HEALTH CONSULTATION

FOLLOW-UP EVALUATION OF GROUNDWATER CONTAMINATION IN THE FAIRMONT NEIGHBORHOOD GOLDEN, JEFFERSON COUNTY, COLORADO

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Statement and Summary of Issues

Introduction

The Colorado Cooperative Program for Environmental Health Assessments's (CCPEHA's) top priority is to ensure that all stakeholders have the best health information possible to protect the community from current and future health hazards associated with groundwater contamination in the Fairmont neighborhood in Jefferson County, Colorado.

Hazen Research Incorporated is an industrial research and development firm, located approximately 10 miles west of downtown Denver in Golden, Colorado. In March 2007, Hazen officials identified a possible leak in a concrete floor drain in the commercial laboratory of their facility. This discovery led to an investigation that revealed the shallow groundwater beneath the facility and the adjacent Fairmont neighborhood was contaminated with Volatile Organic Compounds (VOCs) including tetrachloroethene and trichloroethene.

CCPEHA initially became involved with the site to assist the Hazardous Waste and Waste Management Division of the Colorado Department of Public Health and Environment with community health concerns related to the contaminated groundwater. To date, CCPEHA has conducted two health consultations on the site to address health concerns related to groundwater and indoor air in the Fairmont neighborhood. In addition, CCPEHA also conducted another health consultation to evaluate potential health concerns related to indoor air and worker health at the Hazen facility.

Since the initial health consultation was completed in 2008, Hazen has been conducting semi-annual groundwater sampling events at 6 private wells in the Fairmont neighborhood. The 6 private wells were selected for monitoring due to their history of elevated VOC concentrations. This health consultation is a follow-up activity to previous health consultations, which examines the additional data and current exposure pathways to ultimately determine if health hazards currently exist from using the private wells.

In March 2008, all homes in the Fairmont neighborhood were connected to the municipal water supply, which eliminated the major pathways of exposure. The main exposure pathway evaluated in this health consultation is alternative use of contaminated groundwater such as filling swimming pools and/or hot tubs.

Overview	**CCPEHA has reached three conclusions regarding the public health implications of residents using contaminated groundwater for outdoor uses in the Fairmont neighborhood.**
Conclusion 1	***It is not known if exposure to VOCs present in private wells #5 and #6 could harm the health of current and future residents if the well water is used to fill swimming pools and/or hot tubs.***
Basis for Decision	This conclusion was reached because the concentration of PCE in these wells has been increasing in recent sampling events. Based on the latest sampling data, the estimated theoretical cancer risks for this pathway are near the high-end of the acceptable cancer risk range. If the concentration of PCE continues to increase, the associated cancer risks may also exceed the acceptable risk range. It should be noted that the available groundwater data collected to date from these wells indicates the estimated theoretical cancer risks are at the high-end of the acceptable cancer risk range, which are associated with a low increased risk of developing cancer. However, more data is needed to ensure the wells are safe for homeowners.
Conclusion 2	***Exposure to VOCs present in private wells #1,#2, #3, and #4 is not expected to harm health of current and future residents if the water is used to fill child pools and/or hot tubs.***
Basis for Decision	This conclusion was reached because the estimated non-cancer health hazards are below a level of concern and theoretical cancer risks are within the acceptable cancer risk range. However, it should be noted that this conclusion is associated with some uncertainty since the toxicity value for PCE is a provisional value and the concentration of PCE is fluctuating in some wells.
Conclusion 3	***It is not known if past exposures (prior to 2007) to VOCs present in all private wells could harm the health of current residents if the well water was used to fill child pools and/or hot tubs.***
Basis for Decision	This conclusion was reached because the following critical information is not known: (1) How long VOC contamination has been present in private wells in the Fairmont neighborhood; and (2) the concentration of VOCs before groundwater sampling started in 2007.

Next Steps

Hazen should continue to remediate groundwater onsite at their facility to eliminate potential impacts to groundwater in the Fairmont neighborhood. In addition, Hazen should continue with the groundwater monitoring plan developed in conjunction with CDPHE to ensure the wells are safe for residents.

For More Information

If you have immediate concerns about your health, you should contact your health care provider. Please call Thomas Simmons at 303-692-2961 for more information on the information contained in this health consultation.

Purpose

The Hazardous Materials and Waste Management Division (HWWMD) of the Colorado Department of Public Health and Environment (CDPHE) requested that the Colorado Cooperative Program for Environmental Health Assessments (CCPEHA) evaluate the public health implications associated with outdoor use of contaminated groundwater in 6 private wells in the Fairmont Neighborhood in Jefferson County, Colorado. CCPEHA initially conducted a health consultation on the site in 2008. This document is a follow-up activity, which examines the current state of groundwater contamination at 6 private wells in the Fairmont neighborhood. It should be noted that this health consultation only evaluates the exposure to residents who use or plan to use contaminated groundwater to fill child pools and/or hot tubs.

Background

Hazen Research Incorporated (Hazen) is an industrial research and development firm that was founded in 1961. Hazen currently offers a variety of services for clients in the mineral, chemical, energy, and environmental fields including the development of hydrometallurgical, pyrometallurgical, and mineral benefication processes for most commercial metals, industrial minerals, and inorganic compounds (HWS 2007). In March 2007, Hazen personnel identified a possible floor leak in a concrete drain trench located in the commercial laboratory. The floor trench conveyed wastewater from laboratory sinks to a treatment sump prior to discharge to the sanitary sewer. Hazen contacted the Colorado Department of Public Health and Environment's Hazardous Waste and Waste Management Division (HWWMD) to inform them of the incident and seek further guidance. HWWMD officials recommended the installation of onsite groundwater monitoring wells to identify any potential contaminant releases from the leaking floor drain. PCE, trichloroethene, and chloroform were identified in the onsite monitoring wells with PCE being the most prominent contaminant. Further investigation of the underlying aquifer revealed that contamination was also present in the Fairmont neighborhood, which lies east-southeast of the Hazen facility.

Initially, the HWWMD contacted CCPEHA in July 2007 to examine the potential public health hazards associated with the groundwater contamination in the Fairmont Neighborhood. At the time, some residents in the Fairmont neighborhood were using private wells for household use. In March 2008, everyone that was using a contaminated groundwater well for household purposes was connected to city water, which eliminated the major pathways of exposure. In September 2008, Hazen began remediating the groundwater contamination onsite at their facility.

Hazen has been monitoring the groundwater contamination onsite and in the Fairmont neighborhood on a semi-annual basis since 2009. Six private groundwater wells in the Fairmont neighborhood were selected in Hazen's groundwater monitoring plan. These wells were selected because of their history of elevated contaminant levels, relative to Colorado Groundwater Standards, and their physical location. The focus of this evaluation is to review the additional groundwater data from private groundwater wells and evaluate the potential for health effects from current hypothetical outdoor use.

CCPEHA's initial evaluation examined groundwater, indoor air, and homegrown produce that had been irrigated with contaminated groundwater. Since it is unknown how long the contamination had been present and what the concentration of contaminants was over time, it could not be determined whether the contamination presented a public health hazard. However, it was clear that the levels of contamination in some private wells were not safe for household use (drinking, showering, etc) due to excessive theoretical cancer risks. For more information regarding this evaluation, please refer to the original health consultation (ATSDR 2008).

An additional health consultation was conducted by CCPEHA in 2009 to evaluate the potential health hazards at a Fairmont residence for the new owners of the property (ATSDR 2009). In addition to unacceptable health risks from using the well for household use, it was found that alternative uses of the contaminated water (hot tubs and child pools) could pose health hazards at this home because of estimated theoretical cancer risks greater than the acceptable cancer risk range.

It should be noted that the evaluation of the exact source of VOC contamination is not the focus of this health consultation. The data indicates that VOCs are migrating off of the Hazen property. However, it is unknown if Hazen is the only source of groundwater contamination in the Fairmont neighborhood or if the contamination in all private wells originated at the Hazen property. Rather, the focus of this health consultation is to evaluate public health implications of groundwater contamination that exists in private wells. In no way should this information be construed as a determination of the source of contamination in each well.

Community Health Concerns

Historically, community health concerns have been collected through the CDPHE during phone conversations and a public meeting that occurred in August 2007. This meeting was set up by Hazen to communicate the findings of the initial investigation into the

groundwater plume. CCPEHA staff participated in the meeting to assist CDPHE's Hazardous Waste and Waste Management Division with health related questions. The primary health related community concerns gathered at this meeting were the general health effects of exposure to PCE and how to identify an exposure; the ability of PCE to result in miscarriages, if it was safe to eat fruits and vegetables, and the carcinogenic health effects of PCE. General health effects of PCE are provided as ATSDR Public Health Statement in Appendix C. This health consultation evaluates both non-cancer and carcinogenic health effects from exposure to PCE in private wells in the Fairmont neighborhood.

Discussion

The overall goal of this public health consultation is to determine if PCE in private wells poses a public health hazard and to make recommendations to protect residents if need be. The first step includes an examination of the currently available environmental data and a determination if contaminants of potential concern (COPCs) exist. If exposure pathways to COPCs exist, exposure doses are estimated and compared to health-based guidelines established by the ATSDR and EPA. This is followed by an in-depth health effects evaluation if the estimated exposure doses exceed health-based guidelines.

Environmental Data

The first groundwater samples from private wells were collected in the summer of 2007. Approximately forty private groundwater wells were identified in the Fairmont neighborhood through well surveys and community outreach. PCE was not detected, or was detected at very low concentrations (<1ppb), in over ½ of the private wells that were sampled. During subsequent sampling events, the number of wells that were sampled was pared down and focused primarily on the private wells that showed evidence of contamination. Six private wells have been sampled on a regular basis since 2007. Private groundwater data is being collected on a semi-annual basis from the 6 private wells and sampling events typically occur in the spring and fall. Samples are collected from the private wells and sent to ESC analytical laboratory in Evergreen, Colorado for analysis of volatile organic compounds (VOCs) by EPA method 8260B. This data utilized for this health consultation includes all groundwater data collected between July 2007 and May 2010) from the 6 private groundwater wells.

