# Health Consultation

West County Road 112
Midland, Midland County Texas

EPA ID No. TXN000606992

Prepared by the
Texas Department of State Health Services

March 2, 2022

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
1-800-CDC-INFO
or
Visit our Home Page at: https://www.atsdr.cdc.gov

The Texas Department of State Health Services (DSHS) prepared this Health Consultation for the West County Road 112 site, located in Midland (Midland County) Texas under a cooperative agreement (#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.

HEALTH CONSULTATION

# Evaluation of Chromium in Filtered Groundwater from Private Wells

WEST COUNTY ROAD 112

MIDLAND, MIDLAND COUNTY, TEXAS 79706

EPA FACILITY ID: TXN000606992

Prepared by the
Texas Department of State Health Services
under a Cooperative Agreement with the
U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry

# Table of Contents

## List of Figures



## List of Tables

# Summary

## Introduction

The West County Road (WCR) 112 Superfund site is located in Midland, Texas, in an area with a mixture of agricultural, residential, and commercial/industrial properties. In March 2010, EPA added WCR 112 to the National Priority List (NPL) because of groundwater contaminated with chromium, including hexavalent chromium. The U.S. Environmental Protection Agency (EPA) asked the Texas Department of State Health Services (DSHS) to provide a public health consultation (HC) to evaluate exposures to chromium and provide recommendations aimed at reducing harmful exposures for people in the community. The top priority of Texas Department of State Health Services (DSHS) and Agency for Toxic Substances and Disease Registry (ATSDR) is to ensure people living around the site have the best information possible to protect their health.

Starting in 2009, EPA collected samples from 254 private drinking water wells and detected total chromium above EPA's maximum contaminant level (MCL) of 100 microgram per liter (μg/L) in 51 wells. The Texas Commission on Environmental Quality (TCEQ) installed anion-exchange water filtration systems on these wells to mitigate chromium exposures. TCEQ has collected post-filtration water samples quarterly to monitor the removal efficiency of the filtration systems since May 2009. Therefore, these residents are not likely to experience any harmful effects from current and future exposure to chromium. However, elevated chromium concentrations have been detected occasionally in samples collected post-filtration. If prevention measures (such as water filtration systems) are not continued or if alternative remedies (such as connection to a municipal water supply) are not implemented, long-term continuous exposure to chromium may cause serious adverse health effects to community members.

The purpose of this health consultation is to support the efforts for long-term preventive measures to ensure that long-term actual exposures to chromium are prevented and public health is protected.

To evaluate residents' potential (hypothetical) exposures, DSHS calculated the exposure doses and estimated non-cancer and cancer risks assuming residents were exposed continually to chromium in drinking water post-filtration from the 51 wells. To represent the range of concentrations observed in private drinking wells, DSHS selected a lowest (1 µg/L), low (9 µg/L), low middle (50 µg/l), middle (75 µg/L), and high (180 µg/L) contaminant exposure point concentration (EPC) to calculate exposure doses for different age groups ranging from a child to an adult, including pregnant and lactating women. DSHS then estimated risks of non-cancer and cancer health outcomes that could result from typical and high exposure scenarios.

## Conclusions

Based on the available information, DSHS and ATSDR reached two conclusions about the site:

### Conclusion 1

If residents were exposed (hypothetically) to chromium continuously (above 50 µg/L) in some private groundwater wells at the West County Road 112 site, the levels could harm people's health by causing non-cancer health effects, such as mild changes to the cells lining the small intestines and liver inflammation. Long-term continuous exposure to chromium (above 9 µg/L) could also increase people's cancer risk.

**Basis for Conclusion**

The results of DSHS's evaluation suggested that:

- If people were exposed continuously to levels ranging from 50 µg/L to 75 µg/L, there could be an increased chance of developing chronic non-cancer health effects for children less than 1 year old with a high exposure scenario (RME). Seven (7) out of the 51 wells sampled after filtration had estimated EPCs ranging from 50 µg/L to 75 µg/L.

- If people were exposed continuously to levels ranging from 75 µg/L to 180 µg/L, there could be an increased risk for chronic non-cancer health effects for children less than 2 years old at the high end of the exposure (RME). Six (6) out of the 51 sampled wells had estimated hexavalent chromium EPCs ranging from 75 µg/L to 180 µg/L.
- If people were exposed continuously to 180 µg/L or greater, there could be an increased risk for chronic non-cancer health effects for children birth to less than 1 year old for typical exposure (CTE) and for all age groups for high exposure (RME) scenario. Six (6) out of the 51 sampled wells had estimated hexavalent chromium EPCs equal to or greater than 180 µg/L.
- If people were exposed continuously to low (greater than 9 µg/L) concentrations of chromium in well water, there could be a low increased risk of cancer for adults, and increased risk of cancer for children.
- If people were exposed continuously to low middle (50 µg/L), middle (75 µg/L) and high (180 µg/L) levels of chromium in well water, there could be increased risk of cancer for children and adults.

### Conclusion 2

DSHS does not have enough information to determine if past exposures (before 2009) to chromium in drinking water from these private water wells could have harm people's health.

**Basis for Conclusion**

In 2009, the extent of groundwater contamination was not known and health effects of past ingestion of hexavalent chromium could not be assessed because the data was not available.

## Next Steps

The results of the health consultation show the potential of health risks from long-term continuous (hypothetical) exposure to some levels of chromium. Therefore, a long-term remedy is needed to prevent harmful exposures from occurring in the community.

- As a long-term solution for the protection of public health, the city of Midland is encouraged to consider extending the municipal waterline to homes impacted by groundwater chromium contamination around the West County Road 112 site. Public drinking water systems ensure that residents get high quality water because they must meet health-based federal standards for contaminants, including performing regular monitoring and reporting.

- EPA and TCEQ are encouraged to continue current efforts to protect the health of residents.

- EPA reports all wells with chromium concentrations above the primary drinking water standard (the MCL) to TCEQ to have filtration systems installed. Therefore, adverse health effects are not expected from drinking well water currently or in the future for these residents. EPA is encouraged to report any well that has a chromium exceedance above 9 μg/L to TCEQ as soon as possible. This may further reduce the residents' exposures to chromium from drinking water.

    - Continue groundwater sampling efforts to characterize the hexavalent chromium plume and identify all wells that might be affected.
    - Continue to provide alternative water and/or an onsite water filtration system to residents whose domestic well water contains levels of hexavalent chromium that might harm their health. At homes with treatment systems, sample domestic well water both pre- and post- treatment at least quarterly to ensure the systems' effectiveness.

- Additionally, EPA and TCEQ are encouraged to:

    - Continue efforts to gain access to domestic wells at households that may be affected by the site but have not been previously or recently sampled.
    - Provide and evaluate post-treatment results for other inorganic compounds, such as arsenic and lead.

    - Gather demographic information for households relying on private domestic well water to determine if sensitive individuals (like infants and pregnant women) are using the wells. This information helps prioritize households for monitoring and/or remedial action as necessary.

- Residents with specific health concerns should consult their family physician.

- Residents are encouraged to have their post-filtration water tested for metals, including arsenic and lead, by an independent certified laboratory to ensure the safety of their water.

---

## For More Information

If you have concerns about your health, we recommend you contact your health care provider. For more information about this health assessment, you may contact the DSHS, Health Assessment and Toxicology Program at 1-888-681-0927.

# Background and Statement of Issues

In May 2018, the U.S. Environmental Protection Agency (EPA) asked the Texas Department of State Health Services (DSHS) to provide a public health consultation (HC) for the West County Road (WCR) 112 Superfund site. A HC addresses public health concerns arising from an environmental hazard (such as chromium and hexavalent chromium) by evaluating available exposure information such as environmental data, exposure pathway, duration, and frequency. *The purpose of this health consultation is to support the efforts for maintenance of existing, or establishing alternative, long-term preventive measures to ensure that long-term actual exposures to chromium are prevented and public health is protected*.

The WCR site is located in an area with mixed agriculture, residential, and commercial/industrial properties. It is near the intersection of Cotton Flat Road and U.S. Interstate Highway 20 (I-20) and extends across the City of Midland's city limit boundary (Figure 1) (EA 2013). The portion of the site north of I-20 is predominantly commercial/industrial. Private residential wells with filtration systems to remove chromium from groundwater are located south of I-20. In 2010, the population within a 1-mile radius of the area of contaminated groundwater was 6,082 residents. About 66 percent of these residents are Hispanic/Latino (GRASP 2020).

**Figure 1 Site map to show the location and boundary of West County Road 112 Superfund Site (EA 2013)**

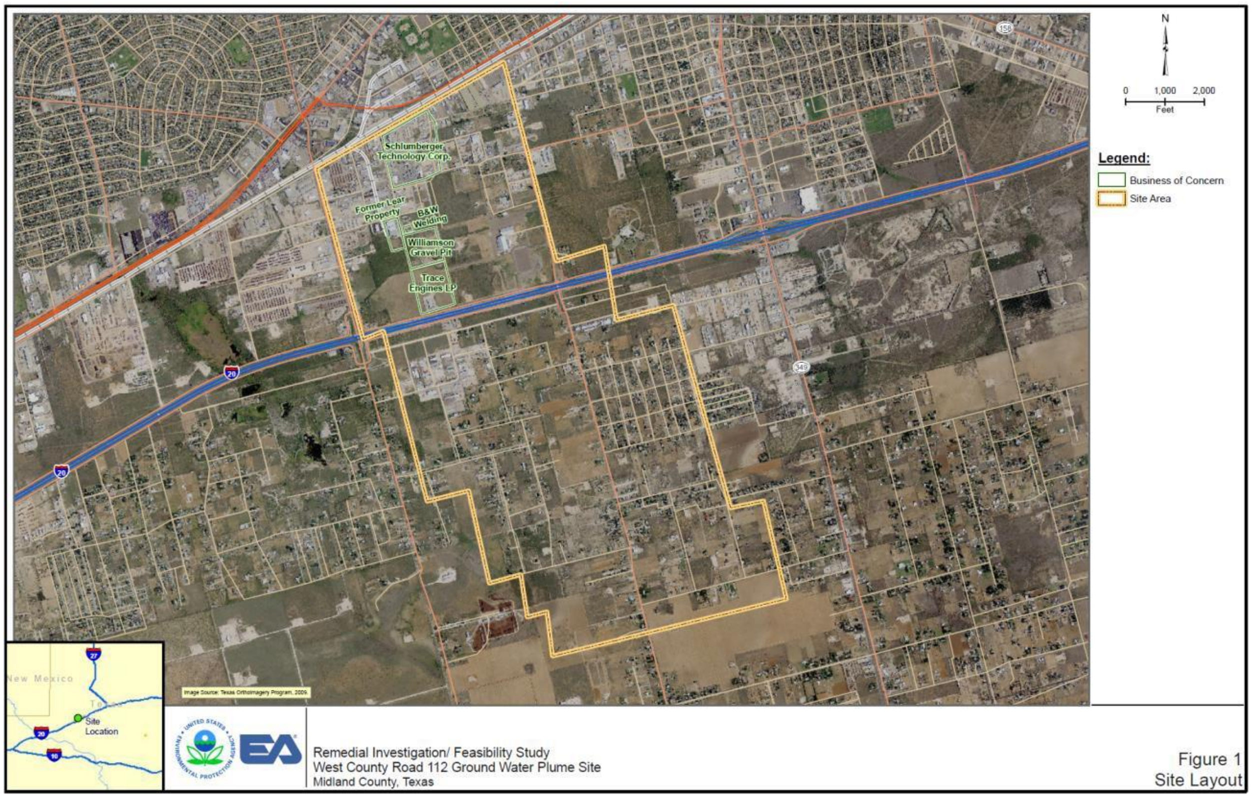


**Figure 2 West County Road 112 Superfund site general site demographics**

EPA FACILITY ID EA 2013

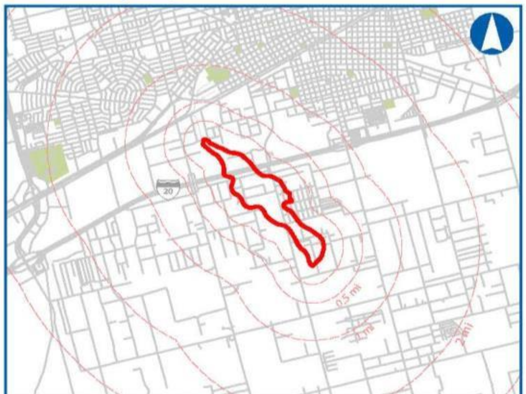
INTRODUCTORY MAP SERIES

# West County Road 112 NPL Site

## Midland, Midland County, TX

### GENERAL SITE PROFILE

#### Site Vicinity Map




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

0 0.5 1 2 Miles

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

#### Demographic Statistics[4,5]

Within 1 Miles buffer of site boundary

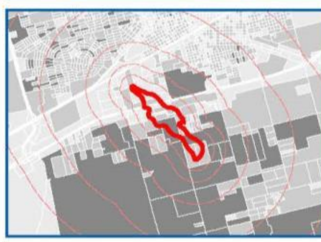
| Measure | 2000 | 2010 | Change |
|---|---|---|---|
| Total Population | 5,312 | 6,082 | +14% |
| White Alone | 3,686 | 3,935 | +6% |
| Black Alone | 185 | 217 | +17% |
| Am. Indian & Alaska Native Alone | 42 | 55 | +30% |
| Asian Alone | 33 | 26 | -21% |
| Native Hawaiian & Other Pacific Islander Alone | 2 | 4 | +100% |
| Some Other Race Alone | 1,227 | 1,692 | +37% |
| Two or More Races | 142 | 148 | +4% |
| Hispanic or Latino[6] | 2,848 | 4,039 | +41% |
| Children Aged 6 and Younger | 713 | 794 | +11% |
| Adults Aged 65 and Older | 441 | 510 | +15% |
| Females Aged 15 to 44 | 1,209 | 1,295 | +7% |
| Housing Units | 2,041 | 2,104 | +3% |
| Housing Units Pre 1950 | 576 | 302 | -47% |

#### General Population Density

**Population Density by Census Block[4] (No. per sq. mi.)**
Zero
0 to 5,000
5,000 to 10,000
> 10,000

#### Sensitive Populations

**No. of Children 6 Yrs & Younger by Census Block[4]**
Zero
1 to 5
6 to 10
> 10



**No. of Adults 65 Yrs & Older by Census Block[4]**
Zero
1 to 10
11 to 100
> 100

**No. of Females Aged 15 to 44 Yrs by Census Block[4]**
Zero
1 to 20
21 to 100
> 100

**Data Sources:** [1]ATSDR GRASP Hazardous Waste Site Boundary Database. [2]ATSDR GRASP. [3]TomTom 2019Q1. [4]US Census 2010. **Notes:** [5]Calculated using area-proportion spatial analysis method. [6]Individuals identifying origin as Hispanic or Latino may be of any race.
**Projection:** Projection used for all map panels is NAD 1983 StatePlane Texas Central FIPS 4203 Feet.

