis (ATSDR 2003). Fluoride was detected in eight residential wells (GW-09C, GW-10, GW-15, GW-21, GW-22, GW-23, GW-41, GW-50) at levels above 1 mg/L. Children drinking water from these wells over long periods may be at increased risk of developing mild dental fluorosis. Fluoride levels in these wells were below those known to cause bone fractures. Therefore, serious harmful effects in residents of these households are unlikely.

Conclusion 5

People who used the Happy Municipal Water System after 1991 have not been exposed to site-related contaminants at levels that are harmful to people's health.

Basis for conclusion

Site-related contaminants have not been detected in water from the Happy Municipal Water System since 1991. All the residences are now connected to Happy Municipal Water System, which is safe to use for domestic purposes. Therefore, people using the water for cooking, drinking, and other residential uses, such as bathing, are not currently being exposed to site-related contaminants in the groundwater.

Conclusion 6

A few people who used the Happy Municipal Water System before 1991 may have been exposed to site-related contaminants at levels that are harmful to people's health.

Basis for conclusion

Carbon tetrachloride was detected in City Well #3 in one sample collected in 1991. DSHS estimated the noncancer and cancer risk for past exposure (prior to 1991) of carbon tetrachloride assuming people were exposed to this level for long periods. Although noncancer effects are unlikely, long-term exposure may cause a low increased risk of developing cancer. However, there is uncertainty to this conclusion. It is based on the results of one sample collected from one municipal well and assumes long-term exposure to carbon tetrachloride at this level for several decades. In addition, around 1991 City Well #3 contributed only 2 percent of the water to the distribution system of the Happy Municipal Water System and served approximately 12 people (USEPA 2009b).

Conclusion 7

Water containing volatile organic compounds and heavy metals from private residential wells is not expected to harm people's health when used for irrigation, gardening, and recreational activities.

Basis for conclusion

DSHS could not assess the pathway of ingestion of contaminants from home-grown garden vegetables because crop and food samples have not been collected. DSHS does not know if people are currently eating crops irrigated with contaminated groundwater. However, heavy metal concentrations in these private residential wells are below the recommended maximum concentrations of trace elements in irrigation waters established by the U.S. Department of Agriculture (USDA 2011). In addition, rural communities are not expected to consume more than 20 percent of their home-grown food/produce, making the total amount ingested very small (USEPA 2018a). Additionally, people could have been exposed by incidentally ingesting water and through dermal contact with the water during recreational activities.

However, exposure would likely be minimal. Inhalation of contaminants through vaporization in outdoor air is not likely since volatile organic compounds evaporate from water relatively quickly and readily disperse in outdoor air. In addition, heavy metals do not easily volatize and are not readily absorbed through the skin.

Conclusion 8

DSHS does not have enough information to determine if past, present, or future inhalation of carbon tetrachloride and benzene resulting from vapor intrusion could harm people's health.

Basis for conclusion

Because carbon tetrachloride and benzene were detected in the groundwater and may be present in the shallow groundwater table, volatile contaminants could potentially migrate through soil in the form of vapor and enter the indoor air of homes and workplaces. This process is called vapor intrusion and could lead to inhalation of contaminants in indoor air. DSHS could not assess this exposure pathway because no indoor air samples have been collected. Also, subsurface soil and soil gas sampling has been limited.

Recommendations

DSHS recommends that:

- Residents in the area should continue to use water from the Happy Municipal Water System for all domestic purposes, such as drinking, cooking, doing dishes, bathing, gardening, and recreating.
- Residents should not use water from their private residential wells impacted by the contaminated groundwater for any purpose.
- Residents are encouraged to use TCEQ[1] and the Texas Department of Licensing and Regulation (TDLR[2]) established methods to abandon their private wells and follow the Texas Well Owner Network[3] suggestions.
- Residents with lead in their drinking water above 15 μg/L should take immediate steps to eliminate or reduce their exposures by either installing lead-specific treatment or by using an alternative drinking water source.
- EPA is encouraged to conduct a private residential well survey for current recreational and irrigation uses, as well as provide education to community members about the site and proper methods to abandon their private residential wells.