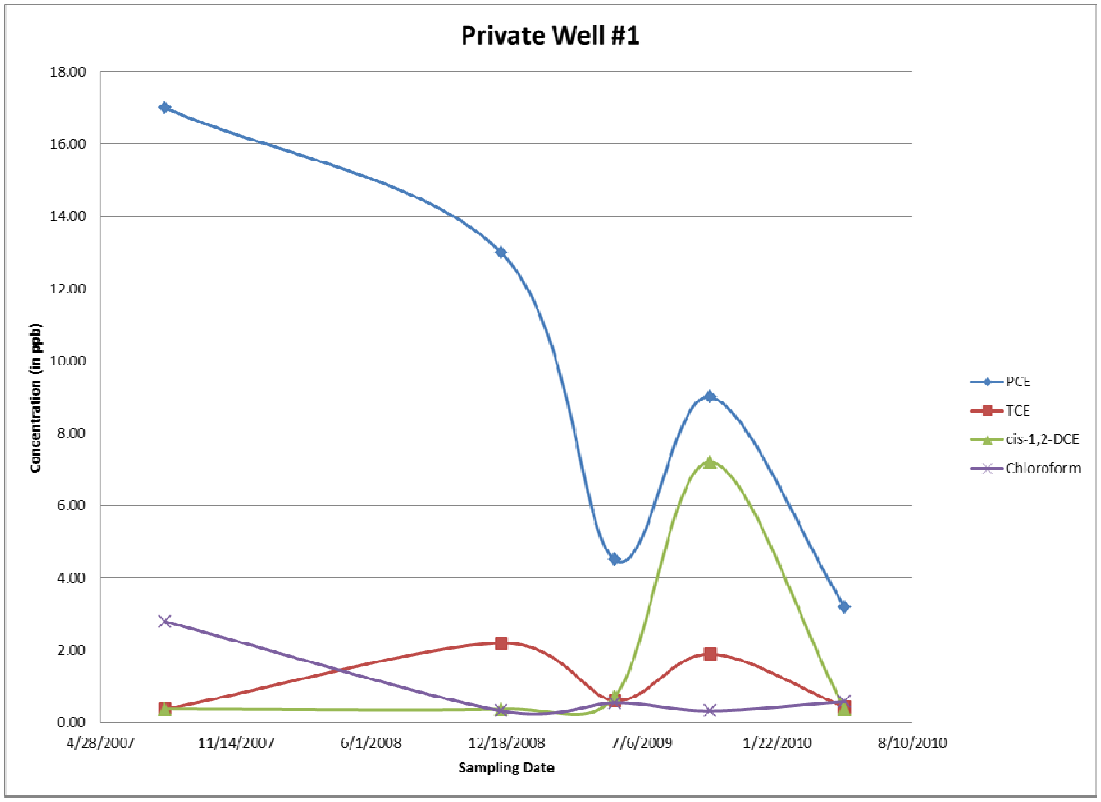
Four primary contaminants have been found in groundwater samples collected from the private groundwater wells: tetrachloroethene, trichloroethene, cis-1,2-dichloroethene, and chloroform. Tetrachloroethene (PCE) has been detected in 100% of the groundwater samples collected from the 6 private wells at various concentrations ranging from 1.4 parts per billion (ppb) to 190 ppb. The other detected compounds are found less frequently and at much lower concentrations. Table 1 is a summary of the groundwater data collected from the 6 private wells in the Fairmont neighborhood.

Overall, the concentration of VOCs, particularly PCE, in groundwater appears to fluctuate and does not follow a typical pattern of distribution throughout the

neighborhood. There has been a generally decreasing PCE concentration trend for all wells. However, the concentration of PCE has been increasing in recent sampling events. In general, PCE is the major contaminant of concern, and the other three VOCs (trichloroethene, cis-1,2-dichloroethene, and chloroform) are found at fairly low and stable concentrations. The groundwater data collected from each private well is presented below.

Private Well #1

Private well #1 is located in the eastern portion of the Fairmont Neighborhood. Five groundwater samples have been collected from this well between August 2007 and the last sampling event in May 2010. The levels of tetrachloroethene in this well have decreased since the initial sampling event in August 2007 when the concentration was 17 ppb. As shown in the graph below, the concentration of tetrachloroethene in this well decreased until October 2009, when the concentration doubled from the previous sampling event in May 2009 (4.5 ppb to 9 ppb). The decreasing trend continued in the latest sampling event where the PCE concentration was 3.2 ppb.

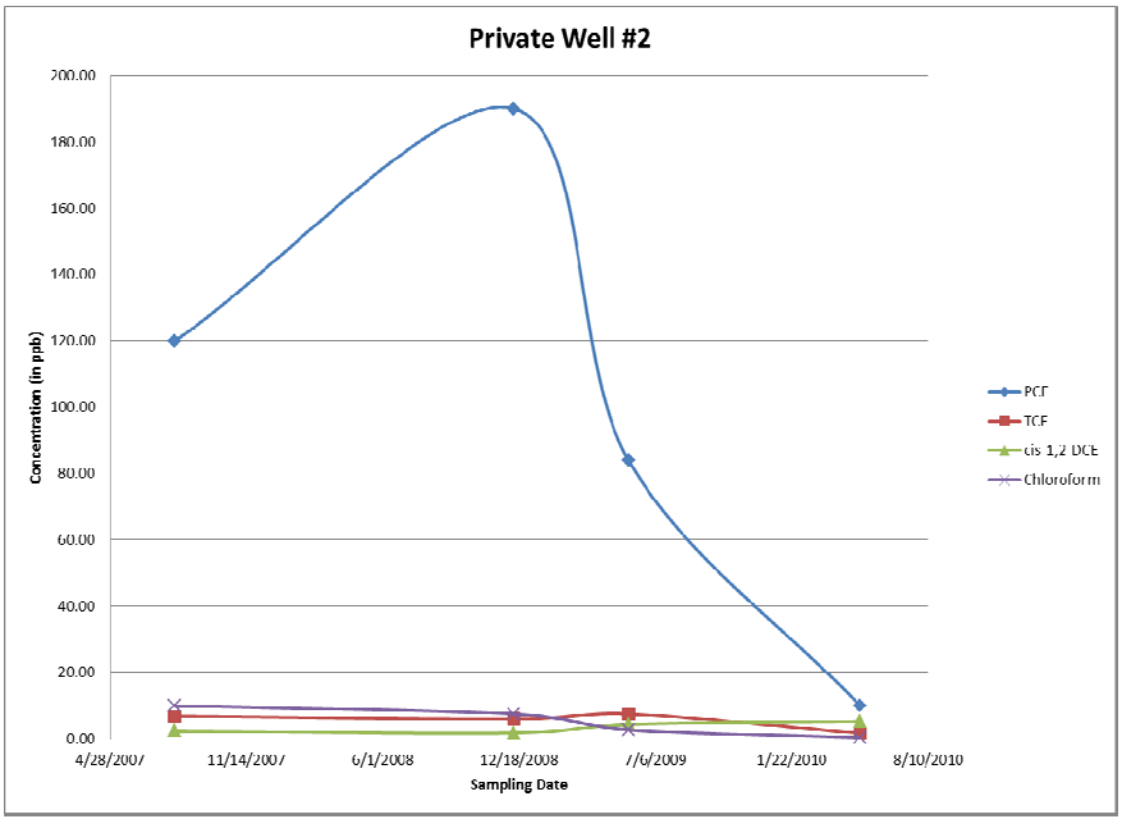


The concentrations of trichloroethene and cis-1,2-dichloroethene followed a similar pattern as PCE. TCE was not detected in the initial sampling event and then increased to 2.2 ppb in December 2008. The concentration of TCE decreased in the following sampling event to 0.61ppb, spiked back to 1.9 ppb in October 2009, and then decreased again to 0.43 ppb in the latest sampling event. Cis-1,2-dichloroethene was not detected

until May 2009 when it was found at a concentration of 0.72 ppb. The following sampling event in October 2009 showed a concentration of cis-1,2-DCE at 7.2 ppb. Then the concentration decreased again to an undetectable level. Chloroform concentrations have decreased from 2.8 ppb to 0.58 ppb since the initial sampling event in August 2007 to the latest sampling event in May 2010.

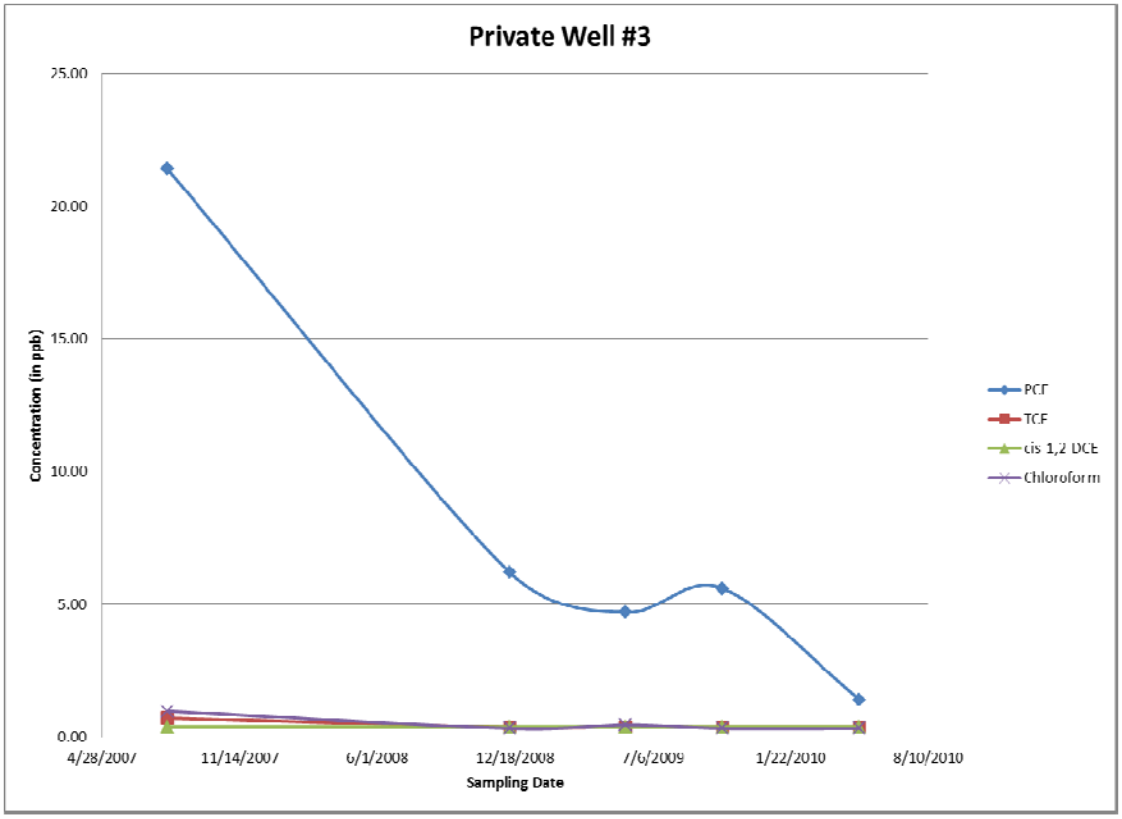
Private Well #2

Private well #2 is also located in the eastern portion of the Fairmont neighborhood about a block from private well #1. However, the concentrations of VOCs in private well #2 is dramatically different than private well #1. Four groundwater samples have been collected from private well #2 between August 2007 and the latest sampling event in May 2010. In August 2007, the concentration of PCE was 120 ppb. This well was sampled again in December 2008 and the concentration of PCE was 190 ppb. Six months later, the concentration of PCE dropped to 84 ppb and by May 2010, the concentration decreased to 10 ppb. During this same time period, the concentration of cis-1,2-DCE has gradually increased from a concentration of 2.4 ppb to 5.3 ppb. Chloroform and trichloroethene concentrations in this well have been decreasing since August 2007. The chloroform concentration has decreased from a maximum of 10 ppb in August 2007 to 0.48 ppb in May 2010. Trichloroethene decreased from 6.8 ppb in August 2007 to 1.8 ppb in May 2010.