PRJ 05942 QCF2 10/27/20

GRASP

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

ATSDR

FINAL - FOR PUBLIC RELEASE

In July 2009, at the request of TCEQ, DSHS assessed the groundwater sampling results from 50 private wells taken by TCEQ in April-May 2009 (ATSDR 2009). The site was initially identified in April 2009 by a local resident who filed a complaint about yellow water to the TCEQ and asked to have their private well water tested. The result showed elevated levels of hexavalent chromium, 5,280 micrograms per liter (μg/L). This level exceeded the EPA's maximum contaminant level (MCL) of 100 μg/L for total chromium (i.e., all forms of chromium, including hexavalent chromium and trivalent chromium). MCLs are enforceable drinking water standards set by EPA for municipal water systems. MCLs are set as close to MCL goals (the level of a substance in drinking water below which there is no known or expected risk to health) as feasible using the best available treatment technology and taking cost into consideration (USEPA 2021). Based on these results, a filtration system was installed at this residence and later at other residences where drinking water exceeded the MCL. In 2009, the extent of groundwater contamination was not known and health effects of ingestion of hexavalent chromium were not assessed. Therefore, past exposures to residents' drinking water from these private water wells could not be evaluated.

Several known industries that have historically used chromium are located hydraulically up-gradient within one mile of the site (Figure 1). Since 2009, TCEQ and EPA conducted several site investigations to gather more information to identify the source and understand the level and extent of contamination. Although no specific known source has been identified, chromium was determined to be the contaminant of concern for the site. The results also showed that about 99 percent of total chromium in the groundwater was hexavalent chromium (USEPA 2010; EA 2013). Trivalent and hexavalent chromium are the most common forms of chromium in the natural environment. Trivalent chromium is essential to human beings and is found in many vegetables, fruits and meats. Hexavalent chromium occurs naturally in the environment or because of industrial processes (ATSDR 2012).

In March 2010, EPA added WCR to the National Priority List (NPL) because of groundwater contaminated with chromium, including hexavalent chromium. Groundwater is the only source of potable water in the area. There are no city water distribution lines within half a mile of the site. The groundwater contamination is found in both the shallower Ogallala Aquifer and the deeper Edwards-Trinity Aquifer (TCEQ 2010a). Therefore, EPA and TCEQ collected untreated groundwater samples from contaminated domestic wells to evaluate the need for filtration systems to remove elevated levels of chromium. The untreated groundwater samples were analyzed for chromium and other metals (Appendix B).

EPA collected samples from 254 private drinking water wells between 2010 to 2012. Any well that was found to exceed the EPA MCL for total chromium was referred to TCEQ for filter installation. TCEQ installed anion-exchange water filtration systems on 51 private wells to mitigate chromium exposures because these wells were determined to be a primary drinking water source for the residences (EA 2013). TCEQ has collected post-filtration water samples quarterly to monitor the removal efficiency of filtration systems. Therefore, adverse health effects from current and future long-term exposures for these residents are not expected. However, elevated chromium concentrations (TCEQ analyzed post-filtration water samples for total chromium only) were detected occasionally in samples collected post-filtration. In this health consultation, DSHS evaluated the potential (hypothetical) health risks by assuming long-term continuous exposures to chromium that occurred after the filtration systems were installed. The assessment was conducted to support the efforts for maintenance of existing, or establishing alternative, long-term preventive measures to ensure that long-term actual exposures to chromium are prevented and public health is protected.

# Discussion

## Process to Evaluate Environmental Contamination

DSHS conducted a three-step process to evaluate the public health implications using available environmental data. First, DSHS conducted an exposure pathway analysis to identify if and how people may be exposed. Second, DSHS conducted a screening analysis by comparing the sampling data to health-based guidelines. Third, DSHS conducted a more detailed public health evaluation of contaminants of concern identified in the screening analysis (ATSDR 2005).

## Environmental Data

DSHS evaluated water samples collected by TCEQ from 2009 to 2018. EPA collected tap water samples from 254 private wells between 2010 and 2012. These water samples were analyzed for hexavalent chromium and other metals. The total chromium concentrations were used to evaluate the need for filtration systems. However, EPA determined that most of the total chromium in water was the more toxic hexavalent chromium (EPA 2013). According to EPA’s sampling results, TCEQ installed anion exchange filtration systems on 51 wells that had total chromium concentrations exceeding EPA’s MCL for total chromium.

TCEQ conducted quarterly sampling events on the 51 filtered (post-filtration) drinking water wells to monitor the water quality. TCEQ collected water samples prior to filtration (pre-filtration), from filtration port B (during the filtration process), and from filtration port C (post-filtration) from 2009 to 2017. TCEQ only collected water samples from filtration port C after 2017. TCEQ samples collected from 2009 to 2011 were analyzed for total chromium and hexavalent chromium. TCEQ samples collected from 2012 to 2018 were only analyzed for total chromium because EPA established that 98-99 percent of total chromium was hexavalent chromium.

The purpose of this health consultation is to support the efforts for maintenance of existing, or establishing alternative, long-term preventive measures to ensure long-term actual exposures to chromium are prevented and public health is protected. Therefore, DSHS only evaluated post-filtration samples after 2009 to best represent the exposures that could occur. High variability in concentrations in post-filtration samples was observed, in some cases, two orders of magnitude within the same well. Some measurements suddenly spiked up by a factor of 100 then dropped when another sample was taken three months later. The capacity of the filter systems was likely breached leading to breakthroughs of chromium in households using larger amounts of water (TCEQ 2010b). To ensure the effectiveness of filter systems, TCEQ provides both technical and physical assistance to residents.

## Exposure Pathway Analysis

The presence of a contaminant in the environment does not necessarily mean that people are coming into contact with it. An exposure pathway describes how a chemical can move from its source and come into physical contact with people. Identifying exposure pathways is important in a health assessment because adverse health impacts from contaminants can only happen if people are exposed to them. DSHS divided exposure pathways into three categories: completed, potential, and eliminated.

There are five elements considered in the evaluation of exposure pathways:

1. a source of contamination,
2. an environmental media that could absorb or transport the contamination,
3. a point of exposure where people could contact the contaminated media,
4. a route of exposure, and
5. an identifiable exposed population.

A *completed exposure pathway* occurs when all five elements are present, and exposure has occurred, is occurring, or will occur in the future. A *potential exposure pathway* occurs when one or more of the five elements cannot be identified but may be present at some point in the future. *Eliminated exposure pathways* are missing one or more elements and exposure cannot occur

Residential exposures to contaminants from private water well use may include ingestion from drinking and cooking as well as inhalation and dermal exposures from washing, bathing, and showering (Table 1). Based on available environmental data and knowledge of the area, DSHS determined that:

*Current and future ingestion is a potential exposure pathway of concern.* There are no city water distribution lines within half a mile of the site (USEPA 2010). People living near the site rely on the groundwater for drinking and cooking purposes. The TCEQ installed anion-exchange water filtration systems on residents' wells to mitigate chromium exposures. TCEQ has collected post-filtration water samples quarterly to monitor the removal efficiency of the filtration systems since May 2009. These residents are not likely to experience any harmful effects from current and future exposure to chromium. However, current and future ingestion pathways are considered potential until a permanent preventive measure is in place.

*Potential (hypothetical) future ingestion may be a primary exposure pathway of concern for chromium.* Elevated chromium concentrations have been detected occasionally in water samples collected post-filtration. If prevention measures (such as water filtration systems) are not continued or if alternative remedies (such as connection to a municipal water supply) are not implemented, long-term continuous exposure to chromium may cause serious adverse health effects to community members.

*Inhalation and dermal (skin contact) exposures are not significant exposure pathways for chromium.* Most metals (such as chromium) tend not to be absorbed through the skin and are not likely to be inhaled by people while showering because they are not volatile (i.e. do not evaporate). Therefore, dermal and inhalation exposures from bathing and showering were not considered in this evaluation.

*Ingestion exposures from contaminated homegrown food is not a significant exposure pathway for chromium*. Some residents also use the water for home gardening irrigation. No specific data is available for chromium concentrations in homegrown produce, but studies showed that very little chromium is taken up by plants (ATSDR 2012). In addition, studies suggest that health risks related to eating homegrown produce are minimal (Fernando et al, 2012; Pan et al. 2016).

**Table 1. Exposure pathway evaluation for post-filtration groundwater**

| Source | Medium | Point of Exposure | Route of Exposure | Potentially Exposed Population | Timeframe and Type of Exposure Pathway |
|---|---|---|---|---|---|
| **Contaminated Groundwater** | Groundwater | Tap | Ingestion * | Residents | Past: completed<br>Current: potential<br>Future: potential<br>Future (hypothetical): completed |
| **Contaminated Groundwater** | Groundwater | Tap | Skin contact, Inhalation[1] | Residents | Past: eliminated<br>Current: eliminated<br>Future: eliminated |
| **Contaminated Homegrown Food** | Homegrown Food | Food | Ingestion[2] | Residents | Past: eliminated<br>Current: eliminated<br>Future: eliminated |

1. Current and future ingestion pathways are considered potential until a permanent preventive measure is in place
2. Skin contact and inhalation and ingestion of homegrown food pathways were eliminated for the purpose of this HC because any chromium exposure from these pathways would be very small compared to the ingestion pathway.

## Screening Analysis: Comparison to Health-Based Comparison Values

Following identification of completed exposure pathways, DSHS conducted a screening analysis to identify contaminants of concern. The analytical results for each contaminant were compared to health-based comparison values (CVs) published by Agency for Toxic Substances and Disease Registry (ATSDR). The ATSDR CVs are media-specific (e.g. air, soil and water) levels below which no adverse health effects are expected to occur. It is important to note that if a chemical concentration exceeds a CV, it does not necessarily mean there is a health concern. It means the chemical- and site-specific exposure scenario warrants further public health evaluation based on site-specific exposure conditions.

DSHS calculated exposure point concentrations (EPCs) to provide conservative estimations of contaminant concentrations people may be exposed to. DSHS compared estimated EPCs to EPA's MCL for total chromium, and ATSDR's chronic Environmental Media Evaluation Guides (EMEG) and Cancer Risk Evaluation Guide (CREG) for hexavalent chromium. MCLs are enforceable standards set by EPA based on the best available knowledge to prevent potential health problem. MCLs are set as close to the health goals as possible after considering cost, benefits, and treatment technology. EMEGs are estimated contaminant concentrations in air, soil, or water below which adverse non-cancer health effects are not expected to occur. CREGs are estimated contaminant concentrations that would be expected to cause no more than one additional excess cancer in one million people exposed over a lifetime.

Given that available sample data were for total chromium and that comparison values for chronic health effects were for hexavalent chromium, the exposure analysis for potential (hypothetical) future exposure assumed the total chromium to be 100 percent hexavalent chromium. This assumption was based on the results from a water analysis collected from a subset of wells at the site, which showed hexavalent chromium to make up 98 to 99 percent of the total chromium (EA 2013). Based on the existing in place prevention measures, adverse health effects from current and future actual chromium exposures are not expected.

An exposure point concentration (EPC) is an estimate of the concentration of a contaminant at the point of human exposure. DSHS first compared individual private water well results to CVs using EPCs. An EPC was determined for each well (ATSDR 2019). 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 more than eight samples were collected and more than four sample results were detected above the MDL (Table 2). Various distribution types and sampling methods were used to obtain 95% UCLs, including percentile bootstrap, and lognormal and gamma distributions.