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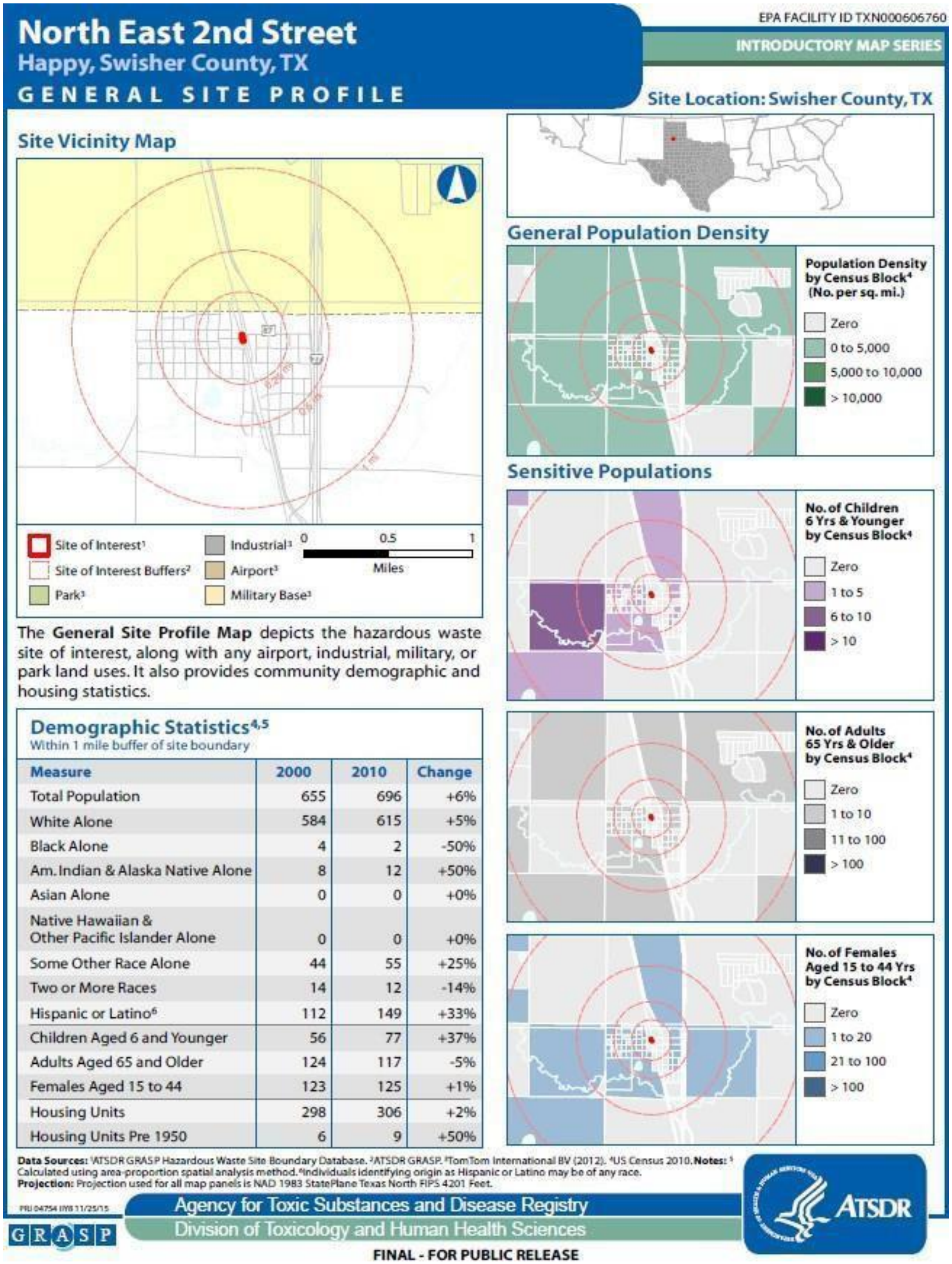
1 TCEQ: https://www.tceq.texas.gov/assets/public/comm_exec/pubs/rg/rg-347.pdf
2 TDLR: https://www.tdlr.texas.gov/
3 Texas Well Owner Network: http://twon.tamu.edu/

- EPA is encouraged to evaluate the potential for vapor intrusion of the carbon tetrachloride groundwater plume in the Ogallala Aquifer centered near 201 North Gordon Street.

Actions Planned

- DSHS will provide a final version of this document to community members, city officials, the TCEQ, the EPA and other interested parties.
- DSHS will provide community education regarding human health concerns in Happy, TX during community events.
- DSHS will continue to work with ATSDR, EPA, and TCEQ to evaluate additional data as they become available.



Measure	2000	2010	Change
Total Population	655	696	+6%
White Alone	584	615	+5%
Black Alone	4	2	-50%
Am. Indian & Alaska Native Alone	8	12	+50%
Asian Alone	0	0	+0%
Native Hawaiian & Other Pacific Islander Alone	0	0	+0%
Some Other Race Alone	44	55	+25%
Two or More Races	14	12	-14%
Hispanic or Latino[6]	112	149	+33%
Children Aged 6 and Younger	56	77	+37%
Adults Aged 65 and Older	124	117	-5%
Females Aged 15 to 44	123	125	+1%
Housing Units	298	306	+2%
Housing Units Pre 1950	6	9	+50%

Figure 2. Maps and General Profile of North East 2nd Street Superfund site, Happy, Texas.