Private Well #3

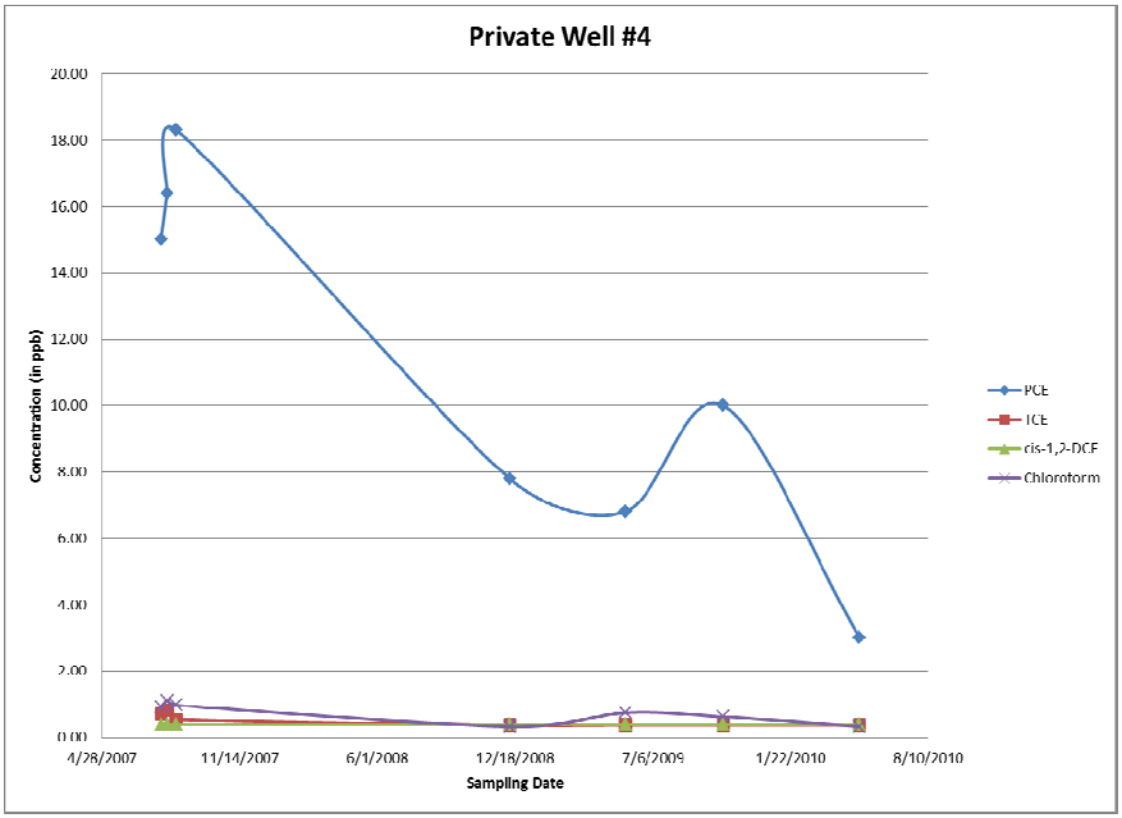
Private well #3 is located east of private wells 1 and 2 in the Fairmont neighborhood. Five groundwater wells have been collected from private well #3 since August 2007. The initial concentration of PCE in this well was 21.4 ppb and has been decreasing ever since to a concentration of 1.4 ppb in the latest sampling event. TCE was only detected in the August 2007 sampling event at 0.71 ppb. In all follow-up samples, TCE was not detected. Similarly, chloroform was detected in the initial sampling event in August 2007 at a concentration of 0.96 ppb, but has been near, or below, the detection limit in all follow-up samples. Cis-1,2-DCE has never been detected in this well.



Private Well #4

Private well #4 is located in the far eastern portion of the Fairmont Neighborhood. Seven groundwater samples have been collected from private well #4 since July 2007. Three samples were collected in July and August 2007 and the concentration of PCE ranged from 15.0-18.3 ppb. The next sampling event took place in December 2008 and the concentration of PCE was 7.8 ppb. The PCE concentration was about the same in May 2009, but then increased slightly to 10.0 ppb in October 2009. In the latest sampling event conducted in May 2010, the concentration of PCE was 3.0 ppb. Similarly, chloroform was detected in 2007 at an average concentration of 0.99 ppb (range 0.9-1.1 ppb). In December 2008, chloroform was not detected, but was detected in May and October 2009 at respective concentrations of 0.74 ppb and 0.62 ppb. During the May 2010 sampling event, chloroform was not detected. TCE was only detected in private well #4 in 2007 at an average concentration of 0.69 ppb (range 0.54-0.82 ppb). In all

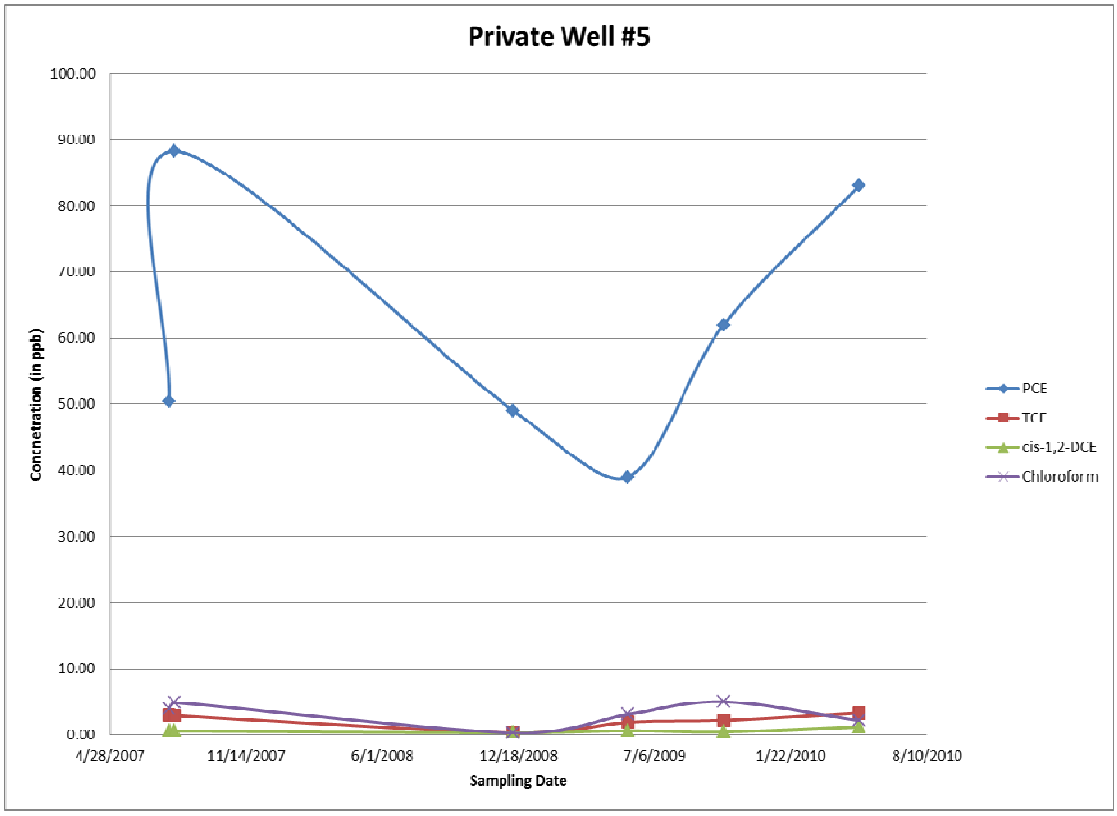
follow-up samples, TCE was not detected. Cis-1,2-DCE has never been detected in private well #4.



Private Well #5

Private well #5 is also located in the far eastern portion of the Fairmont neighborhood, next door to the property of the private well #4. In fact, the two wells are only about 100 ft. apart. However, the concentration of VOCs in private well #5 is drastically different than private well #4. Six groundwater samples have been collected from private well #5 since July 2007. This well was sampled in both July and August, approximately one week apart, and the concentration of PCE was 50.4 ppb in July and 88.2 ppb in August. In December 2008, the concentration of PCE was 49 ppb and decreased to 39 ppb in May 2009. In the last two sampling events in October 2009 and May 2010, the PCE concentration appears to be increasing with respective values of 62 ppb and 83 ppb. All of the other detected VOCs follow a similar pattern although at much lower concentrations. Chloroform was detected in the 2007 sampling events at 3.94 ppb and 4.87 ppb. In December 2008, chloroform was not detected and then increased in 2009 to 3.1 and 5.0 ppb. In the latest sampling event in May 2010, chloroform was found at a concentration of 2.2 ppb. TCE was detected at 3.05 ppb and 2.92 ppb in 2007. TCE was not detected in the December 2008, but began to increase from 1.9 ppb in May 2009 to 3.3 ppb in May 2010. Cis-1,2-DCE was initially detected at 0.65 ppb and 0.60 ppb in 2007. From May 2009 to May 2010, the concentration of cis-1,2-DCE increased again from 0.64 ppb to 1.2 ppb.

The reasoning behind the fluctuations in VOC concentrations is unclear. For TCE, cis-1,2-DCE, and chloroform, the fluctuation in concentrations appears fairly minor and insignificant in terms of public health since the concentrations are relatively low. PCE on the other hand, appears to have decreased and then began increasing back to concentrations of PCE found in 2007.

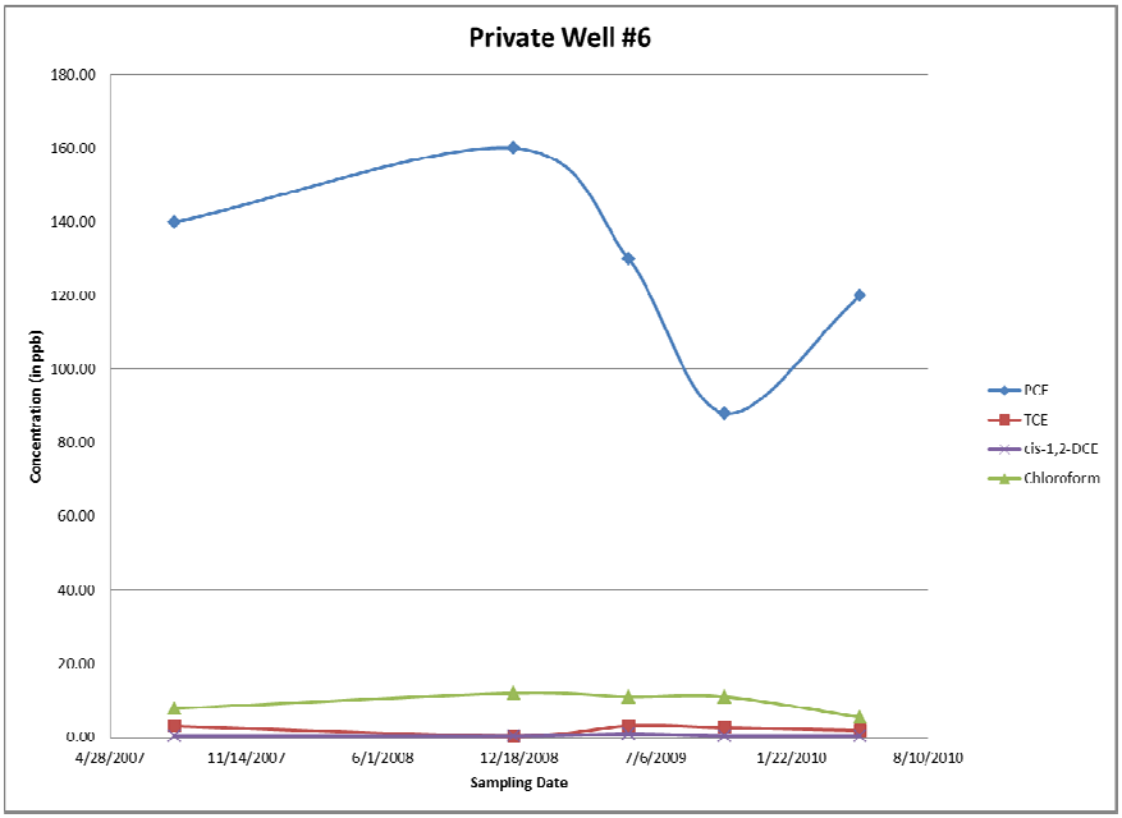


Private Well #6

Private well #6 is also located along the eastern edge of the Fairmont Neighborhood, approximately 100 ft. north of private well #5. Five groundwater samples have been collected from private well #6 between August 2007 and May 2010. Despite the close proximity to private wells numbers 4 and 5, the concentration of PCE found in private well #6 is approximately twice the PCE concentration of private well #5 and ten times higher than the PCE concentration in private well #4.