The results showed 21 out of 51 wells have EPCs above the total chromium MCL. Most wells (45 out of 51 wells) have EPCs above ATSDR's hexavalent chromium EMEG (6.3 µg/L), except groundwater wells GW-019, GW-093, GW-102, GW-125, and GW-261. All wells have EPCs above ATSDR's hexavalent chromium CREG of 0.024 µg/L. For the extent and spatial variations of the concentrations of chromium, please see Appendix A, Figure A 1.  Next, DSHS selected EPCs in various ranges to provide an analysis of the full range of exposures. To represent the range of concentrations observed in private drinking wells, DSHS selected a lowest (1 µg/L), low (9 µg/L), low middle (50 µg/l), middle (75 µg/L), and high (180 µg/L) contaminant EPC.

## Public Health Implications

### Chromium

Chromium is a naturally occurring element that is found in the environment in several different forms. The main three forms of chromium are metallic chromium, trivalent chromium, and hexavalent chromium. Trivalent chromium, which occurs naturally in the environment, is an essential nutrient and has very low toxicity. Hexavalent chromium and metallic chromium are rare in nature and are generally produced by industrial processes or man-made sources (NTP 2008). Additionally, hexavalent chromium can be reduced to other forms of chromium through reactions with organic materials (ATSDR 2012).

The effects of chromium exposure on the human body vary according to the exposure route (i.e., inhalation, ingestion, or skin contact) and the chemical form of chromium. For example, inhaling high levels of hexavalent chromium aerosols can damage the nasal and respiratory tract. Breathing water droplets or steam with low concentrations of hexavalent chromium does not present a health risk. The EPA (EPA) has classified hexavalent chromium as a known human carcinogen through inhalation (USEPA 2005). Similarly, the National Toxicology Program (NTP) has classified hexavalent chromium as a known human carcinogen based on occupational studies where workers exposed by inhalation developed lung cancer (ATSDR 2012). However, mixed results have been found in studies of people living in areas with high levels of hexavalent chromium in the drinking water. Some human studies have reported an association with several cancer types, while other studies have not. In laboratory animals, hexavalent chromium compounds have been shown to cause cancer of the stomach, intestinal tract, and lungs. No cancer effects in animal studies have been identified from dermal exposures to hexavalent chromium (ATSDR 2012). Additionally, hexavalent chromium has been shown to be mutagenic[1] and cytotoxic[2] in several in vitro studies (ATSDR 2012; NTP 2008; McCarroll, et al., 2010).

EPA established the MCL (100 ug/L) for total chromium (including trivalent chromium and hexavalent chromium) in 1991. It is based on potential non-cancer adverse skin effects (such as allergic dermatitis) that can occur after many years of exposure. The NTP reported that ingestion of high levels of sodium dichromate

---

[1] Mutagenic: capable of causing damage to the cell's genetic material (DNA).

[2] Cytotoxic: capable of causing cell damage or death.

dihydrate, a compound containing hexavalent chromium, was associated with an increase in oral and small intestine tumors in laboratory animals (NTP 2008). The California Environmental Protection Agency (CalEPA) derived a cancer slope factor of 0.5 $(mg/kg/day)^{-1}$ based on NTP's animal study. The final release of EPA's Integrated Risk Information System (IRIS) reassessment of the carcinogenic effects of hexavalent chromium through oral ingestion is pending as of 2019 (USEPA 2019). EPA is evaluating the carcinogenic mode of action (MOA) of hexavalent chromium. Some scientists hypothesize that ingestion of high concentrations of hexavalent chromium causes intestinal cell damage (cytotoxicity) and regenerative cell growth (cell proliferation). Health Canada states that this points to the occurrence of a threshold for hexavalent chromium carcinogenesis (Health Canada 2018). Upon completion of the IRIS reassessment, EPA will determine whether the MCL for total chromium needs to be revised (USEPA 2019).

DSHS evaluated both non-cancer and cancer health effects and, as indicated above, assumed that all chromium is hexavalent chromium because most of the chromium in groundwater samples was hexavalent. DSHS used ATSDR's minimal risk level (MRL) for hexavalent chromium to evaluate non-cancer health effects, and CalEPA's cancer slope factor to calculate cancer risks.

## Potential Health Effects Evaluation Process

To evaluate residents' potential (hypothetical) exposures to chromium in drinking water, DSHS calculated exposure doses and estimated non-cancer and cancer risks assuming residents were continually exposed to chromium in post-filtration drinking water. DSHS selected a lowest (1 µg/L), low (9 µg/L), low middle (50 µg/L), middle (75 µg/L), and high (180 µg/L) levels of total chromium EPCs to calculate the exposure doses for different age groups ranging from a child to an adult, including pregnant and lactating women. These EPCs were selected based on the distribution of the estimated EPCs and their representative cancer risks (i.e. between $10^{-6}$ and $9 \times 10^{-5}$, and equal to or greater than $10^{-4}$) for different exposure groups. The lowest (1 µg/L), low (9 µg/L), low middle (50 µg/L), middle (75 µg/L) and high (180 µg/L) represent approximately 1, 25, 75 and 90 percentiles of EPCs, respectively.

No site-specific exposure information was available for how much water people drank. DSHS calculated the exposure doses using health protective exposure assumptions for two exposure scenarios (i.e., typical or central tendency exposure (CTE); and high or reasonable maximum exposure (RME)) as recommended by ATSDR (Appendix C). 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 consume water at a high rate. The CTE is referring to individuals who consume water at average or typical rate.

For non-cancer health effects, the calculated exposure doses were compared to ATSDR's MRL to determine if there is a concern for non-cancer health effects. If the calculated exposure dose is lower than the health guideline, adverse non-cancer health effects are not expected to happen. If the calculated exposure dose exceeded the health guideline, additional in-depth evaluation was conducted to determine the likelihood of harmful health effects. This is done by comparing the dose to known non-carcinogenic health effect levels found in the scientific literature. The equations to calculate exposure doses and exposure assumptions are in Appendix C.

For cancer health effects, the estimated exposure dose was multiplied by the cancer slope factor (CSF). The estimated 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 C). An excess lifetime cancer risk represents the additional risk above the existing background cancer risk. For example, an estimated cancer risk of 2 per million (or 2E-6) potentially represents two extra cancer cases in a population of one million over a lifetime of continuous exposure. 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 men (39.66 percent) and women (37.65 percent) (ACS 2019). Note, cancer risk estimates 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.

## Non-Cancer Health Effect Evaluation

ATSDR's chronic MRL for hexavalent chromium of 0.0009 mg/kg/day was used as a health guideline. Animal studies show that ingestion of high levels of hexavalent chromium affects the intestines of mice and rats. The most sensitive study showed an increase of lesions in the cells lining the small intestine and additional tissue growth (called epithelia hyperplasia) resulting from the lesions in female mice. Rats showed lesions, but no tissue growth. Studies also showed that ingestion of hexavalent chromium caused microcytic, hypochromic anemia and lesions on liver, intestines, lymph nodes, and the pancreas in mice and rats (NTP 2008). The Lowest

Observed Adverse Effect Level (LOAEL),[3] which caused liver (chronic inflammation) and intestinal effects, was 0.38 mg/kg/day (NTP 2008). ATSDR used information from these animal studies and modeling software to estimate the lower confidence limit of the benchmark dose ($BMDL_{10}$)[4] that is expected to show a response in 10 percent of the animals tested. The $BMDL_{10}$ for intestinal effects was 0.009 mg/kg/day. ATSDR calculated the chronic MRL (0.0009 mg/kg/day) using the $BMDL_{10}$ and an uncertainty factor of 100 (ATSDR 2012).

Generally, the estimated age-specific exposure doses are higher for young children (birth to <1-year-old) than for older children (16 to <21 years old) and adults (>21 years old).

- Using the high (180 µg/L) EPC, the estimated exposure doses for children and adults ranged
    - from 0.0019 to 0.012 mg/kg/day for typical exposures (CTE), and
    - from 0.0061 to 0.026 mg/kg/day for high exposures (RME).
- For the lowest (1 µg/L) EPC, the estimated exposure doses for children and adults ranged
    - from 1.1E-5 to 6.5E-5 mg/kg/day for typical exposures (CTE), and
    - from 3.4E-5 to 1.4E-4 mg/kg/day for high exposures (RME).

Tables 2-6 show the estimated age-specific exposure doses for all age groups using a range of concentrations from 1 to 180 µg/L. DSHS calculated hazard quotients (HQs) to compare estimated exposure doses to the MRL, which is a dose at which non-cancerous adverse health effects are not expected. HQs were calculated by dividing the estimated exposure doses by the MRL. If the HQ is less than or equal to 1, then adverse health effects are not likely. If the HQ is greater than 1, DSHS further evaluated site doses by using the margin of exposure (MOE) approach. The MOE is a measure of how close the estimated exposure dose is to the known dose from an animal or human study that showed non-cancer health effects. The higher the MOE, the greater the margin of protection between the estimated ingestion

[3] LOAEL: the lowest exposure level in a study that resulted in a measurable health effect

[4] The $BMDL_{10}$ is lower confidence limit of the lowest theoretical level that would cause a 10 percent increase in the incidence of an effect (such as increased liver enzyme activity, which indicates liver damage) in the experimental group compared to the control group.

exposure and the human effect level. Based on the scientific literature and estimated exposure doses for hexavalent chromium, DSHS determined that non-cancer health effects are more likely to occur when the MOE is less than 18 than when the MOE is 18 and higher.

- *Lowest EPC (1 µg/L): all the resulting HQs were less than 1. Because the estimated exposures were below the chronic MRL (i.e., HQ < 1), non-cancerous effects are not likely (Table 2).*
    - Low EPC (9 µg/L): all the resulting HQs were less than 1 except for the less than 1-year old group. The HQ for this age group was 1.4 at the high exposure scenario (RME). DSHS further evaluated the MOE, which was 69, when compared to the BMDL10 of 0.09 mg/kg/day. This means that the estimated exposure dose in children birth to < 1 year is 69 times less than the lowest theoretical health effect levels. Therefore, non-cancerous effects are not likely (Table 3).
    - Low middle EPC (50 µg/L): the resulting HQs were less than 1 for the 6 to less than 11 years, 11 to less than 16 years, and 16 to less than 21 years age groups at a typical level of exposure (CTE), and non-cancer health effects are not likely. For all other groups the HQs were greater than 1. DSHS evaluated the MOEs for the groups having HQs greater than 1. The MOEs ranged from 23 to 167 when compared to the BMDL10 for all groups except children birth to less than 1 year at RME; therefore, harmful effects are not likely. However, the MOE for children birth to less than 1 year was 13. This group could be at risk of mild cellular changes to the cells lining the intestines and inflammation of the liver (Table 4).
    - Middle EPC (75 µg/L): the resulting HQs were less than 1 for the 11 to less than 16 years, and 16 to less than 21 years age groups at a typical level of exposure (CTE), and non-cancer health effects unlikely. The results HQs were greater than 1 for all other age groups. DSHS evaluated the MOE for the groups having HQs greater than 1. The MOEs ranged from 19 to 75 when compared to the BMDL10.; therefore, harmful effects are not likely. For children 2 years and older and for adults, their estimated exposure ranged from 21 to 35 times below effect levels. Harmful effects are not likely. However, for children birth to two years for high exposure (RME), their MOEs ranged from 8 to 15 below effect levels.

Therefore, children birth to 2 years old could be at risk of mild cellular changes to the cells lining the intestines and inflammation of the liver (Table 5).

- High EPC (180 μg/L): all the resulting HQs were greater than 1 for all groups. Except for children birth to 1 year, the MOEs for typical exposure (CTE) were greater than 18 when compared to the BMDL10. Therefore, children 1 year and older and adults are not at risk of harmful effects. For children and adults with high end exposure (RME) and for children birth to 1 year with typical exposure (CTE), the MOEs were 3 to 15 times below effect levels. These groups may be at risk of mild cellular changes to the cells lining the intestines and inflammation of the liver (Table 6).

Assuming long-term continuous (hypothetical) exposure to chromium levels ranging from 50 μg/L to 75 μg/L, there may be an increased chance of developing chronic non-cancer health effects for children less than 1 year old with a high exposure scenario (RME). Seven (7) out of the 51 wells sampled after filtration had estimated EPCs ranging from 50 μg/L to 75 μg/L. For chromium levels ranging from 75 μg/L to 180 μg/L, there may be an increased risk for chronic non-cancer health effects for children less than 2 years old at the high end of the exposure (RME). Six (6) out of the 51 sampled wells had estimated hexavalent chromium EPCs ranging from 75 μg/L to 180 μg/L. For chromium levels 180 μg/L and above, there may be an increased risk for chronic non-cancer health effects for children birth to less than 1 year old for typical exposure (CTE) and for all age groups for a high exposure scenario (RME). Six (6) out of the 51 sampled wells had estimated hexavalent chromium EPCs equal to or greater than 180 μg/L (Appendix D, Table D 1).

If people were exposed continuously to chromium levels above 50 μg/L, possible (hypothetical) non-cancer health effects from long-term exposure to hexavalent chromium include increased tissue growth of the cells lining the intestine (diffuse epithelial hyperplasia) and liver damage (inflammation) (ATSDR 2012).