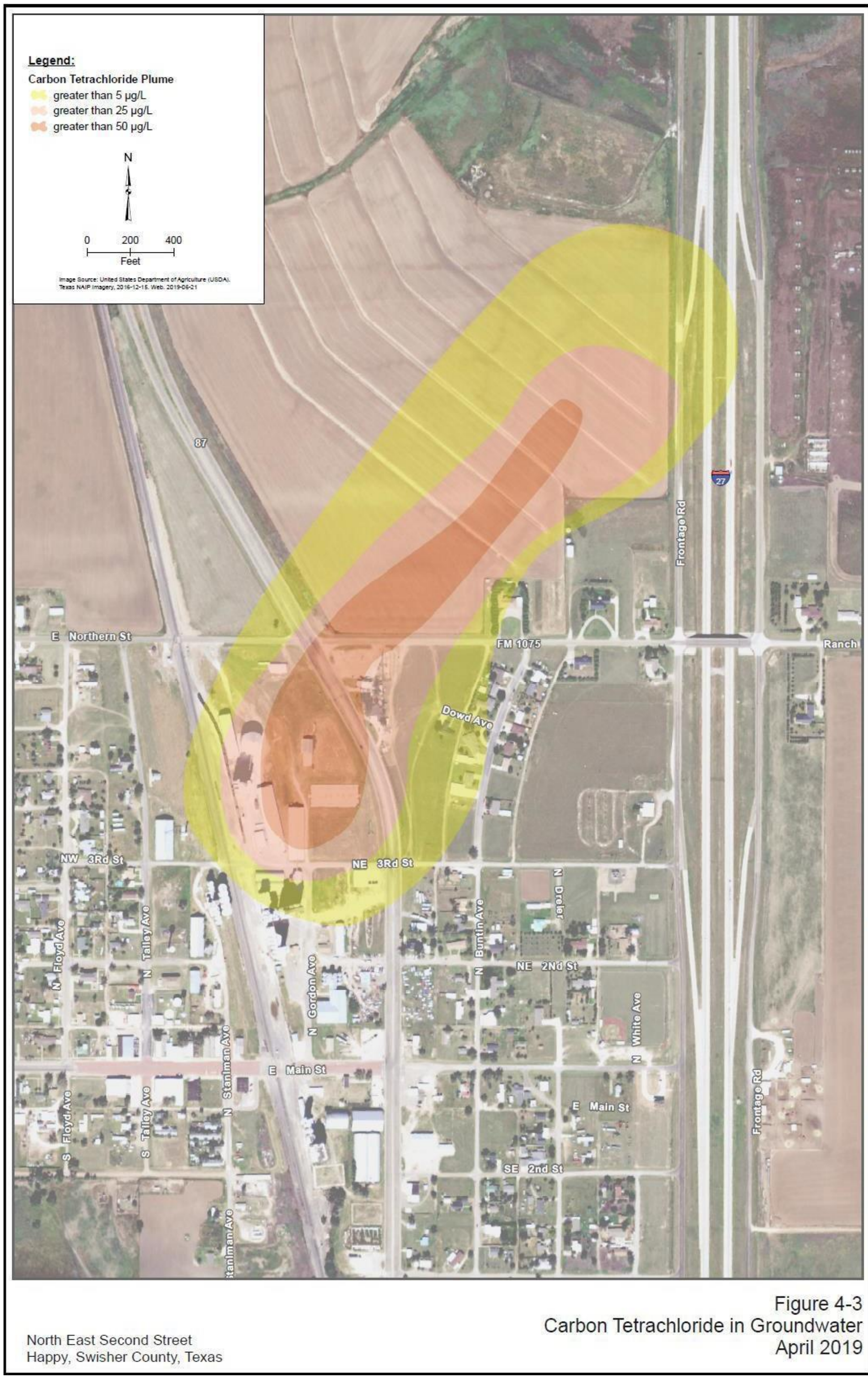


Figure 3. Map of the carbon tetrachloride detected in groundwater at the North East 2nd Street Superfund site, Happy, Texas (USEPA 2019a).

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Appendix A: Contaminants in private residential wells

Table A1. Maximum contaminant concentrations in groundwater from private residential wells near the North East 2nd Street Superfund site in Happy, Texas greater than comparison values or regional screening levels.

Well ID	Contaminant	Number of Detections / Number of Samples	Timeframe Sampled	Concentra-tion Range (µg/L)	Ingestion Comparison Value* (µg/L)	Number of Samples Exceeding Ingestion Comparison Value	Estimated Indoor Air Concentration based on the ATSDR Shower Model (µg/m3)	Inhalation Compari-son Value (CREG) (µg/m3)	Number of Samples Exceeding the Inhalation Compari-son Value
GW-01	Arsenic	1/1	2006	4.55	0.016 (CREG)	1	-	-	-
	Cadmium	1/1	2006	7.54	0.70 (Chronic EMEG child)	1	-	-	-
	Chromium (VI)	1/1	2006	1.13	0.024 (CREG)	1	-	-	-
	Lead	1/1	2006	49.7	NA	-	-	-	-
	Zinc	1/1	2006	6,350	2,100 (Chronic EMEG child)	1	-	-	-
GW-04	Arsenic	1/2	2006 - 2007	ND- 3.10	0.016 (CREG)	1	-	-	-
	Chromium (VI)	1/2	2006 - 2007	ND - 5.28	0.024 (CREG)	1	-	-	-
	Lead	1/2	2006 - 2007	ND - 0.58	NA	1	-	-	-
GW-09A	Arsenic	1/1	2006	2.98	0.016 (CREG)	1			
	Carbon tetrachloride	1/1	2006	50.62	0.35 (CREG)	1	13	0.17	1
	Chromium (VI)	1/1	2006	4.96	0.024 (CREG)	1	-	-	-
	1,2-Dibromoethane	1/1	2006	0.32	0.012 (CREG)	1	0.083	0.0017	1
	1,2-Dichloroethane	1/1	2006	2.1	0.27 (CREG)	1	0.56	0.038	1

Well ID	Contaminant	Number of Detections / Number of Samples	Timeframe Sampled	Concentra -tion Range (µg/L)	Ingestion Comparison Value* (µg/L)	Number of Samples Exceeding Ingestion Comparison Value	Estimated Indoor Air Concentration based on the ATSDR Shower Model (µg/m3)	Inhalation Compari- son Value (CREG) (µg/m3)	Number of Samples Exceeding the Inhalation Compari- son Value
	Lead	1	2006	0.081	NA	--	-	-	-
GW-09C	Arsenic	2/2	2012 - 2013	2.6 - 2.89	0.016 (CREG)	2	-	-	-
	Carbon Tetrachloride	2/10	2007 - 2015	ND - 15.25	0.35 (CREG)	1	3.8	0.17	1
	1,2-Dichloroethane	2/10	2007 - 2015	ND - 1.59	0.27 (CREG)	1	0.42	0.038	2
	Fluoride	1/1	2013	1350	800 (EPA RSL)	1	-	-	-
	Nitrate	1/1	2013	18,900	11,000 (RMEG child)	1	-	-	-
GW-10	Arsenic	2/3	2007 - 2013	ND - 3.23	0.016 (CREG)	2	-	-	-
	Carbon tetrachloride	8/8	2007 - 2013	1.6 - 3.64	0.35 (CREG)	8	0.4	0.17	8
	1,2-Dibromoethane	2/8	2007 - 2013	ND - 0.01	0.012 (CREG)	0	0.0026	0.0017	2
	1,2-Dichloroethane	7/8	2007 - 2013	ND - 2.29	0.27 (CREG)	7	0.61	0.038	7
	Fluoride	1/1	2013	1250	800 (EPA RSL)	1	-	-	-
GW-11	Arsenic	1/1	2006	3.98	0.016 (CREG)	1	-	-	-
	Carbon tetrachloride	1/1	2006	1.57	0.35 (CREG)	1	0.39	0.17	1
	Chromium (VI)	1/1	2006	4.96	0.024 (CREG)	1	-	-	-
	Copper	1/1	2006	3.38	70 (intermediate EMEG child)	1	-	-	-