In August 2007, the concentration of PCE was 140 ppb, the maximum detected concentration of PCE in all of the initial groundwater samples collected from the Fairmont neighborhood. When private well #6 was sampled again in December 2008, the concentration of PCE had risen to 160 ppb in this well. After this point, the concentration of PCE appears to decrease with concentrations of 130 ppb and 88 ppb in May and October 2009, respectively. However, the PCE concentration as of the latest sampling event was back to 120 ppb. The concentration of chloroform has been fairly steady. In 2007, the concentration was 7.8 ppb and increased to 12 ppb in December 2008.

Chloroform concentrations remained at 11 ppb throughout 2009 and decreased to 5.4 ppb in May 2010. The levels of TCE follow a similar pattern, but at lower concentrations than chloroform (less than 5 ppb). The average concentration of TCE in private well #6 is 2.2 ppb with a maximum detected concentration of 3.1 ppb. During the latest sampling event in May 2010, TCE was found at a concentration of 1.9 ppb. Cis-1,2-Dichloroethene has only been detected one time in private well #6 at a concentration of 0.9 ppb in May 2009.



Contaminants of Potential Concern

To identify COPCs, the available groundwater data, collected from private wells, was screened with comparison values established by the ATSDR and EPA. The comparison values (CVs) from both agencies were reviewed and the most conservative value was selected for the screening process (Table 3). The CVs used in this evaluation are derived for residential water use. Residential CVs are based on 350 days exposure per year over a period of 30 year and include drinking water and inhalation of volatile organic compounds such as those found in this assessment. Using these CVs is considered conservative and protective of residents in the Fairmont neighborhood based on what is currently known about the use of contaminated groundwater. Therefore, if the maximum concentration of a particular contaminant is below the CV, it is dropped from further evaluation. If the maximum concentration of the contaminant is above the CV, it is

generally retained for further analysis as a COPC. However, exceeding the CV does not indicate that a health hazard exists; only that additional evaluation is warranted.

Overall, 3 COPCs were selected based on the residential CVs: 1) tetrachloroethene, 2) trichloroethene, and 3) chloroform. Tetrachloroethene is by far the most prominent COPC since it was detected in each well and also has the highest concentration of all contaminants. Chloroform was also selected as a COPC in each private well although at much lower concentrations. Trichloroethene was selected as a COPC in 4 out of the 6 private wells evaluated in this consultation. Cis-1,2-dichloroethene was detected in some private wells, but was below the CV and was not carried further in the evaluation. A summary of the COPC selection is presented below in Table 2 and a more detailed table is presented in Table 3.

Table 2. Contaminants of Potential Concern Detected in 2007-2010

Private Well Location	Tetrachloroethene	Trichloroethene	cis-1,2-Dichloroethene	Chloroform
#1	X	X		X
#2	X	X		X
#3	X			X
#4	X			X
#5	X	X		X
#6	X	X		X

Exposure Evaluation

Since COPCs exist in private wells in the Fairmont neighborhood, the next step is to determine if people are coming into contact with these contaminants. The exposure evaluation examines current and future use of private wells to develop a conceptual site model that describes how people could come into contact with groundwater-related contaminants in the Fairmont neighborhood. Simply having contamination in the environment does not indicate there is a public health hazard. Therefore, it is necessary to determine if and how individuals can be exposed to the contamination.

In 2007, a well survey was conducted at the Colorado Division of Water Resources to identify groundwater wells in the Fairmont neighborhood. In addition, Hazen personnel contacted each household in the neighborhood to determine if there are any additional wells that were not identified in the well survey and what the private wells are actually being used for. Therefore, it is assumed that all private wells that have been or could be affected by groundwater contamination have been accounted for. At the time, some of the wells were being used for household purposes such as drinking water, showering/bathing, cooking, cleaning, etc. Other wells were used for domestic irrigation including gardens and livestock. It is clear that the six private wells that are the subject of this health consultation are not being used for household purposes at this time (all homes connected to municipal water by March 2008). It is unclear if the six private groundwater wells are

currently being used for outdoor purposes such as irrigation, washing cars; filling child pools/hot tubs, etc.

Previous health consultations that have been conducted in the Fairmont neighborhood have addressed other types of environmental data such as indoor air and fruit and vegetable data. However, no additional data from these environmental media is currently available. Therefore, ingestion of home-grown fruits/vegetables irrigated with contaminated groundwater and indoor air exposures are not evaluated in this health consultation. The limited available data from home-grown fruits and vegetables in the Fairmont neighborhood was evaluated in ATSDR 2008 and did not show any contaminants thought to be related to the groundwater contamination under investigation. Indoor air sampling data was also evaluated in ATSDR 2008 and ATSDR 2009. The theoretical cancer risks from inhalation of PCE in indoor air were around the mid-point of the acceptable cancer risk range for this pathway based on the limited available data.

The remaining potential exposure pathways include irrigation and other typical outdoor household uses of water. This includes filling child pools and hot tubs with the groundwater and outdoor cleaning activities that would result in short-term dermal (skin) contact. The main exposure pathway considered in this evaluation is dermal contact and incidental ingestion of contaminated groundwater while wading/bathing in child pools and/or hot tubs. Short-term contact with contaminated groundwater during other potential uses of private wells including outdoor cleaning, connecting hoses, rinsing hands, etc. is not expected to result in significant exposures, at the contaminant levels found in these wells, because of the limited amount of time that people would be in contact with the water. Therefore, these exposures were not considered further in this evaluation. The major exposure pathway information is summarized below in the conceptual site model.

Table 4. Conceptual Site Model of Pathways of Exposure

Source	Affected Environmental Medium	Point of Exposure	Potentially Exposed Populations	Timeframe of Exposure	Route of Exposure
Contaminated soil and groundwater	Private groundwater wells	Child Pools and Hot tubs	Child and Adult Residents	Current and Future	1) Dermal Exposure and 2) Incidental Ingestion of groundwater in child pools and hot tubs

Note: Ingestion of home-grown fruits/vegetables irrigated with contaminated groundwater is considered a complete, but insignificant, pathway based on the limited available historical data. No new data are available for further evaluation. In addition, indoor air contaminated with PCE (vapor intrusion and/or indoor sources) is also a complete pathway, but not evaluated here because no new data are available. For the results of previous evaluations on these pathways, see ATSDR 2008 and ATSDR 2009.

Public Health Implications

Evaluating the public health implications of exposure to groundwater contaminants is a multi-step process. For all contaminants that exceed the CV, exposure doses are estimated for non-cancer and cancer endpoints (if the COPC is a carcinogen) for each exposure pathway identified in the exposure assessment. The estimated exposure doses are then compared with non-cancer and cancer health-based guidelines to evaluate if adverse health effects are likely from contacting groundwater contaminants. If the estimated exposure dose is higher than the health-based reference levels, further evaluation is conducted.

To estimate exposure doses, one must make assumptions to describe the exposure scenario over a period of time. These assumptions, or exposure factors, can be based on scientific literature, site-specific information, or professional judgment. The exposure factors used in this evaluation are the standard exposure factors used by the CCPEHA to describe recreational exposures in Colorado combined with default values for weight, exposure duration, and skin surface area. Overall, it is assumed that residents of the Fairmont neighborhood would use a child pool, hot tubs, etc. approximately 3 hours per week during the warmer months of the year or 1 hour per week throughout the year (hot tubs) for a period of 6 yrs. (children) or 30 years (adult).

Many factors determine individual responses to chemical exposures. These factors include the dose, duration, and individual factors such as age, gender, diet, family traits, lifestyle, and state of health. For these reasons, this evaluation cannot determine the actual health risk to any one particular individual. More information regarding the exposure factors used in this document and the toxic potential of risk driving chemicals is available in Appendix A and Appendix B, respectively.

Exposure doses were calculated for both children and adults for COPCs found at each private well. The primary exposure assumption is that residents will use their private well to fill child pools and/or hot tubs. The exposure doses for dermal contact and incidental ingestion are combined to produce the total estimated dose of wading/bathing in a child pool and hot tub filled with well water. The major contaminant of potential concern (PCE) is considered to be a probable human carcinogen based on sufficient evidence of carcinogenicity in animal studies and limited carcinogenicity in human studies.

In accordance with EPA guidance, the maximum detected concentration of any particular contaminant is used as the exposure point concentration (the concentration used in dose calculations) when only 10 samples or less have been collected from a location. However, since there is a wide range in the data and contaminant levels have been fluctuating, it was determined that a range would more accurately describe the health risk at each well. As such, the minimum and maximum concentrations were used for risk calculations to produce a range of potential health risk. The results of the exposure evaluation and the potential public health implications of the primary exposure scenario

are presented by private well to assist the stakeholders and well owners in determining risk at all locations.

Private Well #1

PCE, TCE, and chloroform were selected as COPCs in private well #1. PCE was detected at the highest concentration and is the major risk driver for non-cancer and cancer health effects from using this well. The estimated non-cancer exposure doses from using a child pool and/or hot tub drawn from private well #1 are below the non-cancer health-based guidelines for each contaminant for both children and adults (Tables 5 and 6). Even at the maximum exposure point concentration, the highest hazard quotient is $1.0 * 10^{-2}$ (PCE HQ for children, Table 5). Hazard quotients are generated by dividing the estimated dose by the health-based guideline of the contaminant. This means the highest estimated non-cancer exposure dose of PCE for children is 100 times lower than the non-cancer health-based guideline for PCE. From this analysis, significant non-cancer adverse health effects are not likely to occur from using the well water to fill child pools/hot tubs under the exposure assumptions made in this evaluation.

Carcinogenic exposure doses are averaged over a lifetime and include exposure as children and adults. Theoretical cancer risks are estimated by calculating carcinogenic exposure doses and multiplying by the oral slope factor of the contaminant. The product of this calculation is compare to the EPA's generally acceptable cancer risk range, which is one excess cancer case (low-end) to 100 excess cancer cases (high-end) per million exposed individuals. At the maximum exposure point concentration, the total combined theoretical cancer risk from exposure to all COPCs is 15 excess cancer cases per 1,000,000 exposed individuals (Table 7). At the minimum concentration level, the combined theoretical cancer risk is 2.8 excess cancer cases per million exposed individuals. The theoretical cancer risks from exposure to private well #1 in child pools/hot tubs are at the low end of the acceptable cancer risk range, which indicates a low increased risk of developing cancer.

Private Well #2

PCE, TCE, and chloroform were identified as COPCs in private Well #2. PCE was detected at the highest concentration and is also the major risk driver for non-cancer and carcinogenic risks (Tables 5 and 6). The child non-cancer hazard quotient for PCE at the maximum exposure point concentration is $1.1 * 10^{-1}$. Thus, at the maximum level of PCE detected in private well #2, the estimated non-cancer dose of PCE for children is approximately 10 times lower than the health-based guideline for PCE. The adult hazard quotient for PCE at the maximum level is approximately 16 times lower than the health-based guideline. This indicates that non-cancer adverse health effects are not likely to occur from wading/bathing in child pools and hot tubs filled from private well #2.