### Cancer Health Effect Evaluation

The results from NTP's rodent studies showed that ingestion of drinking water contaminated with hexavalent chromium could increase the likelihood of oral and small intestine tumors (NTP 2008). CalEPA derived an oral cancer slope factor (CSF) of 0.5 $(mg/kg/day)^{-1}$ (CalEPA 2011). DSHS used the age-dependent adjustment factor (ADAF) approach to account for increased cancer risk from early life exposures (i.e., childhood exposures) because hexavalent chromium is a mutagen (ATSDR 2012; NTP 2008; McCarroll, et al., 2010).

DSHS calculated age-specific exposure doses and corresponding cancer risks for both typical (CTE) and maximum (RME) exposure scenarios, as presented in Tables 2-6.

The estimated cancer risks change with increasing water concentration and whether someone drinks typical amounts of water (CTE exposure) or lots of water (RME exposure). What follows are the cancer risks from drinking tap water containing 1, 9, 50, 75, and 180 µg/L hexavalent chromium for 21 years (children) and for 33 years (adults).

- *If people were exposed to the lowest (1 µg/L) level of hexavalent chromium in well water could result in a low increased risk of cancer for children and adults; that is, the chance of getting cancer from this exposure is low.*
    - Table 3 shows that the estimated cancer risks indicated that exposure to the lowest concentration of hexavalent chromium contaminated water could result in a risk of cancer from 9E-6 to 3E-5 among children (21 years of exposure), and from 1E-6 to 8E-6 among adults (33 years of exposure).
    - Stated another way, the calculated excess cancer risks are 9 to 3 extra cases of cancer for every 1,000,000 and 100,000 exposed children, respectively, and 1 to 8 extra cases of cancer for every 1,000,000 exposed adults.
    - DSHS interpreted this as a low increased risk, and therefore, not likely to harm people's health.
- *If people were exposed to the low (9 µg/L) level of hexavalent chromium in well water could result in a low increased risk of cancer for adults, and increased risk of cancer for children.*
    - Table 3 shows that the estimated cancer risks indicated that exposure to the low concentration of hexavalent chromium in well water could have increased risk of cancer from 8E-5 to 2E-4 among children, and from 1E-5 to 7E-5 among adults.
    - Stated another way, the calculated excess cancer risks are 8 to 2 extra cases of cancer for every 100,000 and 10,000 exposed children, respectively, and 1 to 7 extra cases of cancer for every 100,000 exposed adults.

    - DSHS interprets this as an increased lifetime cancer risk for children, and low increased risk for adults.

- *If people were exposed to the low middle (50 µg/L), middle (75 µg/L) and high (180 µg/L) levels of hexavalent chromium in well water could result in increased risk of cancer for children and adults.*
    - Tables 4, 5 and 6 show that the estimated cancer risks indicated that exposure to the low middle, middle and high concentrations of hexavalent chromium in well water could have increased risk of cancer from 1E-3 to 5E-3 among children, and from 4E-4 to 2E-3 among adults.
    - Stated another way, the calculated excess cancer risks are 1 to 5 extra cases of cancer for every 1,000 exposed children, and 4 to 2 extra cases of cancer for every 10,000 and 1,000 exposed adults, respectively.
    - DSHS considers children and adults exposed to the low middle, middle and high levels of hexavalent chromium contaminated water to be at increased risk for cancer.

**Table 2 Estimated chronic exposure dose, chronic hazardous quotient, and cancer risk estimations for central tendency exposure (CTE) and reasonable maximum exposure (RME) for hexavalent chromium at the lowest exposure point concentration (1 µg/L)**

| Exposure Group | Chronic Exposure Dose[1] (mg/kg/day) CTE[3] | Chronic Exposure Dose[1] (mg/kg/day) RME[4] | Chronic Hazard Quotient[2] CTE | Chronic Hazard Quotient[2] RME | Cancer Risk CTE | Cancer Risk RME | Cancer Risk ED[5] (yrs) |
|---|---|---|---|---|---|---|---|
| **Birth to < 1 year** | 6.5E-05 | 1.4E-04 | 0.072 | 0.160 | 9E-6 | 3E-5 | 1 |
| **1 to < 2 years** | 2.7E-05 | 7.8E-05 | 0.030 | 0.087 | 9E-6 | 3E-5 | 1 |
| **2 to < 6 years** | 2.2E-05 | 5.6E-05 | 0.024 | 0.062 | 9E-6 | 3E-5 | 4 |
| **6 to < 11 years** | 1.6E-05 | 4.4E-05 | 0.018 | 0.049 | 9E-6 | 3E-5 | 5 |
| **11 to < 16 years** | 1.1E-05 | 3.5E-05 | 0.012 | 0.039 | 9E-6 | 3E-5 | 5 |
| **16 to < 21 years** | 1.1E-05 | 3.4E-05 | 0.012 | 0.038 | 9E-6 | 3E-5 | 5 |
| **Adult** | 1.5E-05 | 3.9E-05 | 0.017 | 0.043 | 1E-6 | 8E-6 | 33 |
| **Pregnant Women** | 1.2E-05 | 3.5E-05 | 0.013 | 0.039 | NC | NC | NC |
| **Lactating Women** | 2.3E-05 | 4.9E-05 | 0.025 | 0.055 | NC | NC | NC |

1. mg/kg/day: milligram of chromium per kilogram of body weight per day.
2. Chronic hazardous quotient: exposure dose divided by the intermediate minimum risk level.
3. CTE: central tendency exposure, which is referring to individuals who have an average or typical water consumption rate.
4. RME: reasonable maximum exposure, which is referring to individuals who are at the upper end of the exposure distribution (about the 95%).
5. ED: exposure duration; yrs: years
6. NC: not calculated. Cancer risks are not calculated for pregnant women and lactating women because their cancer risks are similar to an adult woman exposed for 33 years

**Table 3 Estimated chronic exposure dose, non-cancer hazardous quotient, and cancer risk estimations for central tendency exposure (CTE) and reasonable maximum exposure (RME) for hexavalent chromium at the low exposure point concentration (9 µg/L)**

| Exposure Group | Chronic Exposure Dose[1] (mg/kg/day) CTE[3] | Chronic Exposure Dose[1] (mg/kg/day) RME[4] | Chronic Hazard Quotient[2] CTE | Chronic Hazard Quotient[2] RME | Cancer Risk CTE | Cancer Risk RME | Cancer Risk ED[5] (yrs) |
|---|---|---|---|---|---|---|---|
| **Birth to < 1 year** | 0.00058 | 0.0013 | 0.65 | 1.4 | 8E-5 | 2E-4 | 1 |
| **1 to < 2 years** | 0.00024 | 0.00071 | 0.27 | 0.78 | 8E-5 | 2E-4 | 1 |
| **2 to < 6 years** | 0.00019 | 0.00051 | 0.22 | 0.56 | 8E-5 | 2E-4 | 4 |
| **6 to < 11 years** | 0.00014 | 0.00040 | 0.16 | 0.44 | 8E-5 | 2E-4 | 5 |
| **11 to < 16 years** | 0.00010 | 0.00031 | 0.11 | 0.35 | 8E-5 | 2E-4 | 5 |
| **16 to < 21 years** | 0.00010 | 0.00031 | 0.11 | 0.34 | 8E-5 | 2E-4 | 5 |
| **Adult** | 0.00014 | 0.00035 | 0.15 | 0.39 | 1E-5 | 7E-5 | 33 |
| **Pregnant Women** | 0.00011 | 0.00032 | 0.12 | 0.35 | NC | NC | NC |
| **Lactating Women** | 0.00021 | 0.00044 | 0.23 | 0.49 | NC | NC | NC |

1. mg/kg/day: milligram of chromium per kilogram of body weight per day.
2. Chronic hazardous quotient: exposure dose divided by the intermediate minimum risk level
3. CTE: central tendency exposure, which is referring to individuals who have an average or typical water consumption rate.
4. RME: reasonable maximum exposure, which is referring to individuals who are at the upper end of the exposure distribution (about the 95%).
5. ED: exposure duration; yrs: years
6. NC: not calculated. Cancer risks are not calculated for pregnant women and lactating women because their cancer risks are similar to an adult woman exposed for 33 years

**Table 4 Estimated chronic exposure dose, non-cancer hazardous quotient, and cancer risk estimations for central tendency exposure (CTE) and reasonable maximum exposure (RME) for hexavalent chromium at the low middle exposure point concentration (50 µg/L)**

| Exposure Group | Chronic Exposure Dose[1] (mg/kg/day) CTE[3] | Chronic Exposure Dose[1] (mg/kg/day) RME[4] | Chronic Hazard Quotient[2] CTE | Chronic Hazard Quotient[2] RME | Cancer Risk CTE | Cancer Risk RME | Cancer Risk ED[5] (yrs) |
|---|---|---|---|---|---|---|---|
| **Birth to < 1 year** | 0.0032 | 0.0071 | 3.6 | 7.9 | 5E-4 | 1E-3 | 1 |
| **1 to < 2 years** | 0.0014 | 0.0039 | 1.5 | 4.4 | 5E-4 | 1E-3 | 1 |
| **2 to < 6 years** | 0.0011 | 0.0028 | 1.2 | 3.1 | 5E-4 | 1E-3 | 4 |
| **6 to < 11 years** | 0.0008 | 0.0022 | 0.89 | 2.5 | 5E-4 | 1E-3 | 5 |
| **11 to < 16 years** | 0.00056 | 0.0017 | 0.62 | 1.9 | 5E-4 | 1E-3 | 5 |
| **16 to < 21 years** | 0.00054 | 0.0017 | 0.6 | 1.9 | 5E-4 | 1E-3 | 5 |
| **Adult** | 0.00077 | 0.0019 | 0.85 | 2.1 | 6E-5 | 4E-4 | 33 |
| **Pregnant Women** | 0.0006 | 0.0018 | 0.66 | 2.0 | NC | NC | NC |
| **Lactating Women** | 0.0011 | 0.0025 | 1.3 | 2.7 | NC | NC | NC |

1. mg/kg/day: milligram of chromium per kilogram of body weight per day.
2. Chronic hazardous quotient: exposure dose divided by the intermediate minimum risk level
3. CTE: central tendency exposure, which is referring to individuals who have an average or typical water consumption rate.
4. RME: reasonable maximum exposure, which is referring to individuals who are at the upper end of the exposure distribution (about the 95%).
5. ED: exposure duration; yrs: years
6. NC: not calculated. Cancer risks are not calculated for pregnant women and lactating women because their cancer risks are similar to an adult woman exposed for 33 year

**Table 5 Estimated chronic exposure dose, non-cancer hazardous quotient, and cancer risk estimations for central tendency exposure (CTE) and reasonable maximum exposure (RME) for hexavalent chromium at the middle exposure point concentration (75 µg/L)**

| Exposure Group | Chronic Exposure Dose[1] (mg/kg/day) CTE[3] | Chronic Exposure Dose[1] (mg/kg/day) RME[4] | Chronic Hazard Quotient[2] CTE | Chronic Hazard Quotient[2] RME | Cancer Risk CTE | Cancer Risk RME | Cancer Risk ED[5] (yrs) |
|---|---|---|---|---|---|---|---|
| **Birth to < 1 year** | 0.0048 | 0.0110 | 5.4 | 12 | 7E-4 | 2E-3 | 1 |
| **1 to < 2 years** | 0.0020 | 0.0059 | 2.3 | 6.5 | 7E-4 | 2E-3 | 1 |
| **2 to < 6 years** | 0.0016 | 0.0042 | 1.8 | 4.7 | 7E-4 | 2E-3 | 4 |
| **6 to < 11 years** | 0.0012 | 0.0033 | 1.3 | 3.7 | 7E-4 | 2E-3 | 5 |
| **11 to < 16 years** | 0.00084 | 0.0026 | 0.93 | 2.8 | 7E-4 | 2E-3 | 5 |
| **16 to < 21 years** | 0.00081 | 0.0026 | 0.90 | 2.8 | 7E-4 | 2E-3 | 5 |
| **Adult** | 0.0012 | 0.0029 | 1.3 | 3.2 | 9E-5 | 6E-4 | 33 |
| **Pregnant Women** | 0.0009 | 0.0027 | 1.0 | 3.0 | NC | NC | NC |
| **Lactating Women** | 0.0017 | 0.0037 | 1.9 | 4.1 | NC | NC | NC |

1. mg/kg/day: milligram of chromium per kilogram of body weight per day.
2. Chronic hazardous quotient: exposure dose divided by the intermediate minimum risk level.
3. CTE: central tendency exposure, which is referring to individuals who have an average or typical water consumption rate.
4. RME: reasonable maximum exposure, which is referring to individuals who are at the upper end of the exposure distribution (about the 95%).
5. ED: exposure duration; yrs: years
6. NC: not calculated. Cancer risks are not calculated for pregnant women and lactating women because their cancer risks are similar to an adult woman exposed for 33 year

**Table 6 Estimated chronic exposure dose, non-cancer hazardous quotient, and cancer risk estimations for central tendency exposure (CTE) and reasonable maximum exposure (RME) for hexavalent chromium at the high exposure point concentration (180 µg/L)**

| Exposure Group | Chronic Exposure Dose[1] (mg/kg/day) CTE[3] | Chronic Exposure Dose[1] (mg/kg/day) RME[4] | Chronic Hazard Quotient[2] CTE | Chronic Hazard Quotient[2] RME | Cancer Risk CTE | Cancer Risk RME | Cancer Risk ED[5] (yrs) |
|---|---|---|---|---|---|---|---|
| **Birth to < 1 year** | 0.0120 | 0.026 | 13 | 29 | 2E-3 | 5E-3 | 1 |
| **1 to < 2 years** | 0.0049 | 0.014 | 5.4 | 16 | 2E-3 | 5E-3 | 1 |
| **2 to < 6 years** | 0.0039 | 0.010 | 4.3 | 11 | 2E-3 | 5E-3 | 4 |
| **6 to < 11 years** | 0.0029 | 0.0079 | 3.2 | 8.8 | 2E-3 | 5E-3 | 5 |
| **11 to < 16 years** | 0.0020 | 0.0063 | 2.2 | 7.0 | 2E-3 | 5E-3 | 5 |
| **16 to < 21 years** | 0.0019 | 0.0061 | 2.2 | 6.8 | 2E-3 | 5E-3 | 5 |
| **Adult** | 0.0028 | 0.0070 | 3.1 | 7.7 | 2E-4 | 2E-3 | 33 |
| **Pregnant Women** | 0.0022 | 0.0064 | 2.4 | 7.1 | NC[6] | NC[6] | NC[6] |
| **Lactating Women** | 0.0041 | 0.0088 | 4.6 | 9.8 | NC | NC | NC |

1. mg/kg/day: milligram of chromium per kilogram of body weight per day.
2. Chronic hazardous quotient: exposure dose divided by the intermediate minimum risk level.
3. CTE: central tendency exposure, which is referring to individuals who have an average or typical water consumption rate.
4. RME: reasonable maximum exposure, which is referring to individuals who are at the upper end of the exposure distribution (about the 95%).
5. ED: exposure duration; yrs: years
6. NC: not calculated. Cancer risks are not calculated for pregnant women and lactating women because their cancer risks are similar to an adult woman exposed for 33 years.