Well ID	Contaminant	Number of Detections / Number of Samples	Timeframe Sampled	Concentra-tion Range (µg/L)	Ingestion Comparison Value* (µg/L)	Number of Samples Exceeding Ingestion Comparison Value	Estimated Indoor Air Concentration based on the ATSDR Shower Model (µg/m3)	Inhalation Compari-son Value (CREG) (µg/m3)	Number of Samples Exceeding the Inhalation Compari-son Value
	Zinc	1/1	2006	2.69	2,100 (Chronic EMEG child)	1	-	-	-
GW-12	Arsenic	1/1	2006	2.93	0.016 (CREG)	1	-	-	-
	Carbon tetrachloride	1/1	2006	1.29	0.35 (CREG)	1	0.32	0.17	1
	Chromium (VI)	1/1	2006	6.52	0.024 (CREG)	1	-	-	-
	1,2-Dichloroethane	1/1	2006	0.45	0.27 (CREG)	1	0.12	0.038	1
GW-13	Arsenic	1/1	2006	4.06	0.016 (CREG)	1			
	Carbon tetrachloride	1/1	2006	0.63	0.35 (CREG)	1	0.16	0.17	1
	Chromium (VI)	1/1	2006	5.37	0.024 (CREG)	1			
GW-15	Arsenic	3/4	2006 - 2013	ND - 5.87	0.016 (CREG)	3	-	-	-
	Chromium (VI)	1/4	2006 - 2013	ND - 5.61	0.024 (CREG)	1	-	-	-
	Fluoride	1/1	2013	1660	800 (EPA RSL)	1	-	-	-
GW-16	Arsenic	1/2	2006 - 2007	ND - 5.24	0.016 (CREG)	1	-	-	-
	Chromium (VI)	1/2	2006 - 2007	ND - 4.67	0.024 (CREG)	1	-	-	-
GW-17	Arsenic	1/1	2006	3.66	0.016 (CREG)	1	-	-	-
	Benzene	1/1	2006	57.75	0.44 (CREG)	1	15.00	0.13	1
	Carbon tetrachloride	1/1	2006	0.78	0.35 (CREG)	1	0.20	0.17	1

Well ID	Contaminant	Number of Detections / Number of Samples	Timeframe Sampled	Concentra-tion Range (µg/L)	Ingestion Comparison Value* (µg/L)	Number of Samples Exceeding Ingestion Comparison Value	Estimated Indoor Air Concentration based on the ATSDR Shower Model (µg/m3)	Inhalation Compari-son Value (CREG) (µg/m3)	Number of Samples Exceeding the Inhalation Compari-son Value
	Chromium (VI)	1/1	2006	7.19	0.024 (CREG)	1	4.50	0.038	1
	1,2-Dichloroethane	1/1	2006	16.97	0.27 (CREG)	1	-	-	-
GW-19	Arsenic	1/1	2006	4.21	0.016 (CREG)	1	-	-	-
	Carbon tetrachloride	1/2	2006 - 2007	ND - 0.98	0.35 (CREG)	1	0.25	0.17	1
	Chromium (VI)	1/1	2006	4.97	0.024 (CREG)	1	-	-	-
GW-21	Arsenic	2/3	2007 - 2013	ND - 3.54	0.016 (CREG)	2	-	-	-
	Bromodichloromethane	1/6	2007 - 2013	ND - 1.48	0.39 (CREG)	1	0.40	NA	
	Bromoform	1/6	2007 - 2013	ND - 6.60	3.1 (CREG)	1	1.70	0.91	1
	Carbon tetrachloride	4/6	2007 - 2013	ND - 0.67	0.35 (CREG)	4	0.17	0.17	2
	Dibromochloromethane	1/6	2007 - 2013	ND - 4.00	0.39 (CREG)	1	1.10	NA	
	Fluoride	1/1	2013	1400	800 (EPA RSL)	1	-	-	-
GW-22	Arsenic	3/5	2006 - 2016	ND - 4.96	0.016 (CREG)	3	-	-	-
	Benzene	1/13	2006 - 2016	ND - 0.47	0.44 (CREG)	1	0.13	0.13	1
	Bromoform	1/13	2006 - 2016	ND - 4.6	3.1 (CREG)	1	1.20	0.91	1
	Carbon tetrachloride	12/13	2006 - 2016	ND - 2.10	0.35 (CREG)	12	0.45	0.17	12
	Chromium (VI)	1/5	2006 - 2016	ND - 4.59	0.024 (CREG)	1	-	-	-
	Dibromochloromethane	1/13	2006 - 2016	ND - 1.58	0.39 (CREG)	1	0.41	NA	-