At the maximum concentration level, the total combined age-adjusted cancer risk is $1.7 * 10^{-4}$ or 170 excess cancer cases per 1,000,000 exposed individuals. At the minimum level, the total combined theoretical cancer risk is $8.9 * 10^{-6}$ or 8.9 excess cancer cases per million exposed individuals (Table 7). The estimated theoretical cancer risk ranges from the low-end of the acceptable cancer risk range at the minimum concentration to

just above the high-end of the acceptable cancer risk range at the maximum concentration. It should be noted that the maximum concentration of PCE was found in December 2008. Since this time, the concentration of PCE has been decreasing and was last found at the minimum concentration level. Therefore, current theoretical cancer risks may be more consistent with those found at the minimum concentration level, which are well within the generally accepted cancer risk range. This indicates a low increased risk of developing cancer from wading/bathing in child pools/hot tubs filled with groundwater from private well #2 if the concentration of contaminants found in this well remains the same or decrease in the future.

Private Well #3

PCE and chloroform were identified as COPCs in private well #3. The non-cancer hazard quotient for children from exposure to PCE is $1.2 * 10^{-2}$ at the maximum level and $7.6 * 10^{-4}$ at the minimum level (Table 5). Thus, at the maximum level of PCE detected in private well #3, the estimated non-cancer dose for children is approximately 83 times lower than the health-based guideline for PCE. At the maximum level, the adult hazard quotient for PCE is $7.0 * 10^{-4}$ or 1,430 times lower than the health-based guideline for PCE (Table 6). This indicates that significant non-cancer adverse health effects are not likely to occur from wading/bathing in child pools and hot tubs filled from private well #3.

The total combined age-adjusted theoretical cancer risk is $1.9 * 10^{-5}$, or 19 excess cancer cases per 1,000,000 people exposed at the maximum contaminant level found in private well #3 (Table 7). At the minimum contaminant level, the total combined theoretical cancer risk is $1.2 * 10^{-6}$, or 1.2 excess cancer cases per million exposed individuals. The corresponding theoretical cancer risks at both contaminant levels are well within the acceptable cancer risk range. This indicates a low increased risk of developing cancer from wading/bathing in child pools/hot tubs filled with groundwater from Private well #3.

Private Well #4

Two COPCs were identified in private well #4, PCE and chloroform. The contaminant levels in Private well #4 are similar to those found in private well #3. As such, the potential non-cancer health hazards and cancer risks are also similar. For children, the maximum level non-cancer hazard quotient for PCE is $1.1 * 10^{-2}$, or the estimated dose for children is 91 times lower than the health-based guideline for PCE (Table 5). For adults, the maximum level non-cancer dose is approximately 166 times less than the health-based guideline for PCE (Table 6). This indicates that significant non-cancer adverse health effects are not likely to occur from wading/bathing in child pools and hot tubs filled from private well #4. The total combined theoretical cancer risk is also similar. At the maximum contaminant level, the combined theoretical cancer risk is $1.6 * 10^{-5}$, or 16 excess cancer cases per 1,000,000 exposed individuals. At the minimum contaminant level, the total combined theoretical cancer risk is $2.7 * 10^{-6}$, or 2.7 excess cancer cases per million exposed individuals (Table 7). The corresponding theoretical cancer risks at both contaminant levels are well within the acceptable cancer risk range. This indicates a

low increased risk of developing cancer from wading/bathing in child pools/hot tubs filled with groundwater from private well #4.

Private Well #5

PCE, TCE, and chloroform were selected as COPCs in private Well #5. Again, the non-cancer hazards are relatively insignificant. At the maximum PCE level, the child hazard quotients are $5.2 * 10^{-2}$, or the estimated dose for PCE is approximately 19 times lower than the health-based guideline (Table 5). For adults, at the maximum PCE level, the hazard quotient is $2.9 * 10^{-2}$, or the estimated dose is approximately 34 times lower than the health-based guideline (Table 6). This indicates that significant non-cancer adverse health effects are not likely to occur from wading/bathing in child pools and hot tubs filled from private well #5.

The total combined theoretical cancer risk range at the maximum contaminant level is $7.9 *10^{-5}$ or 79 excess cancer cases per 1,000,000 exposed individuals. At the minimum contaminant level, the combined theoretical cancer risk range is $3.5 * 10^{-5}$, or 35 excess cancer cases per 1,000,000 (Table 7). These cancer risk levels are within the acceptable cancer risk range, which indicates a low increased risk of developing cancer from wading/bathing in child pools and hot tubs filled with ground water from private well #5. However, the concentration of PCE in private well #5 has been increasing over the last two sampling events. In fact, in the latest groundwater sample collected, the concentration of PCE was near the maximum concentration of PCE ever detected in this well (last = 83 ppb vs. max = 88.2 ppb). If the concentration of PCE continues to increase, using private well #5 for filling child pools and hot tubs could result in a public health hazard due to theoretical cancer risks above the acceptable risk range.

Private Well #6

All of three COPCs were identified in private well #6. As in all other wells, the non-cancer health hazards are below a level of concern. At the maximum PCE level, the estimated dose for children is approximately 11 times lower than the health-based guideline for PCE (Table 5). For adults, the estimated dose at the maximum PCE concentration is approximately 19 times lower than the health-based guideline (Table 6). This indicates that non-cancer adverse health effects are not likely to occur from wading/bathing in child pools and hot tubs filled from private well #6.

The total combined theoretical cancer risk ranges from $7.8 * 10^{-5}$, or 78 excess cancer case per 1,000,000, at the minimum contaminant level to $1.4 * 10^{-4}$, or 140 excess cancer cases per 1,000,000 exposed individuals at the maximum contaminant level (Table 7). The theoretical cancer risks are at the high-end of the acceptable cancer risk range, which indicates a low increased risk of developing cancer from wading/bathing in child pools and hot tubs filled with ground water from private well #6. The concentration of PCE, which is the major risk driver, has been fluctuating since the initial sample was collected. The maximum concentration of PCE was reached in December 2008 and then the concentration of PCE in this well decreased to the minimum level in October 2009, which equates to an associated cancer risk of $7.8 * 10^{-5}$ (within the acceptable cancer risk range). However, the concentration of PCE began to increase again in the latest sampling

event to 120 ppb. The cancer risk based on the latest sampling event (120 ppb) would be just above the high-end of the acceptable cancer risk range ($1.1 * 10^{-4}$) which indicates a low increased risk of developing cancer. If the concentration of PCE continues to increase, using private well #6 for filling child pools and hot tubs could result in a public health hazard due to theoretical cancer risks above the acceptable risk range.

Uncertainty

In general, the uncertainties associated with any risk-based health consultation are likely to over- or underestimate environmental exposures and the associated health hazards because all aspects of the exposure are typically unknown. This section of the discussion is not intended to be an in-depth description of all the uncertainties associated with this evaluation. Rather, the focus is to highlight the major assumptions and limitations that are specific to this evaluation and result in uncertainty.

- Exposure assumptions for activities related to child pools and hot tubs may result in over- or under-estimation of risk based on the actual use of contaminated groundwater.

- It is likely that VOCs found in private wells in the Fairmont neighborhood would evaporate from child pools and particularly hot tubs. Evaporation would lower the concentration of VOCs in the water. However, the rate of evaporation could not be accounted for since this rate is determined by a number of factors that would change dramatically throughout the year.

- Contaminant levels are fluctuating in some of the private wells (especially well #5 and #6) evaluated in this health consultation. Therefore, it is unknown what contaminant concentrations may be in the future. The potential health risks may be higher or lower in the future, depending on contaminant levels.

- Both carcinogenic and noncarcinogenic risks for multiple contaminants are assumed to be additive. This assumption, however, is associated with limitations and, therefore, there is potential for under- or over-estimation of risk. For example, the assumption of additivity of risk does not account for synergistic and antagonistic chemical interactions, which are known to occur for some chemical combinations.

- Toxicity values for TCE and PCE are currently being evaluated by the EPA and theoretical cancer risks may be underestimated based on the provisional toxicity values. However, the concentrations of TCE are so low that the use of an additional 100-fold protection factor would make an insignificant difference in the cancer risk estimates (i.e., caner risk will still be at the low-end of the acceptable level of one in a million). See additional discussion in Appendix B.

- Exposure to VOCs from ingestion of home-grown vegetables and/or fruits, irrigated with contaminated well water, cannot be fully evaluated at this time because of the limited amount of fruit and vegetable data available. However, the limited available data for fruits/vegetables collected from gardens irrigated with some of the most highly contaminated wells in the neighborhood did not show any evidence of PCE or other VOCs related to the groundwater contamination in the Fairmont neighborhood.

- Exposure to contaminants in indoor air, either through vapor intrusion and/or household sources of VOCs, is a complete exposure pathway that was not evaluated in this health consultation because no new indoor air data is available. Based on the previously collected limited amount of indoor air data from the Fairmont neighborhood, the estimated theoretical cancer risks for this pathway seem to be within the acceptable cancer risk range. However, due to the limited amount of indoor air data that is available, the health risks for this pathway could be higher or lower than found in previous health consultations. This is of particular concern for private wells #5 & #6, which have shown increasing levels of PCE in groundwater over recent sampling events. If the concentration of PCE continues to increase in these wells, it is possible that the concentration of PCE in indoor from vapor intrusion may pose a health risk.

Child Health Considerations

In communities faced with air, water, or food contamination, the many physical and behavioral differences between children and adults demand special emphasis. Children could be at greater risk than are adults from certain kinds of exposure to hazardous substances. Children play outdoors and sometimes engage in hand-to-mouth behaviors that increase their exposure potential. Children are shorter than are adults; this means they breathe dust, soil, and vapors close to the ground. A child's lower body weight and higher intake rate results in a greater dose of hazardous substance per unit of body weight. If toxic exposure levels are high enough during critical growth stages, the developing body systems of children can sustain permanent damage. Finally, children are dependent on adults for access to housing, for access to medical care, and for risk identification. Thus adults need as much information as possible to make informed decisions regarding their children's health. In this evaluation, child health concerns were evaluated and no special health concerns were identified for children. As expected, child residents are the most sensitive exposure group evaluated in this health consultation. However, the results indicate that there is little chance that children would experience adverse non-cancer health effects from wading in child pools and/or bathing in hot tubs filled with groundwater in the Fairmont neighborhood. Theoretical Cancer risks include children in the age-adjusted equation. As discussed in the Public Health Implication section, there is some risk of children developing cancer at some locations.

Conclusion

CCPEHA has reached the following three conclusions regarding current and future exposures to groundwater in the Fairmont neighborhood:

It is not known if exposure to VOCs present in private wells #5 and #6 could harm the health of current and future residents if the well water is used to fill child pools and/or hot tubs. This conclusion was reached because the concentration of PCE in these wells has been increasing in recent sampling events. It should, however, be noted that the currently available data indicates a low increased risk of developing cancer because the estimated theoretical cancer risks are at the high-end of the acceptable cancer risk range. The estimated non-cancer health hazards are below a level of concern in these wells. However, if the concentration of PCE continues to increase in these wells, the associated theoretical cancer risks may exceed the acceptable risk range. More sampling data is needed to ensure that these wells are safe for homeowners.