**Table 7 Calculated margin of exposures (MOEs) for chromium exposure point concentrations (EPC) at 50 micrograms per liter (µg/L), 75 µg/L and 180 µg/L for both central tendency exposure (CTE) and reasonable maximum exposure (RME) scenarios**

| Exposure Point Concentration (µg/L) | Exposure Group | MOE[1] for $BMDL_{10}$[2] CTE[3] | MOE[1] for $BMDL_{10}$[2] RME[4] |
|---|---|---|---|
| 50 | Birth to < 1 year | 28 | 13 |
| 50 | 1 to < 2 years | 64 | 23 |
| 50 | 2 to < 6 years | 82 | 32 |
| 50 | 6 to < 11 years | 113 | 41 |
| 50 | 11 to < 16 years | 161 | 53 |
| 50 | 16 to < 21 years | 167 | 53 |
| 50 | Adult | 117 | 47 |
| 50 | Pregnant Women | 150 | 50 |
| 50 | Lactating Women | 82 | 36 |
| 75 | Birth to < 1 year | 19 | 8 |
| 75 | 1 to < 2 years | 45 | 15 |
| 75 | 2 to < 6 years | 56 | 21 |
| 75 | 6 to < 11 years | 75 | 27 |
| 75 | 11 to < 16 years | 107 | 35 |
| 75 | 16 to < 21 years | 111 | 35 |

| Exposure Point Concentration (µg/L) | Exposure Group | MOE[1] for $BMDL_{10}$[2] CTE[3] | MOE[1] for $BMDL_{10}$[2] RME[4] |
|---|---|---|---|
| 75 | Adult | 75 | 31 |
| 75 | Pregnant Women | 100 | 33 |
| 75 | Lactating Women | 53 | 24 |
| 180 | Birth to < 1 year | 8 | 3 |
| 180 | 1 to < 2 years | 18 | 6 |
| 180 | 2 to < 6 years | 23 | 9 |
| 180 | 6 to < 11 years | 31 | 11 |
| 180 | 11 to < 16 years | 45 | 14 |
| 180 | 16 to < 21 years | 47 | 15 |
| 180 | Adult | 32 | 13 |
| 180 | Pregnant Women | 41 | 14 |
| 180 | Lactating Women | 22 | 10 |

1. MOE: margin of exposure, which is calculated using the estimated exposure dose divided by the $BMDL_{10}$. Bold values indicate MOE less than 18.
2. $BMDL_{10}$: benchmark dose, which is an estimate of (using modeling software) the lower confidence limit of the dose that would cause 10% increase in the incidence of a particular adverse health effect.
3. CTE: central tendency exposure, which is referring to individuals who have an average or typical water consumption rate.
4. RME: reasonable maximum exposure, which is referring to individuals who are at the upper end of the exposure distribution (about the 95%).

## Limitations

This health consultation has several limitations, some of which are listed below.

- DSHS cannot be certain that the collected water samples fully captured the temporal variation of impacted wells. Samples were collected over limited and varying time frames. Failure events in drinking water filtration systems have been observed. As a result, the actual health risk due to chromium exposures could be over- or underestimated, depending on the operating conditions of residential well water filtration systems. The actual exposure doses may be under- or over-estimated due to a high proportion of non-detects for some wells.

- Evaluation of potential (hypothetical) future chromium exposures was determined assuming total chromium concentration is made up entirely of hexavalent chromium. This assumption was based on the results from a water analysis collected from a subset of wells (41) at the site, which showed hexavalent chromium to make up 98 to 99 percent of the total chromium.

- DSHS used ATSDR's default assumptions to estimate potential (hypothetical) future drinking water exposure doses. This could lead to over- or underestimated potential exposure doses depending on how much water residents in each household drank over time.

- Other chemicals have been detected in groundwater samples collected by EPA and TCEQ (Appendix B). However, post-filtration water data is not available for these non-site related chemicals of interest. Therefore, DSHS cannot estimate the drinking water exposure doses for non-site related chemicals. Furthermore, DSHS cannot assess exposures of chemical mixtures because of the lack of enough information on other chemicals.

# Conclusions

Based on the available information, DSHS reached the following two conclusions.

### Conclusion 1

If residents were exposed (hypothetically) to chromium continuously (above 50 μg/L) in some private groundwater wells at the West County Road 112 site could harm people's health by causing non-cancer health effects, such as mild changes to the cells linking the small intestines and liver inflammation. Long-term exposure to chromium (above 9 µg/L) could also increase people's cancer risk.

Basis for Conclusion

The results of DSHS's evaluation suggested that:

- If people were exposed continuously to levels ranging from 50 µg/L to 75 µg/L, there could be an increased chance of developing chronic non-cancer health effects for children less than 1 year old with a high exposure scenario (RME). Seven (7) out of the 51 wells sampled after filtration had estimated EPCs ranging from 50 µg/L to 75 µg/L.

- If people were exposed continuously to levels ranging from 75 µg/L to 180 µg/L, there is an increased risk for chronic non-cancer health effects for children less than 2 years old at the high end of the exposure (RME). Six (6) out of the 51 sampled wells had estimated hexavalent chromium EPCs ranging from 75 µg/L to 180 µg/L.

- If people were exposed continuously to 180 µg/L or greater, there is an increased risk for chronic non-cancer health effects for children birth to less than 1 year old for typical exposure (CTE) and for all age groups for high exposure (RME) scenario. Six (6) out of the 51 sampled wells had estimated hexavalent chromium EPCs equal to or greater than 180 µg/L.

- If people were exposed to low (greater than 9 µg/L) concentrations of chromium in well water, there could be a low increased risk of cancer for adults, and increased risk of cancer for children.

- If people were exposed to low middle (50 µg/L), middle (75 µg/L) and high (180 µg/L) levels of chromium in well water, there could be an in increased risk of cancer for children and adults.

## Conclusion 2

DSHS does not have enough information to determine if past exposures (before 2009) to chromium in drinking water from these private water wells could have harm people's health.

Basis for Conclusion

- In 2009, the extent of groundwater contamination was not known and health effects of past ingestion of hexavalent chromium could not be assessed because the data was not available.

# Recommendations

The results of the health consultation show the potential of health risks from long-term continuous (hypothetical) exposure to some levels of chromium. Therefore, a long-term remedy is needed to prevent harmful exposures from occurring in the community.

- As a long-term solution for the protection of public health, the city of Midland is encouraged to consider extending the waterline to homes impacted by groundwater chromium contamination. Public drinking water systems ensure that residents get high quality water because they must meet health-based federal standards for contaminants, including performing regular monitoring and reporting.

- EPA and TCEQ are encouraged to continue current efforts to protect the health of residents.

    - EPA reports all wells with chromium concentrations above the primary drinking water standard (the MCL) to TCEQ to have filtration systems installed. Therefore, adverse health effects are not expected from drinking well water currently or in the future. EPA is encouraged to report any well that has chromium exceedances above 9 μg/L to TCEQ as soon as possible. This may reduce the residents' exposures to chromium from drinking water.
    - Continue groundwater sampling efforts to fully characterize the hexavalent chromium plume and identify all wells that might be affected.
    - Continue to provide alternative water and/or an onsite water filtration system to residents whose domestic well water contains levels of hexavalent chromium that might harm their health. At homes with treatment systems, sample domestic well water both pre- and post-treatment at least quarterly to ensure the systems' effectiveness for removing chromium and other inorganic compounds.

- Additionally, EPA and TCEQ are encouraged to:

    - Continue efforts to gain access to domestic wells at households that may be affected by the site but have not been previously or recently sampled.
    - Provide and evaluate post-treatment results for other inorganic compounds.
    - Gather demographic information for households relying on private domestic well water to determine if sensitive individuals (like infants and pregnant women) are using the wells. This data helps prioritize households for monitoring and/or remedial action as necessary.

- Residents with specific health concerns should consult their family physician.

- Residents are encouraged to have their post-filtration water tested for metals, including arsenic and lead, by an independent certified laboratory to ensure the safety of their water.

# Public Health Action Plan

No public meetings are scheduled at this time but DSHS will attend future meetings as needed. DSHS will continue to work with TCEQ and EPA to review data and provide technical assistance, as requested.

Preparers of Report

The Texas Department of State Health Services (DSHS) prepared this Health Consultation for the West County Road 112 site, located in Midland (Midland County) Texas. This publication was made possible by Grant Number NU61TS000304 under a cooperative agreement 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 Texas Department of State Health Services.

## Authors:

Hsin-I Lin, ScD
Health Assessment and Toxicology Program
Texas Department of State Health Services (DSHS)- Austin, Texas

Emily Hall, MPH
Environmental Surveillance and Toxicology Branch
Texas Department of State Health Services (DSHS)-Austin, Texas

## State Reviewers

Jessica Kessinger, MPH
Health Assessment and Toxicology Program
Texas Department of State Health Services (DSHS)-Austin, Texas

Heidi Bojes, PhD, MPH
Environmental Epidemiology and Disease Registries
Texas Department of State Health Services (DSHS)- Austin, Texas

## State Accessibility Reviewer

Jessica Price, MS
Texas Department of State Health Services (DSHS)- Austin, Texas

## ATSDR Cooperative Agreement Coordinator and Technical Project Officer

Audra Henry, MS
Cooperative Agreement Coordinator
Office of Capacity Development and Applied Prevention Science (OCDAPS)

John Truhe, MPH
Technical Project Officer
Office of Capacity Development and Applied Prevention Science (OCDAPS)

## ATSDR Regional Representative

Egide Louis, PhD
Region 6 Director
Office of Community Health and Hazard Assessment (OCHHA)

# References

[ACS] American Cancer Society. 2019. Lifetime risk of developing or dying from cancer. Available at: https://www.cancer.org/cancer/cancer-basics/lifetime-probability-of-developing-or-dying-from-cancer.html. Last accessed: October 2019.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2004. Toxicological Profile for Copper. United States Department of Health and Human Services: Atlanta, Georgia.

[ATSDR] Agency for Toxic Substances and Disease Registry. January 2005. Public Health Assessment Guidance Manual.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2007. Toxicological Profile for Arsenic. United States Department of Health and Human Services: Atlanta, Georgia.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2007. Toxicological Profile for Lead. United States Department of Health and Human Services: Atlanta, Georgia.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2009. Evaluation of Chromium in Private Wells, West County Road 112, Midland, Midland County, Texas. Prepared by Texas Department of State Health Services. June 3, 2009.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2012. Toxicological Profile for Cadmium. United States Department of Health and Human Services: Atlanta, Georgia.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2012. Toxicological Profile for Chromium. United States Department of Health and Human Services: Atlanta, Georgia.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2012. Toxicological Profile for Manganese. United States Department of Health and Human Services: Atlanta, Georgia.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2015. Toxicological Profile for Barium. United States Department of Health and Human Services: Atlanta, Georgia.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2019. Exposure Point Concentration Guidance for Discrete Sampling. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, July 12.

[CalEPA] California Environmental Protection Agency. 2011. Public Health Goals for Chemicals in Drinking Water. Hexavalent Chromium (Cr VI). Available at: https://oehha.ca.gov/water/public-health-goals-phgs. Last accessed: October 2019.

[EA] EA Engineering, Science and Technology. Inc. 2013. Conceptual Understanding of the Site Technical Memorandum. Remedial Investigation/ Feasibility Study. West County Road 112 Ground Water Plume Site, Midland, Midland County, Texas.