Well ID	Contaminant	Number of Detections / Number of Samples	Timeframe Sampled	Concentra -tion Range (µg/L)	Ingestion Comparison Value* (µg/L)	Number of Samples Exceeding Ingestion Comparison Value	Estimated Indoor Air Concentration based on the ATSDR Shower Model (µg/m3)	Inhalation Compari-son Value (CREG) (µg/m3)	Number of Samples Exceeding the Inhalation Compari-son Value
	1,2-Dibromoethane	4/13	2006 - 2016	ND - 0.28	0.012 (CREG)	4	0.07	0.0017	4
	1,2-Dichloroethane	11/13	2006 - 2016	ND - 2.11	0.27 (CREG)	11	0.52	0.038	11
	Fluoride	1/1	2013	1720	800 (EPA RSL)	1	-	-	-
GW-23	Arsenic	3/5	2006 - 2016	ND - 4.07	0.016 (CREG)	3	-	-	-
	Benzene	6/10	2006 - 2016	ND - 42.70	0.44 (CREG)	3	4.00	0.13	3
	Carbon tetrachloride	8/10	2006 - 2016	ND - 1.94	0.35 (CREG)	8	0.38	0.17	8
	Chromium (VI)	1/5	2006 - 2016	ND - 5.79	0.024 (CREG)	1	-	-	-
	1,2-Dichloroethane	10/10	2006 - 2016	4.95 - 11.10	0.27 (CREG)	10	2.30	0.038	10
	Fluoride	1/1	2013	1460	800 (EPA RSL)	1	-	-	-
GW-36	Arsenic	1/1	2006	3.43	0.016 (CREG)	1	-	-	-
	Benzene	1/1	2006	67.75	0.44 (CREG)	1	18.00	0.13	1
	Carbon tetrachloride	1/1	2006	0.37	0.35 (CREG)	1	0.09	0.17	1
	Chromium (VI)	1/1	2006	9.1	0.024 (CREG)	1	-	-	-
	1,2-Dichloroethane	1/1	2006	24.45	0.27 (CREG)	1	6.50	0.038	1
GW-39	Bromodichloromethane	1/1	2007	1.1	0.39 (CREG)	1	0.31	-	-
	Bromoform	1/1	2007	16	3.1 (CREG)	1	4.3	0.91	1
	Dibromochloromethane	1/1	2007	7	0.39 (CREG)	1	1.9	-	-

Well ID	Contaminant	Number of Detections / Number of Samples	Timeframe Sampled	Concentra-tion Range (µg/L)	Ingestion Comparison Value* (µg/L)	Number of Samples Exceeding Ingestion Comparison Value	Estimated Indoor Air Concentration based on the ATSDR Shower Model (µg/m3)	Inhalation Compari-son Value (CREG) (µg/m3)	Number of Samples Exceeding the Inhalation Compari-son Value
GW-41	Arsenic	2/2	2012 - 2013	5.2 - 5.23	0.016 (CREG)	2	-	-	-
	Fluoride	1/1	2013	1970	800 (EPA RSL)	1	-	-	-
GW-50	Arsenic	1/1	2013	5.03	0.016 (CREG)	1	-	-	-
	Fluoride	1/1	2013	1900	800 (EPA RSL)	1	-	-	-
GW-51	1,2-Dichloroethane	1/1	2018	0.64	0.27 (CREG)	1	-	-	-

[1]Total chromium was compared to the CV for hexavalent chromium
CREG = Cancer Risk Evaluation Guide
RMEG = Reference Dose Media Evaluation Guide
*EPA regional screening level (RSL) or action level was used in absence of a CV
µg/L = Micrograms per liter
µg/m^3 = Micrograms per cubic meter
ND = not detected
- = not available.

Table A2. Chronic ingestion exposure doses and noncancer hazard quotients in cadmium and fluoride contaminated groundwater in private residential wells near the North East 2nd Street Superfund site in Happy, Texas.

Well ID	Contaminant	Exposure Group	EPC Value (µg/L) and Type	Ingestion Dose CTE (mg/kg/day)	Ingestion HQ CTE	Ingestion Dose RME (mg/kg/day)	Ingestion HQ RME
GW-01	Cadmium	Birth to < 1 year	7.54 (Max.)	0.00050	5	0.0011	11
		1 to < 2 years		0.00020	2	0.00060	6
		2 to < 6 years		0.00020	2	0.00040	4
		6 to < 11 years		0.00010	1	0.00030	3
		11 to < 16 years		0.00010	0.9	0.00030	3
		16 to < 21 years		0.00010	0.8	0.00030	3
		Adult		0.00010	1	0.00030	3
		Pregnant Women		0.00010	0.9	0.00030	3
		Lactating Women		0.00020	2	0.00040	4
GW-09C	Fluoride	Birth to < 1 year	1350 (Max.)	0.087	2	0.19	4
		1 to < 2 years		0.036	0.7	0.11	2
		2 to < 6 years		0.029	0.6	0.076	2
		6 to < 11 years		0.022	0.4	0.060	1
		Adult		0.021	0.4	0.052	1
		Lactating Women		0.031	0.6	0.066	1

Well ID	Contaminant	Exposure Group	EPC Value (µg/L) and Type	Ingestion Dose CTE (mg/kg/day)	Ingestion HQ CTE	Ingestion Dose RME (mg/kg/day)	Ingestion HQ RME
GW-10	Fluoride	Birth to < 1 year	1250 (Max.)	0.081	2	0.18	4
		1 to < 2 years		0.034	0.7	0.098	2
		2 to < 6 years		0.027	0.5	0.070	1
		6 to < 11 years		0.020	0.4	0.055	1
		Lactating Women		0.0290	0.6	0.061	1
GW-15	Fluoride	Birth to < 1 year	1660 (Max.)	0.11	2	0.24	5
		1 to < 2 years		0.045	0.9	0.13	3
		2 to < 6 years		0.036	0.7	0.093	2
		6 to < 11 years		0.027	0.5	0.073	2
		11 to < 16 years		0.019	0.4	0.058	1
		16 to < 21 years		0.018	0.4	0.057	1
		Adult		0.025	0.5	0.064	1
		Pregnant Women		0.020	0.4	0.059	1
		Lactating Women		0.038	0.8	0.082	2
GW-21	Fluoride	Birth to < 1 year	1400 (Max.)	0.090	2	0.20	4
		1 to < 2 years		0.038	0.8	0.11	4
		2 to < 6 years		0.030	0.6	0.079	2