If private groundwater wells are used to fill child pools and/or hot tubs, exposure to VOCs present in private wells #1,#2, #3, and #4 is not expected to harm health of current and future residents based on the exposure duration of 30 years at the currently available concentrations of VOCs. This conclusion was reached because 1) the non-cancer health hazards are well below the health-based guidelines for each contaminant indicating an extremely low increased risk of developing non-cancer adverse health effects, and 2) the theoretical cancer risks from exposure to detected contaminants range from the low-end to the high-end of the acceptable cancer risk range; thereby, indicating a low increased risk of developing cancer. It is, however, important to note that these conclusions are associated with the following major uncertainties: (1) the risk estimates for the major risk driving chemical, PCE, are based on the provisional toxicity value that might have underestimated cancer risk; and (2) the future risks may be higher or lower than the risks estimated here because the concentrations of PCE are fluctuating in some wells.

It is not known if past exposures (prior to 2007) to VOCs present in all private groundwater wells could harm the health of residents if the well water was used to fill child pools and/or hot tubs. This conclusion was reached because the following critical information is not known: (1) How long VOC contamination has been present in private wells in the Fairmont neighborhood; and (2) the concentration of VOCs before groundwater sampling began in 2007.

Recommendations

Based upon CCPEHA's review of the environmental data, exposure pathways, and potential public health implications of exposure to groundwater contaminants located in the Fairmont neighborhood, the following actions are appropriate and protective of current and future residents.

- Hazen should continue to remediate groundwater onsite at their facility to eliminate potential impacts to groundwater in the Fairmont neighborhood.

- Hazen should continue with the groundwater monitoring plan that has been established in conjunction with CDPHE.

- If the concentration of PCE in private wells #5 & #6 continues to increase beyond levels of PCE found in 2007, indoor air sampling should be considered.

- PCE is a carcinogen that is found in private wells of the Fairmont neighborhood. To be prudent of public health, the following recommendations are made to reduce the risk of developing adverse health effects from exposure to PCE in private wells:
    - Residents of private wells #5 and #6 should avoid using well water for filling child pools and hot tubs because the level of PCE in these wells has been increasing in recent sampling events. If the residents decide to use the well water for this purpose, they may want to consider some risk reduction methods such as a filtration system.
    - If the residents of private wells #5 and #6 decide to use well water for irrigation purposes, they may want to consider some risk reduction methods such as a filtration system, the use of spray irrigation, and testing of a variety of the fruits and vegetables from their garden for PCE and other chemicals.[1]
    - It is highly recommended that the private wells (#1 to #6) not be used for indoor household purposes (drinking, showering, etc.) in the future unless contaminant levels in the wells have consistently decreased (to meet state standards) or the well water is filtered to reduce contaminant levels prior to groundwater entering the house.

Public Health Action Plan

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

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[1] This determination represents a professional judgment that critical data are missing and CCPEHA has judged the data insufficient to support a health conclusion on the consumption of homegrown fruits and vegetables that were irrigated with PCE contaminated groundwater. This does not necessarily imply all data are incomplete, but that some additional data are required to support a decision.

Public health actions that will be implemented include:

- CDPHE should continue evaluating groundwater contaminant levels in the Fairmont neighborhood,
- CCPEHA will conduct additional health consultations as needed or requested.
- CCPEHA will provide the appropriate level of health education on the findings of this health consultation to stakeholders and the community.

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Additional Tables and Figures

Table 1. Private Well Groundwater Data Summary

Private Well	Contaminant	Minimum (in μg/L)	Maximum (in μg/L)	Mean* (in μg/L)	Number of Samples
#1	Tetrachloroethene	3.2	17	9.3	5
	Trichloroethene	ND	2.2	1.1	5
	Cis-1,2-Dichloroethene	ND	7.2	1.8	5
	Chloroform	ND	2.8	0.57	5
#2	Tetrachloroethene	10	190	101	4
	Trichloroethene	1.8	7.5	22.1	4
	Cis-1,2-Dichloroethene	1.9	5.3	3.5	4
	Chloroform	0.48	10	5.2	4
#3	Tetrachloroethene	1.4	21.4	7.9	5
	Trichloroethene	ND	0.71	0.29	5
	Cis-1,2-Dichloroethene	ND	ND	0.19	5
	Chloroform	ND	0.96	0.38	5
#4	Tetrachloroethene	3.0	18.3	11.0	7
	Trichloroethene	ND	0.82	0.40	7
	Cis-1,2-Dichloroethene	ND	ND	0.19	7
	Chloroform	ND	1.1	0.67	7
#5	Tetrachloroethene	39	88.2	61.9	6
	Trichloroethene	ND	3.3	2.3	6
	Cis-1,2-Dichloroethene	ND	1.2	0.63	6
	Chloroform	ND	5.0	3.2	6
#6	Tetrachloroethene	88	160	127.6	5
	Trichloroethene	ND	3.1	2.2	5
	Cis-1,2-Dichloroethene	ND	0.90	0.33	5
	Chloroform	5.4	12.0	9.4	5

*Mean values calculated using ½ of the Practical Quantitation Limit (PQL)
μg/L: micrograms contaminant per liter of water
ND: Contaminant was not detected

Table 3. Comparison Values and Selection of Contaminants of Potential Concern (COPCs)

Private Well	Contaminant	Maximum (in μg/L)	EPA Regional Screening Level (in μg/L)	ATSDR Comparison Value (in μg/L)	COPC
#1	Tetrachloroethene	17	0.11	10[2]	X
	Trichloroethene	2.2	2.0	5.0[3]	X
	Cis-1,2-Dichloroethene	7.2	70 (MCL)	70[2]	
	Chloroform	2.8	0.19	100[1]	X
#2	Tetrachloroethene	190	0.11	10[2]	X
	Trichloroethene	7.5	2.0	5.0[3]	X
	Cis-1,2-Dichloroethene	5.3	70 (MCL)	70[2]	
	Chloroform	10	0.19	100[1]	X
#3	Tetrachloroethene	21.4	0.11	10[2]	X
	Trichloroethene	0.71	2.0	5.0[3]	
	Cis-1,2-Dichloroethene	ND	70 (MCL)	70[2]	
	Chloroform	0.96	0.19	100[1]	X
#4	Tetrachloroethene	18.3	0.11	10[2]	X
	Trichloroethene	0.82	2.0	5.0[3]	
	Cis-1,2-Dichloroethene	ND	70 (MCL)	70[2]	
	Chloroform	1.1	0.19	100[1]	X
#5	Tetrachloroethene	88.2	0.11	10[2]	X
	Trichloroethene	3.3	2.0	5.0[3]	X
	Cis-1,2-Dichloroethene	1.2	70 (MCL)	70[2]	
	Chloroform	5.0	0.19	100[1]	X
#6	Tetrachloroethene	160	0.11	10[2]	X
	Trichloroethene	3.1	2.0	5.0[3]	X
	Cis-1,2-Dichloroethene	0.90	70 (MCL)	70[2]	
	Chloroform	12.0	0.19	100[1]	X

[1] Chronic Environmental Media Evaluation Guide
[2] Lifetime Health Advisory
[3] Maximum Contaminant Level
μg/L: micrograms contaminant per liter of water
ND: Contaminant was not detected
MCL: Maximum Contaminant Level that is permissible in public drinking water supplies

Table 5. Non-cancer Hazard Quotients for Children

Well Number	Exposure Pathway	Exposure Level	Tetrachloroethene Hazard Quotient	Trichloroethene Hazard Quotient	Chloroform Hazard Quotient
Private Well #1	Dermal	Maximum	9.27E-03	1.26E-02	3.15E-04
		Minimum	1.75E-03	2.84E-03	1.85E-05
	Incidental Ingestion	Maximum	8.07E-04	3.01E-03	1.33E-04
		Minimum	1.52E-04	6.81E-04	7.84E-06
	Combined Pool Exposure	**Maximum**	**1.01E-02**	**1.56E-02**	**4.48E-04**
		Minimum	**1.90E-03**	**3.52E-03**	**2.64E-05**
Private Well #2	Dermal	Maximum	1.04E-01	4.96E-02	1.12E-03
		Minimum	5.45E-03	1.19E-02	5.39E-05
	Incidental Ingestion	Maximum	9.02E-03	1.19E-02	4.75E-04
		Minimum	4.75E-04	2.85E-03	2.28E-05
	Combined Pool Exposure	**Maximum**	**1.13E-01**	**6.15E-02**	**1.60E-03**
		Minimum	**5.93E-03**	**1.47E-02**	**7.67E-05**
Private Well #3	Dermal	Maximum	1.17E-02	4.69E-03	1.08E-04
		Minimum	7.64E-04	1.22E-03	1.85E-05
	Incidental Ingestion	Maximum	3.83E-10	1.43E-09	6.31E-11
		Minimum	7.22E-11	3.23E-10	3.72E-12
	Combined Pool Exposure	**Maximum**	**1.17E-02**	**4.69E-03**	**1.08E-04**
		Minimum	**7.64E-04**	**1.22E-03**	**1.85E-05**
Private Well #4	Dermal	Maximum	9.98E-03	5.42E-03	1.24E-04
		Minimum	1.64E-03	1.22E-03	1.85E-05
	Incidental Ingestion	Maximum	8.69E-04	1.30E-03	5.22E-05
		Minimum	1.42E-04	2.93E-04	7.84E-06
	Combined Pool Exposure	**Maximum**	**1.09E-02**	**6.72E-03**	**1.76E-04**
		Minimum	**1.78E-03**	**1.52E-03**	**2.64E-05**
Private Well #5	Dermal	Maximum	4.81E-02	2.18E-02	5.62E-04
		Minimum	2.13E-02	1.22E-03	1.85E-05
	Incidental Ingestion	Maximum	4.19E-03	5.22E-03	2.37E-04
		Minimum	1.85E-03	2.93E-04	7.84E-06
	Combined Pool Exposure	**Maximum**	**5.23E-02**	**2.70E-02**	**7.99E-04**
		Minimum	**2.31E-02**	**1.52E-03**	**2.64E-05**

Table 5. Non-cancer Hazard Quotients for Children (continued)

Well Number	Exposure Pathway	Exposure Level	Tetrachloroethene Hazard Quotient	Trichloroethene Hazard Quotient	Chloroform Hazard Quotient
Private Well #6	Dermal	Maximum	8.73E-02	2.05E-02	1.35E-03
		Minimum	4.80E-02	1.22E-03	6.07E-04
	Incidental Ingestion	Maximum	7.60E-03	4.91E-03	5.70E-04
		Minimum	4.18E-03	2.93E-04	2.56E-04
	Combined Pool Exposure	**Maximum**	**9.49E-02**	**2.54E-02**	**1.92E-03**
		Minimum	**4.80E-02**	**1.22E-03**	**6.09E-04**

NOTES:

1) The Hazard Quotient (HQ) is equivalent to the estimated exposure dose of a contaminant (Table A5) divided by the health-based guideline for that contaminant (Table B1).
2) HQs greater than 1 indicate that the estimated exposure dose is greater than the health-based guideline.
3) **Bolded material is the combined dermal and ingestion dose that would result from swimming, wading, or bathing in a hot tubs and/or child pools.**