Fernando, G., Trevizam, A., Muraoka, T., Marcante, N., Canniatti-Brazaca, S. Heavy metals in vegetables and potential for human health. Sci. Agric., 2012. 69(1): p. 54-60.

[Health Canada] Guidelines for Canadian Drinking Water Quality: Guideline Technical Document Chromium. 2018. Available at: https://www.canada.ca/en/health-canada/services/publications/healthy-living/guidelines-canadian-drinking-water-quality-guideline-technical-document-chromium.html#a93. Last accessed: June 2020.

McCarroll, N., Keshava, N., Chen, J., Akerman, G., Kligerman, A. and Rinde, E. An evaluation of the mode of action framework for mutagenic carcinogens case study II: Chromium (VI). Environ. Mol. Mutagen., 2010. 51:p 89-111.

[NTP] National Toxicology Program. 2008. Toxicology and carcinogenesis studies of sodium dichromate dihydrate (Cas No. 7789-12-0) in F344/N rats and B6C3F1 mice (drinking water studies). Natl Toxicol Program Tech Rep Ser, (546): p. 1-192

Pan, XD., Wu, PG. & Jiang, XG. Levels and potential health risk of heavy metals in marketed vegetables in Zhejiang, China. Sci. Rep., 2016. 6:20317.

[TCEQ] Texas Commission of Environmental Quality. 2010(a). Expanded Site Inspection Report, West County Road 112 Groundwater, Midland County, Texas. TXN000606992, Volume 1 of IV.

[TCEQ] Texas Commission on Environmental Quality. 2010(b). Meeting with Superfund staff regarding private water well testing and filtration. September 23, 2010.

[USEPA] U.S. Environmental Protection Agency. 2005. Toxic chemical release inventory reporting forms and instructions. Office of Environmental Information.

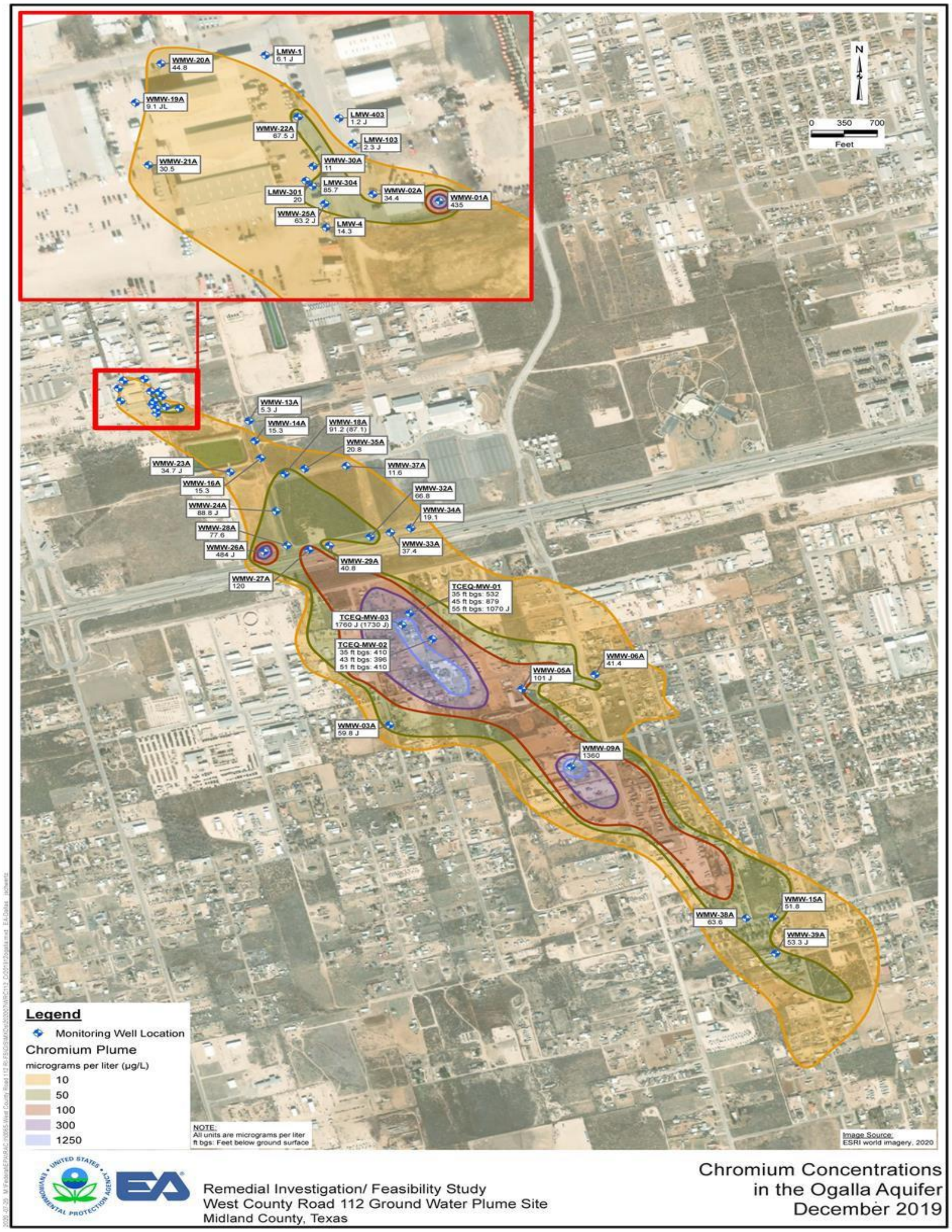
[USEPA] U.S. Environmental Protection Agency. 2010. Hazardous Ranking System (HRS), E.R. 6, Editor. Midland County, Texas.

[USEPA] U.S. Environmental Protection Agency. 2019. Integrated Risk Information System (IRIS). Available at: https://cfpub.epa.gov/ncea/iris_drafts/recordisplay.cfm?deid=221433. Last accessed: October 2019.

[USEPA] U.S. Environmental Protection Agency. 2021. National Primary Drinking Water Regulations. Available at: https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations. Last accessed: August 2021.

# Appendix A

### Figure A-1 Extent of chromium detections in groundwater, Midland, Texas



# Appendix B

**Table B 1. Screening analysis for post-filtration total chromium groundwater data sampled from 2009 to 2018**

| Well ID | Concentration range µg/L | Number of samples [number detected] | EPC µg/L (method*) | Did EPC exceed MCL? [number exceeded] | Did EPC exceed EMEG? [number exceeded] | Did EPC exceed CREG? [number exceeded] |
|---|---|---|---|---|---|---|
| **GW-011** | 0.557—1,010 | 27 [6] | 140 (percentile bootstrap[a]) | Yes [2] | Yes [4] | Yes [6] |
| **GW-019** | NA | 22[1] | 1 (maximum) | No [0] | No [0] | Yes [1] |
| **GW-020** | 1.72—465 | 27 [13] | 72 (percentile bootstrap[a]) | Yes [2] | Yes [4] | Yes [13] |
| **GW-023** | 0.567—887 | 27 [15] | 130 (percentile bootstrap[a]) | Yes [3] | Yes [7] | Yes [15] |
| **GW-029** | 1.4—35.4 | 19 [7] | 35 (lognormal[b]) | No [0] | Yes [3] | Yes [7] |
| **GW-038** | 2.65—98.9 | 12 [4] | 43 (gamma[c]) | No [0] | Yes [3] | Yes [4] |
| **GW-042** | 2.39—31 | 25[4] | 31 (maximum) | No [0] | Yes [1] | Yes [4] |
| **GW-043** | 0.67—428 | 27[4] | 428 (maximum) | Yes [1] | Yes [1] | Yes [4] |
| **GW-044** | 1.21—65 | 26 [7] | 9 (percentile bootstrap[a]) | No [0] | Yes [1] | Yes [7] |
| **GW-045** | 1.24—866 | 26 [15] | 190 (percentile bootstrap[a]) | Yes [5] | Yes [8] | Yes [15] |

| Well ID | Concentration range µg/L | Number of samples [number detected] | EPC µg/L (method*) | Did EPC exceed MCL? [number exceeded] | Did EPC exceed EMEG? [number exceeded] | Did EPC exceed CREG? [number exceeded] |
|---|---|---|---|---|---|---|
| **GW-046** | 2.84—1,090 | 21 [14] | 270 (percentile bootstrap[a]) | Yes [4] | Yes [8] | Yes [14] |
| **GW-047** | 1.16—27 | 27 [8] | 5.4 (percentile bootstrap[a]) | No [0] | Yes [4] | Yes [8] |
| **GW-048** | 0.535—7 | 23[4] | 7 (maximum) | No [0] | Yes [1] | Yes [4] |
| **GW-049** | 2—10 | 27[5] | 10 (maximum) | No [0] | Yes [2] | Yes [5] |
| **GW-050** | 0.789—10 | 27[4] | 10 (maximum) | No [0] | Yes [1] | Yes [4] |
| **GW-064** | 0.961—302 | 21 [13] | 63 (percentile bootstrap[a]) | Yes [2] | Yes [5] | Yes [13] |
| **GW-080** | 2—10 | 25[3] | 10 (maximum) | No [0] | Yes [1] | Yes [3] |
| **GW-081** | 2—10 | 25[2] | 10 (maximum) | No [0] | Yes [1] | Yes [2] |
| **GW-086** | 3.12—10 | 25[4] | 10 (maximum) | No [0] | Yes [2] | Yes [4] |
| **GW-090** | 1—8 | 27[2] | 8 (maximum) | No [0] | Yes [1] | Yes [2] |
| **GW-091** | 0.575—1,410 | 25 [16] | 180 (percentile bootstrap[a]) | Yes [2] | Yes [3] | Yes [16] |
| **GW-092** | 0.715—331 | 27 [12] | 39 (percentile bootstrap[a]) | Yes [1] | Yes [4] | Yes [12] |

| Well ID | Concentration range µg/L | Number of samples [number detected] | EPC µg/L (method*) | Did EPC exceed MCL? [number exceeded] | Did EPC exceed EMEG? [number exceeded] | Did EPC exceed CREG? [number exceeded] |
|---|---|---|---|---|---|---|
| **GW-093** | 1—3.8 | 26 [6] | 1.9 (percentile bootstrap[a]) | No [0] | No [0] | Yes [6] |
| **GW-094** | 2—36.8 | 27 [9] | 7.2 (percentile bootstrap[a]) | No [0] | Yes [3] | Yes [9] |
| **GW-095** | 1—51 | 26 [9] | 8.6 (percentile bootstrap[a]) | No [0] | Yes [3] | Yes [9] |
| **GW-096** | 1—218 | 25 [20] | 58 (percentile bootstrap[a]) | Yes [5] | Yes [9] | Yes [20] |
| **GW-097** | 1—1,180 | 25 [16] | 180 (percentile bootstrap[a]) | Yes [3] | Yes [6] | Yes [16] |
| **GW-098** | 2—82.9 | 14 [6] | 30 (gamma[c]) | No [0] | Yes [3] | Yes [6] |
| **GW-099** | 1—286 | 22 [6] | 48 (percentile bootstrap[a]) | Yes [2] | Yes [2] | Yes [6] |
| **GW-100** | 1.16—165 | 26[5] | 165 (maximum) | Yes [1] | Yes [2] | Yes [5] |
| **GW-101** | 2.38—91.8 | 26 [17] | 17 (percentile bootstrap[a]) | No [0] | Yes [5] | Yes [17] |
| **GW-102** | 3—3.41 | 25[2] | 3.41 (maximum) | No [0] | No [0] | Yes [2] |
| **GW-103** | 0.803—57.1 | 25 [7] | 9.9 (percentile bootstrap[a]) | No [0] | Yes [3] | Yes [7] |
| **GW-104** | 1.14—9 | 25[4] | 9 (maximum) | No [0] | Yes [1] | Yes [4] |

| Well ID | Concentration range µg/L | Number of samples [number | EPC µg/L (method*) | Did EPC exceed MCL? [number exceeded] | Did EPC exceed EMEG? [number exceeded] | Did EPC exceed CREG? [number exceeded] |
|---|---|---|---|---|---|---|
| **GW-105** | 2—76 | 14[3] | 76 (maximum) | No [0] | Yes [2] | Yes [3] |
| **GW-108** | 0.669—169 | 22 [8] | 24 (percentile bootstrap[a]) | Yes [1] | Yes [1] | Yes [8] |
| **GW-125** | 1.37—5.37 | 21 [5] | 2.9 (percentile bootstrap[a]) | No [0] | No [0] | Yes [5] |
| **GW-126** | 0.521—68 | 27 [10] | 12 (percentile bootstrap[a]) | No [0] | Yes [3] | Yes [10] |
| **GW-146** | 1.41—234 | 25 [13] | 33 (percentile bootstrap[a]) | Yes [1] | Yes [4] | Yes [13] |
| **GW-150** | 1—326 | 63 [48] | 69 (percentile bootstrap[a]) | Yes [16] | Yes [29] | Yes [48] |
| **GW-151** | 2.11—181 | 19 [11] | 24 (lognormal[b]) | Yes [1] | Yes [3] | Yes [11] |
| **GW-176** | 2.05—260 | 51 [38] | 73 (percentile bootstrap[a]) | Yes [11] | Yes [21] | Yes [38] |
| **GW-187** | 2.53—234 | 40 [29] | 60 (percentile bootstrap[a]) | Yes [6] | Yes [6] | Yes [29] |
| **GW-254** | 0.699—214 | 24[4] | 214 (maximum) | Yes [1] | Yes [1] | Yes [4] |
| **GW-259** | 0.892—37.9 | 23 [5] | 5.7 (percentile bootstrap[a]) | No [0] | Yes [1] | Yes [5] |
| **GW-260** | NA | 1[0] | NA (maximum) | NA | NA | NA |

| Well ID | Concentration range µg/L | Number of samples [number detected] | EPC µg/L (method*) | Did EPC exceed MCL? [number exceeded] | Did EPC exceed EMEG? [number exceeded] | Did EPC exceed CREG? [number exceeded] |
|---|---|---|---|---|---|---|
| **GW-261** | 2—3.92 | 22[2] | 3.92 (maximum) | No [0] | No [0] | Yes [2] |
| **GW-292** | 2.11—72.5 | 19 [18] | 66 (percentile bootstrap[a]) | No [0] | Yes [9] | Yes [18] |
| **GW-299** | 2.11—433 | 21 [18] | 130 (lognormal[b]) | Yes [5] | Yes [11] | Yes [18] |
| **GW-313** | 0.62—84.3 | 40[7] | 84.3 (maximum) | No [0] | Yes [2] | Yes [7] |
| **GW-563** | 1.41—48.2 | 19 [5] | 14 (lognormal[b]) | No [0] | Yes [1] | Yes [5] |