Well ID	Contaminant	Exposure Group	EPC Value (µg/L) and Type	Ingestion Dose CTE (mg/kg/day)	Ingestion HQ CTE	Ingestion Dose RME (mg/kg/day)	Ingestion HQ RME
		6 to < 11 years		0.022	0.4	0.062	1
		Adult		0.021	0.4	0.054	1
		Pregnant Women		0.017	0.3	0.050	1
		Lactating Women		0.032	0.6	0.069	1
GW-22	Fluoride	Birth to < 1 year	1720 (Max.)	0.11	2	0.25	5
		1 to < 2 years		0.046	0.9	0.13	3
		2 to < 6 years		0.037	0.7	0.097	2
		6 to < 11 years		0.028	0.6	0.076	2
		11 to < 16 years		0.019	0.4	0.060	1
		16 to < 21 years		0.018	0.4	0.059	1
		Adult		0.026	0.5	0.066	1
		Pregnant Women		0.021	0.4	0.061	1
		Lactating Women		0.039	0.8	0.085	2
GW-23	Fluoride	Birth to < 1 year	1460 (Max.)	0.094	2	0.21	4
		1 to < 2 years		0.039	0.8	0.11	2
		2 to < 6 years		0.032	0.6	0.082	2
		6 to < 11 years		0.023	0.5	0.064	1

Well ID	Contaminant	Exposure Group	EPC Value (µg/L) and Type	Ingestion Dose CTE (mg/kg/day)	Ingestion HQ CTE	Ingestion Dose RME (mg/kg/day)	Ingestion HQ RME
		11 to < 16 years		0.016	0.3	0.051	1
		16 to < 21 years		0.016	0.3	0.050	1
		Adult		0.022	0.4	0.056	1
		Pregnant Women		0.017	0.3	0.052	1
		Lactating Women		0.033	0.7	0.072	1
GW-41	Fluoride	Birth to < 1 year	1970 (Max.)	0.13	3	0.28	6
		1 to < 2 years		0.053	1	0.15	3
		2 to < 6 years		0.043	0.9	0.11	2
		6 to < 11 years		0.032	0.6	0.087	2
		11 to < 16 years		0.022	0.4	0.069	1
		16 to < 21 years		0.021	0.4	0.067	1
		Adult		0.030	0.6	0.076	2
		Pregnant Women		0.024	0.5	0.07	1
		Lactating Women		0.045	0.9	0.097	2
GW-50	Fluoride	Birth to < 1 year	1900 (Max.)	0.12	3	0.27	5
		1 to < 2 years		0.051	2	0.15	3
		2 to < 6 years		0.041	0.8	0.11	2

Well ID	Contaminant	Exposure Group	EPC Value (µg/L) and Type	Ingestion Dose CTE (mg/kg/day)	Ingestion HQ CTE	Ingestion Dose RME (mg/kg/day)	Ingestion HQ RME
		6 to < 11 years		0.031	0.6	0.084	2
		11 to < 16 years		0.021	0.4	0.066	1
		16 to < 21 years		0.020	0.4	0.065	1
		Adult		0.029	0.6	0.073	2
		Pregnant Women		0.023	0.5	0.067	1
		Lactating Women		0.043	0.9	0.093	2

EPC = Exposure Point Concentration
µg/L = micrograms chemical per liter water
mg/kg/day = milligram chemical per kilogram body weight per day
CTE = Central Tendency Exposure (average)
RME = Reasonable Maximum Exposure
HQ = Hazard Quotient
Max. = maximum

Appendix B: Exposure Dose Equation Analysis

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 (ATSDR 2005b), EPA's Exposure Factors Handbook (USEPA 2018b), ATSDR's Exposure Dose Guidance for Water Ingestion (ATSDR 2016a), and the Shower and Household Water-use Exposure (SHOWER) Model (V1.0.1) (ATSDR 2016b and 2018) when site-specific information is unknown.

Ingestion Dose

The contaminant concentration for the water ingestion exposure dose is based on maximum concentration if less than eight samples were collected or more than four sample results had concentrations below the method detection limit (MDL). The 95 percent upper confidence limit (95% UCL) of the mean was used if eight or more samples were collected and more than four sample results were detected above the MDL. DSHS calculated the 95% UCL using EPA's ProUCL software. Age-specific ingestion rates and body weights were used with the below formula to calculate age-specific estimated exposure doses for drinking water (ATSDR 2016a).

Water Ingestion Exposure Dose Equation

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

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

*default of 1, assuming person daily exposure.