Table 6. Non-cancer Hazard Quotients for Adults

Well Number	Exposure Pathway	Exposure Level	Tetrachloroethene Hazard Quotient	Trichloroethene Hazard Quotient	Chloroform Hazard Quotient
Private Well #1	Dermal	Maximum	5.42E-03	7.34E-03	1.84E-04
		Minimum	1.02E-03	1.66E-03	1.08E-05
	Incidental Ingestion	Maximum	1.73E-04	6.44E-04	2.85E-05
		Minimum	3.26E-05	1.46E-04	1.68E-06
	Combined Pool Exposure	**Maximum**	**5.59E-03**	**7.99E-03**	**2.12E-04**
		Minimum	**1.05E-03**	**1.81E-03**	**1.25E-05**
Private Well #2	Dermal	Maximum	6.06E-02	2.90E-02	6.57E-04
		Minimum	3.19E-03	6.95E-03	3.15E-05
	Incidental Ingestion	Maximum	1.93E-03	2.54E-03	1.02E-04
		Minimum	1.02E-04	6.11E-04	4.88E-06
	Combined Pool Exposure	**Maximum**	**6.25E-02**	**3.15E-02**	**7.59E-04**
		Minimum	**3.29E-03**	**7.57E-03**	**3.64E-05**
Private Well #3	Dermal	Maximum	6.82E-03	2.74E-03	6.31E-05
		Minimum	4.46E-04	7.15E-04	1.08E-05
	Incidental Ingestion	Maximum	2.18E-04	2.41E-04	9.77E-06
		Minimum	1.42E-05	6.28E-05	1.68E-06
	Combined Pool Exposure	**Maximum**	**7.04E-03**	**2.98E-03**	**7.28E-05**
		Minimum	**4.60E-04**	**7.78E-04**	**1.25E-05**
Private Well #4	Dermal	Maximum	5.83E-03	3.17E-03	7.23E-05
		Minimum	9.56E-04	7.15E-04	1.08E-05
	Incidental Ingestion	Maximum	1.86E-04	2.78E-04	1.12E-05
		Minimum	3.05E-05	6.28E-05	1.68E-06
	Combined Pool Exposure	**Maximum**	**6.02E-03**	**3.45E-03**	**8.34E-05**
		Minimum	**9.87E-04**	**7.78E-04**	**1.25E-05**
Private Well #5	Dermal	Maximum	2.81E-02	1.28E-02	3.28E-04
		Minimum	1.24E-02	7.15E-04	1.08E-05
	Incidental Ingestion	Maximum	8.98E-04	1.12E-03	5.09E-05
		Minimum	3.97E-04	6.28E-05	1.68E-06
	Combined Pool Exposure	**Maximum**	**2.90E-02**	**1.39E-02**	**3.79E-04**
		Minimum	**1.28E-02**	**7.78E-04**	**1.25E-05**

Table 6 (continued). Non-cancer Hazard Quotients for Adults

Well Number	Exposure Pathway	Exposure Level	Tetrachloroethene Hazard Quotient	Trichloroethene Hazard Quotient	Chloroform Hazard Quotient
Private Well #6	Dermal	Maximum	5.10E-02	1.20E-02	7.88E-04
		Minimum	2.81E-02	7.15E-04	3.55E-04
	Incidental Ingestion	Maximum	1.63E-03	1.05E-03	1.22E-04
		Minimum	8.95E-04	6.28E-05	5.50E-05
	Combined Pool Exposure	**Maximum**	**5.26E-02**	**1.30E-02**	**9.10E-04**
		Minimum	**2.89E-02**	**7.78E-04**	**4.10E-04**

NOTES:

1) Hazard Quotient is equivalent to the estimated exposure dose of a contaminant (Table A6) divided by the health-based guideline for that contaminant (Table B1).
2) HQs greater than 1 indicate that the estimated exposure dose is greater than the health-based guideline.
3) **Bolded material is the combined dermal and ingestion dose that would result from swimming, wading, or bathing in a hot tubs and/or child pools.**

Table 7. Age-Adjusted Theoretical Cancer Risks

Well Number	Exposure Pathway	Exposure Level	Tetrachloroethene Theoretical Cancer Risks	Trichloroethene Theoretical Cancer Risks	Chloroform Theoretical Cancer Risks	Total Theoretical Cancer Risks
Private Well #1	Dermal	Maximum	1.43E-05	6.36E-09	2.79E-08	---
		Minimum	2.70E-06	1.44E-09	1.64E-09	---
	Incidental Ingestion	Maximum	6.91E-07	8.44E-10	6.54E-09	---
		Minimum	1.30E-07	1.91E-10	3.85E-10	---
	Combined Pool Exposure	**Maximum**	**1.50E-05**	**7.20E-09**	**3.44E-08**	**1.51E-05**
		Minimum	**2.83E-06**	**1.63E-09**	**2.03E-09**	**2.83E-06**
Private Well #2	Dermal	Maximum	1.60E-04	2.51E-08	9.97E-08	---
		Minimum	8.43E-06	6.03E-09	4.78E-09	---
	Incidental Ingestion	Maximum	7.73E-06	3.33E-09	2.33E-08	---
		Minimum	4.07E-07	8.00E-10	1.12E-09	---
	Combined Pool Exposure	**Maximum**	**1.68E-04**	**2.84E-08**	**1.23E-07**	**1.68E-04**
		Minimum	**8.83E-06**	**6.83E-09**	**5.90E-09**	**8.85E-06**
Private Well #3	Dermal	Maximum	1.80E-05	---	9.57E-09	---
		Minimum	1.18E-06	---	1.64E-09	---
	Incidental Ingestion	Maximum	8.70E-07	---	2.24E-09	---
		Minimum	5.69E-08	---	3.85E-10	---
	Combined Pool Exposure	**Maximum**	**1.89E-05**	**---**	**1.18E-08**	**1.89E-05**
		Minimum	**1.24E-06**	**---**	**2.03E-09**	**1.24E-06**

Table 7. Age-Adjusted Theoretical Cancer Risks (cont.)

Well Number	Exposure Pathway	Exposure Level	Tetrachloroethene Theoretical Cancer Risks	Trichloroethene Theoretical Cancer Risks	Chloroform Theoretical Cancer Risks	Total Theoretical Cancer Risks
Private Well #4	Dermal	Maximum	1.54E-05	---	1.10E-08	---
		Minimum	2.53E-06	---	1.64E-09	---
	Incidental Ingestion	Maximum	7.44E-07	---	2.57E-09	---
		Minimum	1.22E-07	---	3.85E-10	---
	Combined Pool Exposure	**Maximum**	**1.62E-05**	**---**	**1.35E-08**	**1.62E-05**
		Minimum	**2.65E-06**	**---**	**2.03E-09**	**2.65E-06**
Private Well #5	Dermal	Maximum	7.43E-05	1.10E-08	4.98E-08	---
		Minimum	3.29E-05	6.19E-10	1.64E-09	---
	Incidental Ingestion	Maximum	3.59E-06	1.47E-09	1.17E-08	---
		Minimum	1.59E-06	8.22E-11	3.85E-10	---
	Combined Pool Exposure	**Maximum**	**7.79E-05**	**1.25E-08**	**6.15E-08**	**7.80E-05**
		Minimum	**3.44E-05**	**7.02E-10**	**2.03E-09**	**3.44E-05**
Private Well #6	Dermal	Maximum	1.35E-04	1.04E-08	1.20E-07	---
		Minimum	7.41E-05	6.19E-10	5.38E-08	---
	Incidental Ingestion	Maximum	6.51E-06	1.38E-09	2.80E-08	---
		Minimum	3.58E-06	8.22E-11	1.26E-08	---
	Combined Pool Exposure	**Maximum**	**1.41E-04**	**1.18E-08**	**1.48E-07**	**1.41E-04**
		Minimum	**7.77E-05**	**7.02E-10**	**6.64E-08**	**7.78E-05**

NOTES: Age-adjusted theoretical cancer risks account for exposure as a child and as an adult. Acceptable cancer risks range from 1E-06 (low-end) to 1E-04 (high-end).

Appendices

Appendix A. Additional Exposure Assessment Information

The first step to determine if adverse health effects are likely to occur from exposure to contamination found in the Fairmont Neighborhood site is to estimate exposure doses for the people that are likely to come into contact with site-related contamination. The estimated exposure doses are designed to be conservative estimations of actual contaminant intake, accounting for the majority of potential exposures at the site. As mentioned previously in the document, exposure doses are only estimated for Contaminants of Potential Concern (COPC), which have exceeded the comparison values (CVs). Estimating the exposure dose requires assumptions to made regarding various exposure parameters such as the frequency of a particular activity, duration of exposure to site-related contamination, and the amount of a particular substance that is taken in by an individual during a given activity. Site-specific exposure information is always preferable when estimating exposure doses. However, site-specific information is rarely available due to time and financial constraints. In lieu of site-specific information, default exposure parameters that are established by the U.S. Environmental Protection Agency (EPA) and Agency for Toxic Substances and Disease (ATSDR) are used in the exposure dose estimation. At times, professional judgment is used when default values are not available or seem unreasonable for the site exposures.

Two primary receptors were identified in this evaluation that are likely to come into contact with site-related contamination now or in the future, child and adult residents. The major exposure factors used are listed below in Table A1. The primary exposure pathway evaluated in this health consultation is exposure from secondary uses of contaminated groundwater (kiddie pools, hot tubs, etc.). Overall, the main dose estimations calculated in this evaluation assume exposure to contaminated groundwater in hot tubs and child pools for 52 hours per year over a period of 6 yrs. (children) or 30 yrs. (adults). Two routes of exposure exist in this exposure pathway scenario: 1) dermal exposure to water containing VOCs and 2) incidental ingestion of water containing VOCs. Since both routes of exposure occur at the same time, the estimated doses for each exposure route are combined to form a total dose for each contaminant. Non-cancer and cancer exposure doses are estimated for both pathways. The major difference between estimating non-cancer and cancer doses are that non-cancer doses are averaged over the exposure duration and cancer doses are averaged over a lifetime.

Table A1. Exposure Factors

Receptor	Body Weight (BW)	Exposure Frequency (EF)	Exposure Duration (ED)	Incidental Water Ingestion Rate* (IRW)	Skin Surface Area** (SA)	Time per Event (t_{ev})	Non-cancer Averaging Time (AT_{NC})	Cancer Averaging Time (AT_C)	Conversion Factor (CF)
Child Residents	15 kg. (EPA 1997)	52 days per year (professional judgment)	6 years (EPA 1997)	50 ml. Per hour or event (EPA 1997)	6600 cm^2 (EPA RAGS, Part E 2004)	1 hr. (professional judgment)	2190 days (EPA RAGS A, 1989)	25550 days (EPA RAGS A, 1989)	10^{-3} mg/µg
Adult Residents	70 kg. (EPA 1997)	52 days per year (professional judgment)	30 year (non-cancer) 24 years (cancer) (EPA 1997)	50 ml. per hour or event (EPA 1997)	18000 cm^2 (EPA RAGS, Part E 2004)	1 hr. (professional judgment)	10950 days (EPA RAGS A, 1989)	25550 days (EPA RAGS A, 1989)	10^{-3} mg/µg

Notes:
*Age-adjusted water ingestion rate (IRW_{adj}) equals 0.037 L-yr/kg based on the exposure duration of 6 years as a child and 24 years as an adult
**Age-adjusted dermal exposure factor (SA_{adj}) 8811.43 cm^2-yr/kg-event (EPA RAGS, Part E 2004)
cm.^{2} = square centimeters
kg. = kilogram
mg. = milligram
µg. = microgram
EPA (1997) = Environmental Protection Agency, Exposure Factors Handbook
EPA RAGS, Part E (2004) = Environmental Protection Agency, Risk Assessment Guidance for Superfund, Part E. Supplemental Guidance for Dermal Exposure

Table A2. Chemical-Specific Dermal Exposure Factors (EPA RAGS, Part E 2004)

COPC	Fraction Absorbed FA (dimensionless)	Dermal Permeability Coefficient of Compound in Water K_p (cm./hr.)	Lag Time per event τ_{event} (hour/event)	Time to reach steady-state t^* (in hours)
Tetrachloroethene	1.0	3.3E-02	0.91	2.18
Trichloroethene	1.0	1.2E-02	0.58	1.39
Cis-1,2-Dichloroethene	NA	NA	NA	NA
Chloroform	1.0	6.8E-03	0.50	1.19

NOTE: cm./hr. = centimeters per hour

Another critical component of the exposure dose estimation is the concentration of chemicals of potential concern that individuals are likely to be exposed to in a particular medium, which is referred to as the Exposure Point Concentration (EPC). The EPA has established guidelines for determining the EPC. In Region 8, if there are less than 10 samples available for a contaminant, the maximum detected concentration is used as the EPC since there is a limited amount of information about the actual concentration in a particular medium and area. In this health consultation, there were less than 10 samples available for each private well. Therefore, the maximum concentration was used as the high-end exposure point concentration. Because the concentrations of groundwater contaminants appear to be fluctuating up and down over time, a low-end value was also selected to provide a range of potential risk to private wells owners. The EPCs used in this evaluation are presented in Table A3.