Notes:
EPC: exposure point concentration; MCL: EPA maximum contaminant level; EMEG = ATSDR's chronic environmental media evaluation guides; and CREG: ATSDR's cancer risk evaluation guide.
*Method used to obtain EPC. Maximum = maximum value was used as the EPC; 95% UCL = 95% upper confidence limit of the mean was taken as the EPC. Various distributions and sampling methods were used to obtain 95% UCLs, including a) Percentile bootstrap: Resampling with replacement methods were used on original well values to estimate a sampling distribution, from which the 95% UCL of the sampling distribution was obtained (the 97.5$^{th}$ percentile); b) lognormal: used for data where the logarithm (ln) of values is normally distributed, and the 95% UCL is obtained using log-transformed values/the lognormal distribution; c) gamma: the 95% UCL is calculated using the gamma distribution, which is applied when values appear mostly normally distributed, but are over-dispersed (too much variance) and are skewed to the right, as is often seen with environmental data.

Multiple activities were conducted to investigate the site-related hazardous substances and the possible sources since 2009. Although no known sources were identified during the investigation, chromium was determined to be the contaminant of concern for the site. EPA and TCEQ collected untreated groundwater samples from impacted domestic wells to evaluate the need for filtration systems to remove elevated levels of chromium. The untreated groundwater samples were also analyzed for other metals.

During the evaluation process, DSHS reviewed the chemical concentrations in the untreated groundwater samples and compared them to ATSDR's health-based comparison values (CVs). DSHS found that some of the untreated groundwater samples containing barium, cadmium, copper, lead, manganese, selenium, and vanadium exceeding their CVs (Table B 1). These metals were also detected in some of the background samples. As mentioned previously, when a chemical concentration exceeds a CV, it does not necessarily mean there is a health concern. A further evaluation using site-specific exposure parameters (i.e. post-filtration chemical concentrations, exposure frequency, and exposure duration) will provide a more realistic estimatio

**Table B 2. Results of screening analysis for untreated (unfiltered) groundwater samples collected from 2010 to 2016**

| Chemical | Detected Concentration Ranges (ppb[1]) | Total number of wells sampled | Frequency of Detects[2] | ATSDR's comparison value (ppb) | Number of samples exceeding ATSDR's comparison value[g] |
|---|---|---|---|---|---|
| **Arsenic** | ND[6] – 119 | 193 | 540/795 | 0.016 (CREG[3]) | 795 |
| **Barium** | ND – 2,940 | 193 | 654/791 | 1,400 (EMEGc[4]) | 2 |
| **Cadmium** | ND – 1.5 | 193 | 1/791 | 0.7 (EMEGc) | 789 |
| **Copper** | ND – 652 | 193 | 289/789 | 70 (EMEGc) | 40 |
| **Lead** | ND – 187 | 193 | 182/791 | NA[5] | – |
| **Manganese** | ND – 414 | 193 | 59/789 | NA | 1 |
| **Selenium** | ND – 419 | 193 | 628/791 | 35 (EMEGc) | 189 |
| **Vanadium** | ND – 166 | 193 | 365/789 | 70 (EMEGc) | 82 |

1. ppb: parts per billion
2. Frequency of detects is presented by the total number of detected samples/total number of collected samples
3. CREG: Cancer Risk Evaluation Guide
4. EMEGc: Environmental Media Evaluation Guide for children. EMEGs are estimated contaminant concentrations in a media where noncancer health effects are not likely to occur over a specific duration of exposure. EMEGs are derived from ATSDR's minimal risk levels (MRLs)
5. NA: not available
6. Non-detection (ND) results were given the value of the reporting limit when screened against the corresponding comparison value.

DSHS could not quantify the potential health impacts because the post-filtration concentrations are not available for these chemicals. Post-filtration concentrations represent the actual amount of chemicals that may be in the tap water used for domestic purposes. Therefore, well owners are encouraged to have their post-filtration water tested for these metals by an independent certified laboratory to ensure the safety of their water. Additional information regarding potential health impacts and recommended standards (or health guidelines) of these metals are listed below.

**Table B 3. Potential health impact for selected chemicals**

| Chemical | Standards or Health Guidelines (mg/L) | Sources | Potential Health Impacts for Exposure Above the Recommended Levels |
|---|---|---|---|
| Arsenic | 10 | EPA MCL[1] | Drinking water containing arsenic above the EPA MCL for a long time can cause problems in skin (e.g., skin discoloration and thickening), circulatory systems, and increased risk of getting cancer (e.g., skin, bladder, and prostate cancers) (ATSDR 2007). |
| Barium | 2,000 | EPA MCL | Drinking water containing barium above the EPA MCL for a short period of time can cause gut irritation and muscular weakness. Some people may experience vomiting, abdominal cramps, diarrhea, difficulties in breathing, increased or decreased blood pressure, and numbness around the face. (ATSDR 2015). |
| Cadmium | 5 | EPA MCL | Cadmium can build up in the kidneys after long-term consumption above EPA MCL from food or drinking water (ATSDR 2012). |
| Copper | 1,300 | EPA Action Level | Small amount of copper is important for good health; however, it can be harmful if too much is ingested from drinking water or food. Copper above the EPA action level can cause nausea, vomiting, and diarrhea. Drinking water containing high levels of copper for a long period time can damage liver or kidney (ATSDR 2004). |
| Lead | 0.015 | EPA Action Level | Nervous system is the main target for lead toxicity for children and adults. Children are more vulnerable to lead toxicity than adults. Long-term exposure can |

| Chemical | Standards or Health Guidelines (mg/L) | Sources | Potential Health Impacts for Exposure Above the Recommended Levels |
|---|---|---|---|
| | | | cause problems related to decreased learning, memory, and attention. It can also increase the chance of having kidney problems, high blood pressure, anemia, weakness in fingers, toes, or ankles (ATSDR 2007). |
| Manganese | 350 | Not available | Exposure to manganese can affect the nervous system, such as behavioral changes, and slow and clumsy movements. Children are more vulnerable to the manganese toxicity because they can absorb more manganese from their intestine. Studies showed that exposure to extreme high levels of manganese can affect brain development and decrease the ability to learn and remember (ATSDR 2012). |
| Selenium | 50 | EPA MCL | Small amount of selenium is essential for good health. Intake high levels of selenium for a long time can lead to selenosis causing fragile nail, hair loss, numbness in fingers and toes, and circulatory problems (ATSDR 2003). |
| Vanadium | 70 | ATSDR EMEGc[2] (ATSDR 2007) | Most foods contain low levels of vanadium, especially in seafoods. Ingesting high levels of vanadium may lead to nausea, mild diarrhea, and stomach cramps in people. Animals studies have showed that high levels of vanadium can cause decreases in number of red blood cells, increases in blood pressure, and mild neurological effects (ATSDR 2012). |

1. MCL: Maximum Contaminant Level. MCLs are enforceable standards set by EPA. MCLs are the highest level of a contaminant allowed in public drinking water. MCLs are set as close to the MCLGs (the level of a contaminant in drinking water below which there is no known or expected risk to health) as feasible using the best available treatment technology and taking cost into consideration.
2. EMEGc: Environmental Media Evaluation Guides for children. EMEGs are estimated contaminant concentrations in a media where noncancer health effects are not likely to occur over a specific duration of exposure. EMEGs are derived from ATSDR's minimal risk levels (MRLs).

# Appendix C

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 or site-specific exposure parameters from site-specific surveys or documents, and EPA's Exposure Factors Handbook when site-specific information is unknown.

The contaminant concentration for the water ingestion exposure dose is based on determined Exposure Point Concentration (EPC) for each well sampled. Age-specific ingestion rates and body weights can be seen in Table were used with the below formula to calculate age-specific estimated exposure doses for ingestion of drinking water from the corresponding well.

**Water Ingestion Exposure Dose Equation**

**D = (C x IR x EF) / BW**

**D** = Exposure Dose (mg/kg-day),
**C** = Contaminant Concentration (mg/L)
**IR** = Intake Rate (L/day),
**BW** = Body Weight (kg),
**EF non-cancer**= Exposure Factor (unitless) = 1,
**EF cancer** = EF non-cancer x Age-Specific Exposure Duration (years)/78 years (unitless)

**Table C 1. 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 |

**For example:**

Non-cancer Exposure dose calculation for adult at exposure concentration of 75 μg/L = 0.075 mg/L

*Central Tendency Exposure Scenario:*

**D** = 0.075 (mg/L) × 1.23 (L/day) × 1 / 80 (kg) = 0.0012 mg/kg/day

*Reasonable Maximum Exposure Scenario:*

**D** = 0.075 (mg/L) × 3.09 (L/day) × 1 / 80 (kg) = 0.0029 mg/kg/day

Cancer Exposure dose calculation for adult at exposure concentration of 75 μg/L = 0.075 mg/L

*Central Tendency Exposure Scenario:*

**D** = 0.075 (mg/L) × 1.23 (L/day) × 0.42 / 80 (kg) = 0.00048 mg/kg/day

*Reasonable Maximum Exposure Scenario:*

**D** = 0.075 (mg/L) × 3.09 (L/day) × 0.42 / 80 (kg) = 0.00122 mg/kg/day

**Water Ingestion Cancer Risk Equation**

**R** = D × SF
**R** = Cancer Risk,
**D** = Cancer Exposure Dose (mg/kg/day),
**SF** = Slope Factor (mg/kg/day)-1 = 0.5 (mg/kg/day)-1

**For Example: Cancer risk calculation for adults:**

Cancer risk for central tendency exposure scenario:
**R** = 0.00048 (mg/kg/day) × 0.5 $(mg/kg/day)^{-1}$ = 0.00024 = 2.4E-4
Cancer risk for reasonable maximum exposure scenario:
**R** = 0.00122 (mg/kg/day) × 0.5 $(mg/kg/day)^{-1}$ = 0.00061 = 6.1E-4

# Appendix D

**Table D 1. Summary of non-cancer and cancer risks for exposure groups based on the range of exposure point concentrations**

| Range of Exposure Point Concentrations (mg/L) | Exposure Group | Is there an increased chance for noncancer health effect? (CTE[1]) | Chance to develop cancer health effect (CTE) | Is there an increased risk for noncancer health effect? (RME[2]) | Chance to develop cancer health effect (RME) | List of wells with estimated Exposure Point Concentration in the range |
|---|---|---|---|---|---|---|
| <1 | Birth to < 1 year | No | unlikely increase in risk | No | unlikely increase in risk | GW-260 |
| <1 | 1 to < 2 years | No | unlikely increase in risk | No | unlikely increase in risk | GW-260 |
| <1 | 2 to < 6 years | No | unlikely increase in risk | No | unlikely increase in risk | GW-260 |
| <1 | 6 to < 11 years | No | unlikely increase in risk | No | unlikely increase in risk | GW-260 |
| <1 | 11 to < 16 years | No | unlikely increase in risk | No | unlikely increase in risk | GW-260 |
| <1 | 16 to < 21 years | No | unlikely increase in risk | No | unlikely increase in risk | GW-260 |
| <1 | Adult | No | unlikely increase in risk | No | unlikely increase in risk | GW-260 |
| <1 | Lactating Women | No | unlikely increase in risk | No | unlikely increase in risk | GW-260 |

| Range of Exposure Point Concentrations (mg/L) | Exposure Group | Is there an increased chance for noncancer health effect? (CTE[1]) | Chance to develop cancer health effect (CTE) | Is there an increased risk for noncancer health effect? (RME[2]) | Chance to develop cancer health effect (RME) | List of wells with estimated Exposure Point Concentration in the range |
|---|---|---|---|---|---|---|
| <1 | Pregnant Women | No | unlikely increase in risk | No | unlikely increase in risk | GW-260 |
| 1—<9 | Birth to < 1 year | No | low increased risk | No | low increased risk | GW-019, GW-047, GW-048, GW-090, GW-093, GW-094, GW-095, GW-102, GW-125, GW-259, GW-261 |
| 1—<9 | 1 to < 2 years | No | low increased risk | No | low increased risk | GW-019, GW-047, GW-048, GW-090, GW-093, GW-094, GW-095, GW-102, GW-125, GW-259, GW-261 |
| 1—<9 | 2 to < 6 years | No | low increased risk | No | low increased risk | GW-019, GW-047, GW-048, GW-090, GW-093, GW-094, GW-095, GW-102, GW-125, GW-259, GW-261 |
| 1—<9 | 6 to < 11 years | No | low increased risk | No | low increased risk | GW-019, GW-047, GW-048, GW-090, GW-093, GW-094, GW-095, GW-102, |