Exposure Factor Equation

$$EF = F\,x\,\frac{ED}{AT}$$

F = frequency of exposure (days/year)
ED = exposure duration (years)
AT = averaging time (days--ED x 365 days/year for non-carcinogens; 78 years x 365 days/year for carcinogens)

Table B1. Parameters used for calculating water ingestion exposure dose for central tendency exposures (CTE) and reasonable maximum exposure (RME) doses

Exposure Group	Body Weight (kg)	Age-Specific Exposure Duration (years) (CTE)	Age-Specific Exposure Duration (years) (RME)	Intake Rate (L/day) (CTE)	Intake Rate (years) (RME)
Birth to < 1 year	7.8	1	1	0.504	1.113
1 to < 2 years	11.4	1	1	0.308	0.893
2 to < 6 years	17.4	4	4	0.376	0.977
6 to < 11 years	31.8	5	5	0.511	1.404
11 to < 16 years	56.8	1	5	0.637	1.976
16 to < 21 years	71.6	0	5	0.770	2.444
Adult	80	12	33	1.227	3.092
Pregnant Women	73	NA	NA	0.872	2.589
Lactating Women	73	NA	NA	1.665	3.588

Water Ingestion Cancer Risk Equation

$$R = D \times SF \times \frac{ED}{LY}$$

R = Cancer Risk
D = Cancer Exposure Dose (mg/kg/day)
SF = Slope Factor (mg/kg/day)
ED = Age-specific exposure during in years
LY = Lifetime in years (DSHS assumed 78 years)

Usage of SHOWER model for calculation of dermal doses and inhalation exposure concentrations

DSHS used the ATSDR SHOWER model to calculate estimated indoor air concentrations (ATSDR 2018). If a contaminant surpassed either the indoor air comparison values (CVs) or the drinking water CVs, DSHS calculated inhalation and dermal exposure using the SHOWER model. The SHOWER model outputs dermal doses and inhalation exposure concentrations for each exposure group based on the maximum water concentration of VOCs. The doses and exposure concentrations are modeled based on many assumptions in the SHOWER model.

DSHS used a conservative approach to calculate the inhalation exposure and dermal doses by selecting the highest exposed person in the modeled scenario. This scenario included a person showering after four consecutive morning showers in a four-person household with no ventilation fan and assumed that the person is home all day. Each household member takes an eight-minute shower with a five-minute stay in the bathroom. About 9 percent of children 1 to less than 2 years and 14 percent of children 2 to less than 6 years take showers (USEPA 2011).

Dermal Dose

Dermal absorption of VOCs through the skin during showering, and hand contact with faucet water is also an exposure pathway that can contribute to the total dose of exposure for a person (ATSDR 2018).The dermal equations below were used to calculate the total dermal absorbed dose from showering, and handwashing exposure based on the maximum concentration of each VOC in each well. To estimate dermal uptake, the SHOWER model assumed the person would have a total of five-bathroom sink uses events per day and fifteen main house sink uses per day (e.g., kitchen, utility sinks), and one shower.

Dermal Dose Equation

Part 1: $DA\ event = FA \times Kp \times\ C'w \times \frac{tevent}{1+\ B} + 2\ \times\ tevent\ \times (\frac{1+3B+3B2}{(1+B)2})$

$$where, B\ =\ Kp\ \times \frac{\sqrt{MW}}{2.6}$$

DA$_{event}$ = Absorbed dose per event (mg/cm^2-event)
FA = Fraction absorbed water (dimensionless)
C’W = Average chemical concentration in shower, or faucet water(mg/cm^3)
τevent = Lag time per event (hr/event)
tevent = Site-specific event duration (hr/event)
t* = Chemical-specific time to reach steady state (hr)

Kp = Dermal permeability coefficient of compound in water (cm/hr)
B = Dimensionless ratio of the permeability coefficient of a compound through the stratum corneum relative to its permeability coefficient across the viable epidermis (dimensionless)
MW = Molecular weight of contaminant

Part 2: $$\boldsymbol{DAD} = \frac{DA\ event\ x\ SA\ x\ EV\ x\ EF}{BW}$$

DAD = Dermal absorbed dose (mg/kg/day)
DA event = Absorbed dose per event (mg/cm^2/event)
SA = Exposed body surface area (cm^2)
EV = Event frequency (events/day)
EF = Exposure factor (unitless)
BW = Body weight (kg)

The SHOWER model calculates the total DAD by adding the individual DADs from showering, and hand contact with water throughout the day. The total absorbed dermal dose equation is shown here:

Part 3: $$\boldsymbol{DAD_{total}} = DAD_{Shower} + DAD_{hand\ contact}$$

Usage of SHOWER model for calculation of dermal doses
Explanation of Equations

Equation in Part 1

This equation identifies the absorbed contaminant dose per dermal event. The left side of the equation is a single variable representing the absorbed dose per event, and the right side contains a summation of two terms. The first term is the product of the following variables: fraction absorbed water, dermal permeability coefficient, average chemical concentration, and a fraction consisting of the site-specific event duration in the numerator and a function of the dimensionless permeability coefficient ratio "B" in the denominator. The second term is equal to two times the product of the site-specific event duration and another fraction that is a function of the dimensionless permeability coefficient ratio "B".

Equation in Part 2

This equation identifies the contaminant dermal absorbed dose. The left side of the equation is a single variable representing the dermal absorbed dose, and the right side of the variable is a fraction. The fraction numerator is the product of the following variables: absorbed dose per event, exposure body surface area, event frequency, and exposure factor. The denominator of the fraction is the person's body weight.

Equation in Part 3

This equation identifies the total dermal absorbed dose of the contaminant. The left side of the equation is the total dermal absorbed dose, and the right side is the sum of the dermal absorbed doses from showering and from hand contact with water.

Inhalation Exposure

VOCs escape or volatize from contaminated water in indoor air when water is used for household purposes such as showering, bathing, or using the toilet and dishwasher. Inhalation of VOCs while taking a shower can contribute significantly to the total exposure for an exposed person.

VOC concentrations in the main house rise and fall depending upon movement of contaminated air from the shower and bathroom as well as from other water sources being turned on and off throughout the day. The SHOWER model calculates the concentration in the indoor air for multiple sections of the house including the main house, the shower stall, and the bathroom. The shower stall has one direct source (i.e., shower water), while the bathroom has three direct sources (i.e., the toilet, the sink faucet, and the bathtub). The main house has three direct sources (i.e., the kitchen faucet, the clothes washer, and the dishwasher). The SHOWER model also accounts for VOCs entering a different section of the house either directly from the sources within a room or indirectly from another room. Thus, based on when and how long a source is used during the day (e.g., shower, bathtub, faucet, washers), the model predicts the concentration in the shower, the bathroom, and the main house for each second of the day (i.e., 86,400 seconds) (ATSDR 2018).

The SHOWER model then calculates the average daily human exposure concentration (ADHEC) for the person. This ADHEC is a time-weighted average. The ADHEC is calculated by using the sum of all the contaminant air concentrations in the compartment where the person is located at each second of the day and divides it by the total number of seconds in a day (86,400 seconds). In general, the chemical air concentrations in the shower and bathroom increase when persons take a shower or a bath and slowly decline afterwards.

For certain chemicals that target the same organ or systems when ingested or breathed, the daily inhalation concentration calculated by the SHOWER model can be converted into an inhaled dose using age-specific breathing rates. The age-specific inhaled doses can be added to the ingestion doses calculated by ATSDR’s Public Health Assessment Site Tool (PHAST) to yield a combined (total) dose from both pathways.

Inhalation Dose Equation

$$Dose = \frac{C\ x\ BR\ x\ EF}{BW}$$

C = Contaminant concentration in the air (mg/m^3)
BR = Breathing rate (L/min)
EF = Exposure factor (unitless)
BW = Body weight (kg)

Table B2. Parameters used in calculations for inhalation and dermal doses from exposures to VOCs through drinking, showering, washing wands and usage of indoor household appliances

Room	Appliance	Parameter	Value
Shower	Shower	Flow rate	7.6 L/min
Bathroom	Bathroom sink	Flow rate	3.2 L/min
Bathroom	Bathroom sink	Average duration per use	0.5 min
Bathroom	Bathroom sink	Uses per person per day	5 uses/person/day
Bathroom	Bathtub	Bathtub volume	76.5 L
Bathroom	Bathtub	Flow rate	22.7 L/min
Bathroom	Toilet	Volume per flush	10.8 L/flush
Bathroom	Toilet	Flushes per person per day	5 flushes/person/day
Main house	Clothes washer	Volume per cycle	117 L/load
Main house	Clothes washer	Average cycle duration	44 min
Main house	Dishwasher	Volume per cycle	23.1 L/load
Main house	Dishwasher	Average cycle duration	73 min
Main house	Kitchen sink	Flow rate	3.2 L/min
Main house	Kitchen sink	Average duration per use	0.5 min
Main house	Kitchen sink	Uses per person per day	15 uses/person/day
Main house	Other main house faucets	Average volume use per person per day	10.2 L/person/day

L/min= liters per minute; L/flush = liters per flush; L/load = liters per load; min=minute; L/person/day=liter per person per day

Table B3 provides the information used in the SHOWER model to determine exposure from the shower. The table includes the number of persons in the household, the shower or bath start time and duration, and the bathroom stay duration immediately after the shower or bath for each person.

Table B3. Timing and duration of showers and bathroom stays based on household size

1-Person Household size	2-Person Household size	3-Person Household size	4-Person Household size	Shower Start time	Shower Duration (min)	Bathroom stay after shower (min)
			1	6:18 a.m.	8	5
		1	2	6:32 a.m.	8	5
	1	2	3	6:46 a.m.	8	5
1*	2*	3*	4*	7:00 a.m.	8	5

Table B4. Routine times of day appliances are used in the SHOWER model

Clothes washer	Dishwasher
7:00 p.m.	9:00 p.m.

Table B5 shows an average human activity pattern throughout the day for the person with the highest exposure. This person starts out in the main house and then moves to other areas (the bathroom, the shower, away from home) at pre-determined times during the day (ATSDR 2018).

Table B5. Human activity pattern throughout the day for the most highly exposed person scenario used in the SHOWER Model.

Start Time	Location
12:00 a.m.	Main House
7:00 a.m.	Shower
7:08 a.m.	Bathroom
7:13 a.m.	Main House
10:00 a.m.	Bathroom
10:05 a.m.	Main House
2:30 p.m.	Bathroom
2:35 p.m.	Main House
6:30 p.m.	Bathroom
6:35 p.m.	Main House
10:00 p.m.	Bathroom
10:15 p.m.	Main House

Table B6 shows information on the size of each compartment in the house, the flow rate of the bathroom fan, and the air-exchange rate between different compartments. For scenarios in which the bathroom fan is turned off, the fan has a flowrate of 0 L/min.

- The shower stall is based on a standard small shower (3 x 3 x 8 ft);
- The bathroom is based on a standard, small bathroom (5 x 8 x 8 ft); and
- The house is based on a median size house (1,500 ft^2) with 8 ft ceilings (ATSDR 2018).

Table B6. Room volumes, air exchange rates, and fan flow rates used in the SHOWER model.

Parameter	Value
Shower volume	2,040 L
Bathroom volume (excluding shower)	7,020 L
Remainder of house volume	330,500 L
Flow rate of bathroom exhaust fan	0 L/min
Shower/bathroom air-exchange rate	6,100 L/hr
Bathroom/main house air-exchange rate	14,000 L/hr
House/outdoor air-exchange rate	153,200 L/hr

L=liter; L/min=liters per minute; L/hr=liter per hour