| Range of Exposure Point Concentrations (mg/L) | Exposure Group | Is there an increased chance for noncancer health effect? (CTE[1]) | Chance to develop cancer health effect (CTE) | Is there an increased risk for noncancer health effect? (RME[2]) | Chance to develop cancer health effect (RME) | List of wells with estimated Exposure Point Concentration in the range |
|---|---|---|---|---|---|---|
| | | | | | | GW-125, GW-259, GW-261 |
| 1—<9 | 11 to < 16 years | No | low increased risk | No | low increased risk | GW-019, GW-047, GW-048, GW-090, GW-093, GW-094, GW-095, GW-102, GW-125, GW-259, GW-261 |
| 1—<9 | 16 to < 21 years | No | low increased risk | No | low increased risk | GW-019, GW-047, GW-048, GW-090, GW-093, GW-094, GW-095, GW-102, GW-125, GW-259, GW-261 |
| 1—<9 | Adult | No | low increased risk | No | low increased risk | GW-019, GW-047, GW-048, GW-090, GW-093, GW-094, GW-095, GW-102, GW-125, GW-259, GW-261 |
| 1—<9 | Lactating Women | No | low increased risk | No | low increased risk | GW-019, GW-047, GW-048, GW-090, GW-093, GW-094, GW-095, GW-102, |

| Range of Exposure Point Concentrations (mg/L) | Exposure Group | Is there an increased chance for noncancer health effect? (CTE[1]) | Chance to develop cancer health effect (CTE) | Is there an increased risk for noncancer health effect? (RME[2]) | Chance to develop cancer health effect (RME) | List of wells with estimated Exposure Point Concentration in the range |
|---|---|---|---|---|---|---|
| | | | | | | GW-125, GW-259, GW-261 |
| 1—<9 | Pregnant Women | No | low increased risk | No | low increased risk | GW-019, GW-047, GW-048, GW-090, GW-093, GW-094, GW-095, GW-102, GW-125, GW-259, GW-261 |
| 9 — <50 | Birth to < 1 year | No | low increased risk | Yes | Increased risk | GW-99, GW-038, GW-092, GW-029, GW-146, GW-042, GW-098, GW-108, GW-151, GW-101, GW-503, GW-126, GW-049, GW-050, GW-080, GW-081, GW-086, GW-103, GW-044, GW-104 |
| 9 — <50 | 1 to < 2 years | No | low increased risk | No | Increased risk | GW-99, GW-038, GW-092, GW-029, GW-146, GW-042, GW-098, GW-108, GW-151, GW-101, GW-503, GW-126, GW-049, GW-050, GW-080, GW-081, |

| Range of Exposure Point Concentrations (mg/L) | Exposure Group | Is there an increased chance for noncancer health effect? (CTE[1]) | Chance to develop cancer health effect (CTE) | Is there an increased risk for noncancer health effect? (RME[2]) | Chance to develop cancer health effect (RME) | List of wells with estimated Exposure Point Concentration in the range |
|---|---|---|---|---|---|---|
| | | | | | | GW-086, GW-103, GW-044, GW-104 |
| 9 — <50 | 2 to < 6 years | No | low increased risk | No | Increased risk | GW-99, GW-038, GW-092, GW-029, GW-146, GW-042, GW-098, GW-108, GW-151, GW-101, GW-503, GW-126, GW-049, GW-050, GW-080, GW-081, GW-086, GW-103, GW-044, GW-104 |
| 9 — <50 | 6 to < 11 years | No | low increased risk | No | Increased risk | GW-99, GW-038, GW-092, GW-029, GW-146, GW-042, GW-098, GW-108, GW-151, GW-101, GW-503, GW-126, GW-049, GW-050, GW-080, GW-081, GW-086, GW-103, GW-044, GW-104 |
| 9 — <50 | 11 to < 16 years | No | low increased risk | No | Increased risk | GW-99, GW-038, GW-092, GW-029, GW-146, GW-042, GW-098, GW-108, GW-151, GW-101, |

| Range of Exposure Point Concentrations (mg/L) | Exposure Group | Is there an increased chance for noncancer health effect? (CTE[1]) | Chance to develop cancer health effect (CTE) | Is there an increased risk for noncancer health effect? (RME[2]) | Chance to develop cancer health effect (RME) | List of wells with estimated Exposure Point Concentration in the range |
|---|---|---|---|---|---|---|
| | | | | | | GW-503, GW-126, GW-049, GW-050, GW-080, GW-081, GW-086, GW-103, GW-044, GW-104 |
| 9 — <50 | 16 to < 21 years | No | low increased risk | No | Increased risk | GW-99, GW-038, GW-092, GW-029, GW-146, GW-042, GW-098, GW-108, GW-151, GW-101, GW-503, GW-126, GW-049, GW-050, GW-080, GW-081, GW-086, GW-103, GW-044, GW-104 |
| 9 — <50 | Adult | No | low increased risk | No | Low increased risk | GW-99, GW-038, GW-092, GW-029, GW-146, GW-042, GW-098, GW-108, GW-151, GW-101, GW-503, GW-126, GW-049, GW-050, GW-080, GW-081, GW-086, GW-103, GW-044, GW-104 |

| Range of Exposure Point Concentrations (mg/L) | Exposure Group | Is there an increased chance for noncancer health effect? (CTE[1]) | Chance to develop cancer health effect (CTE) | Is there an increased risk for noncancer health effect? (RME[2]) | Chance to develop cancer health effect (RME) | List of wells with estimated Exposure Point Concentration in the range |
|---|---|---|---|---|---|---|
| 9 — <50 | Lactating Women | No | low increased risk | No | Increased risk | GW-99, GW-038, GW-092, GW-029, GW-146, GW-042, GW-098, GW-108, GW-151, GW-101, GW-503, GW-126, GW-049, GW-050, GW-080, GW-081, GW-086, GW-103, GW-044, GW-104 |
| 9 — <50 | Pregnant Women | No | low increased risk | No | Increased risk | GW-99, GW-038, GW-092, GW-029, GW-146, GW-042, GW-098, GW-108, GW-151, GW-101, GW-503, GW-126, GW-049, GW-050, GW-080, GW-081, GW-086, GW-103, GW-044, GW-104 |
| 50-<75 | Birth to < 1 year | No | Increased risk | Yes | Increased risk | GW-176, GW-020, GW150, GW-292, GW-064, GW-187, GW-096 |
| 50-<75 | 1 to < 2 years | No | Increased risk | No | Increased risk | GW-176, GW-020, GW150, GW-292, |

| Range of Exposure Point Concentrations (mg/L) | Exposure Group | Is there an increased chance for noncancer health effect? (CTE[1]) | Chance to develop cancer health effect (CTE) | Is there an increased risk for noncancer health effect? (RME[2]) | Chance to develop cancer health effect (RME) | List of wells with estimated Exposure Point Concentration in the range |
|---|---|---|---|---|---|---|
| | | | | | | GW-064, GW-187, GW-096 |
| 50-<75 | 2 to < 6 years | No | Increased risk | No | Increased risk | GW-176, GW-020, GW150, GW-292, GW-064, GW-187, GW-096 |
| 50-<75 | 6 to < 11 years | No | Increased risk | No | Increased risk | GW-176, GW-020, GW150, GW-292, GW-064, GW-187, GW-096 |
| 50-<75 | 11 to < 16 years | No | Increased risk | No | Increased risk | GW-176, GW-020, GW150, GW-292, GW-064, GW-187, GW-096 |
| 50-<75 | 16 to < 21 years | No | Increased risk | No | Increased risk | GW-176, GW-020, GW150, GW-292, GW-064, GW-187, GW-096 |
| 50-<75 | Adult | No | Low increased risk | No | Increased risk | GW-176, GW-020, GW150, GW-292, GW-064, GW-187, GW-096 |

| Range of Exposure Point Concentrations (mg/L) | Exposure Group | Is there an increased chance for noncancer health effect? (CTE[1]) | Chance to develop cancer health effect (CTE) | Is there an increased risk for noncancer health effect? (RME[2]) | Chance to develop cancer health effect (RME) | List of wells with estimated Exposure Point Concentration in the range |
|---|---|---|---|---|---|---|
| 50-<75 | Lactating Women | No | Low increased risk | No | Increased risk | GW-176, GW-020, GW150, GW-292, GW-064, GW-187, GW-096 |
| 50-<75 | Pregnant Women | No | Low increased risk | No | Increased risk | GW-176, GW-020, GW150, GW-292, GW-064, GW-187, GW-096 |
| 75 — <180 | Birth to < 1 year | No | Increased risk | Yes | Increased risk | GW-011, GW-023, GW-100, GW-105, GW-299, GW-313 |
| 75 — <180 | 1 to < 2 years | No | Increased risk | Yes | Increased risk | GW-011, GW-023, GW-100, GW-105, GW-299, GW-313 |
| 75 — <180 | 2 to < 6 years | No | Increased risk | No | Increased risk | GW-011, GW-023, GW-100, GW-105, GW-299, GW-313 |
| 75 — <180 | 6 to < 11 years | No | Increased risk | No | Increased risk | GW-011, GW-023, GW-100, GW-105, GW-299, GW-313 |
| 75 — <180 | 11 to < 16 years | No | Increased risk | No | Increased risk | GW-011, GW-023, GW-100, GW-105, GW-299, GW-313 |

| Range of Exposure Point Concentrations (mg/L) | Exposure Group | Is there an increased chance for noncancer health effect? (CTE[1]) | Chance to develop cancer health effect (CTE) | Is there an increased risk for noncancer health effect? (RME[2]) | Chance to develop cancer health effect (RME) | List of wells with estimated Exposure Point Concentration in the range |
|---|---|---|---|---|---|---|
| 75 — <180 | 16 to < 21 years | No | Increased risk | No | Increased risk | GW-011, GW-023, GW-100, GW-105, GW-299, GW-313 |
| 75 — <180 | Adult | No | Low increased risk | No | Increased risk | GW-011, GW-023, GW-100, GW-105, GW-299, GW-313 |
| 75 — <180 | Lactating Women | No | Low increased risk | No | Increased risk | GW-011, GW-023, GW-100, GW-105, GW-299, GW-313 |
| 75 — <180 | Pregnant Women | No | Low increased risk | No | Increased risk | GW-011, GW-023, GW-100, GW-105, GW-299, GW-313 |
| ≥ 180 | Birth to < 1 year | Yes | Increased risk | Yes | Increased risk | GW-043, GW-045, GW-046, GW-091, GW-097, GW-254 |
| ≥ 180 | 1 to < 2 years | No | Increased risk | Yes | Increased risk | GW-043, GW-045, GW-046, GW-091, GW-097, GW-254 |
| ≥ 180 | 2 to < 6 years | No | Increased risk | Yes | Increased risk | GW-043, GW-045, GW-046, GW-091, GW-097, GW-254 |

| Range of Exposure Point Concentrations (mg/L) | Exposure Group | Is there an increased chance for noncancer health effect? (CTE[1]) | Chance to develop cancer health effect (CTE) | Is there an increased risk for noncancer health effect? (RME[2]) | Chance to develop cancer health effect (RME) | List of wells with estimated Exposure Point Concentration in the range |
|---|---|---|---|---|---|---|
| ≥ 180 | 6 to < 11 years | No | Increased risk | Yes | Increased risk | GW-043, GW-045, GW-046, GW-091, GW-097, GW-254 |
| ≥ 180 | 11 to < 16 years | No | Increased risk | Yes | Increased risk | GW-043, GW-045, GW-046, GW-091, GW-097, GW-254 |
| ≥ 180 | 16 to < 21 years | No | Increased risk | Yes | Increased risk | GW-043, GW-045, GW-046, GW-091, GW-097, GW-254 |
| ≥ 180 | Adult | No | Increased risk | Yes | Increased risk | GW-043, GW-045, GW-046, GW-091, GW-097, GW-254 |
| ≥ 180 | Lactating Women | No | Increased risk | Yes | Increased risk | GW-043, GW-045, GW-046, GW-091, GW-097, GW-254 |
| ≥ 180 | Pregnant Women | No | Increased risk | Yes | Increased risk | GW-043, GW-045, GW-046, GW-091, GW-097, GW-254 |

1. CTE: central tendency exposure, which is referring to individuals who have an average or typical water consumption rate.
2. RME: reasonable maximum exposure, which is referring to individuals who are at the upper end of the exposure distribution (about the 95%).

**Non-cancer Exposure dose calculation for adult at exposure concentration of 75 µg/L = 0.075 mg/L**

Non-cancer exposure dose calculation for adult at exposure concentration of seventy five micrograms per liter equals seventy five thousandths milligrams per liter.