Table A3. Exposure Point Concentrations used in Dose Calculations

Well Location	Contaminant	High-end Value (µg/L or ppb)	Low-end Value (µg/L or ppb)
Private Well #1	Tetrachloroethene	17.0	3.2
	Trichloroethene	1.9	0.43
	Cis-1,2-Dichloroethene	7.2	0.19
	Chloroform	2.8	0.165
Private Well #2	Tetrachloroethene	190.0	10.0
	Trichloroethene	7.5	1.8
	Cis-1,2-Dichloroethene	5.3	1.9
	Chloroform	10.0	0.48
Private Well #3	Tetrachloroethene	21.4	1.4
	Trichloroethene	0.71	0.185
	Cis-1,2-Dichloroethene	0.19	0.19
	Chloroform	0.96	0.165
Private Well #4	Tetrachloroethene	18.3	3.0
	Trichloroethene	0.82	0.185
	Cis-1,2-Dichloroethene	0.19	0.19
	Chloroform	1.1	0.165
Private Well #5	Tetrachloroethene	88.2	39.0
	Trichloroethene	3.3	0.185
	Cis-1,2-Dichloroethene	1.2	0.19
	Chloroform	5.0	0.165
Private Wells #6	Tetrachloroethene	160	88.0
	Trichloroethene	3.1	0.185
	Cis-1,2-Dichloroethene	0.9	0.19
	Chloroform	12.0	5.4

NOTE: ppb = parts per billion, µg/L = micrograms contaminant per liter of water
Values in red indicate ½ of the detection limit; these samples were not detected.

Non-cancer and cancer health endpoints are evaluated differently so the estimation of exposure dose also differs slightly (non-cancer doses are averaged over the timeframe of exposure and cancer doses are averaged over a lifetime). The exposure dose equations used in this evaluation are presented below. Use the equations below and the values presented above in Tables A1-A3 to reproduce the output Tables A4-A7.

Dose Equations (See Tables A1, A2, and A3 for equation parameters)

Non-Cancer Surface Water Ingestion Dose

Non-Cancer Dose = $(C_w * IRW * CF * EF * ED) / (BW * AT_{NC})$

Where:
C_w = Chemical Concentration in Water (in ug/L or micrograms contaminant per liter of water)
IRW = Ingestion Rate of Water (in liters of water per event)
CF = Conversion Factor (in milligrams per microgram)
EF = Exposure Frequency (in days per year)
ED = Exposure Duration (in years)
BW = Body Weight (in kilograms)
AT_{NC} = Non-Cancer Averaging Time (in days)

*Example: Non-cancer child ingestion dose for maximum level PCE at Private well #1 = (17 ug/L * 0.050L * 10^{-3} mg/ug * 52 days * 6 years)/(15kg * 2190 days)= 8.07* 10^{-6}mg/kg-day*

Age-Adjusted Water Ingestion Cancer Dose

Cancer Dose = $(C_w * CF * IRW_{adj} * EF) / AT_C$

Where:
C_w = Chemical Concentration in Water (in ug/L or micrograms contaminant per liter of water)
IRW_{adj} = Age adjusted Ingestion Rate of Water (in Liter-years per kilogram)
CF = Conversion Factor (in milligrams per microgram)
EF = Exposure Frequency (in days per year)
BW = Body Weight (in kilograms)
AT_C = Cancer Averaging Time (in days)

Example: Age-adjusted cancer ingestion dose for maximum level PCE at Private well #1=
*(17 ug/L * 10^{-3} mg/ug * 0.037 L-year/kg * 52 days)/(25550 days)= 1.28 * 10^{-6}mg/kg-day*

Non-Cancer Dermal Absorbed Dose

DA event (mg/cm^2-event) = 2 FA * K_p * C_w * CF $\sqrt{(6\tau ev * tev \div \pi)}$ (EPA 2004, Equation 3-2)

DAD (mg/kg-day) = $\frac{\textbf{DAev * EF * ED *SA}}{\textbf{BW * AT}_{\textbf{NC}}}$ (EPA 2004, Equation 3-1)

Where:
DAev = Absorbed dose per event (in milligrams per square centimeter event)
FA = Fraction Absorbed Water (dimensionless)
K_p = Dermal permeability coefficient of compound in water (in centimeters per hour)
C_w = Chemical concentration in water (in micrograms per liter)
CF = Conversion factor (in milligrams contaminant per milliliter water)
τev = Lag time per event (in hours)
tev = Event Duration (in hours)
EF = Exposure Frequency (in days per year)
ED = Exposure Duration (in years)
SA = Skin Surface Area (in square centimeters)
BW = Body Weight (in kilograms)
AT_{NC} = Non-Cancer Averaging Time (in days)

Example: Non-cancer child dermal absorbed dose for maximum level PCE at Private well#1 =

$DA_{ev} = 2 * 1 * 3.3 * 10^{-2} cm/hr * 17 * 10^{-3} mg/ug \sqrt{(6 * 0.91 * 1 \div \pi)} = 1.48 * 10^{-6}$ *mg/cm^2-event*

*DAD = (1.48 * 10^{-6} mg/cm^2-event * 52 days * 6 years * 6600cm^2)/ (15kg * 2190 days)= 9.27 * 10^{-5}mg/kg-day*

Age-Adjusted Cancer Dermal Absorbed Dose

$$\textbf{DAD (mg/cm}^2\textbf{-event)} = \frac{\textbf{DAev * IRW}_{\textbf{adj}}\textbf{ * EF}}{\textbf{AT}_{\textbf{C}}}$$

Where:
DAev = Absorbed dose per event (in milligrams per square centimeter event)
IRW_{adj} = Age-adjusted dermal absorption factor (in square centimeter-year per kilogram)
EF = Exposure Frequency (in days)
AT_C = Cancer Averaging Time (in days)

NOTE: The DA event calculation for non-cancer and cancer dermal absorbed dose equations is the same (EPA 2004, Equation 3-2).

*Example: ($1.48*10^6$mg/cm^2-event * 8811.43cm^2-year/kg * 52 days)/25550 days = $2.65*10^{-5}$mg/kg-day*

Table A4. Dermal Absorbed Dose Per Event (DA_{ev})

Well Number	Exposure Level	Tetrachloroethene (mg/cm^2-event)	Trichloroethene (mg/cm^2-event)	Chloroform (mg/cm^2-event)
Private Well #1	Maximum	1.48E-06	6.01E-08	5.02E-08
	Minimum	2.78E-07	1.36E-08	2.96E-09
Private Well #2	Maximum	1.65E-05	2.37E-07	1.79E-07
	Minimum	8.70E-07	5.70E-08	8.61E-09
Private Well #3	Maximum	1.86E-06	2.25E-08	1.72E-08
	Minimum	1.22E-07	5.85E-09	2.96E-09
Private Well #4	Maximum	1.59E-06	2.59E-08	1.97E-08
	Minimum	2.61E-07	5.85E-09	2.96E-09
Private Well #5	Maximum	7.67E-06	1.04E-07	8.96E-08
	Minimum	3.39E-06	5.85E-09	2.96E-09
Private Well #6	Maximum	1.39E-05	9.81E-08	2.15E-07
	Minimum	7.66E-06	5.85E-09	9.68E-08

Table A5. Child Non-Cancer Exposure Dose Estimations

Well Number	Exposure Pathway	Exposure Level	Tetrachloroethene Dose (mg/kg-day)	Trichloroethene Dose (mg/kg-day)	Chloroform Dose (mg/kg-day)
Private Well #1	Dermal	Maximum	9.27E-05	3.77E-06	3.15E-06
		Minimum	1.75E-05	8.53E-07	1.85E-07
	Incidental Ingestion	Maximum	8.07E-06	9.02E-07	1.33E-06
		Minimum	1.52E-06	2.04E-07	7.84E-08
Private Well #2	Dermal	Maximum	1.04E-03	1.49E-05	1.12E-05
		Minimum	5.45E-05	3.57E-06	5.39E-07
	Incidental Ingestion	Maximum	9.02E-05	3.56E-06	4.75E-06
		Minimum	4.75E-06	8.55E-07	2.28E-07
Private Well #3	Dermal	Maximum	1.17E-04	1.41E-06	1.08E-06
		Minimum	7.64E-06	3.67E-07	1.85E-07
	Incidental Ingestion	Maximum	3.83E-12	4.28E-13	6.31E-13
		Minimum	7.22E-13	9.70E-14	3.72E-14
Private Well #4	Dermal	Maximum	9.98E-05	1.63E-06	1.24E-06
		Minimum	1.64E-05	3.67E-07	1.85E-07
	Incidental Ingestion	Maximum	8.69E-06	3.89E-07	5.22E-07
		Minimum	1.42E-06	8.79E-08	7.84E-08
Private Well #5	Dermal	Maximum	4.81E-04	6.55E-06	5.62E-06
		Minimum	2.13E-04	3.67E-07	1.85E-07
	Incidental Ingestion	Maximum	4.19E-05	1.57E-06	2.37E-06
		Minimum	1.85E-05	8.79E-08	7.84E-08
Private Well #6	Dermal	Maximum	8.73E-04	6.15E-06	1.35E-05
		Minimum	4.80E-04	3.67E-07	6.07E-06
	Incidental Ingestion	Maximum	7.60E-05	1.47E-06	5.70E-06
		Minimum	4.18E-05	8.79E-08	2.56E-06

mg/kg-day = milligrams of contaminant per kilogram day

Table A6. Adult Non-Cancer Exposure Dose Estimations

Well Number	Exposure Pathway	Exposure Level	Tetrachloroethene Dose (mg/kg-day)	Trichloroethene Dose (mg/kg-day)	Chloroform Dose (mg/kg-day)
Private Well #1	Dermal	Maximum	5.42E-05	2.20E-06	1.84E-06
		Minimum	1.02E-05	4.98E-07	1.08E-07
	Incidental Ingestion	Maximum	1.73E-06	1.93E-07	2.85E-07
		Minimum	3.26E-07	4.38E-08	1.68E-08
Private Well #2	Dermal	Maximum	6.06E-04	8.69E-06	6.57E-06
		Minimum	3.19E-05	2.09E-06	3.15E-07
	Incidental Ingestion	Maximum	1.93E-05	7.63E-07	1.02E-06
		Minimum	1.02E-06	1.83E-07	4.88E-08
Private Well #3	Dermal	Maximum	6.82E-05	---	6.31E-07
		Minimum	4.46E-06	---	1.08E-07
	Incidental Ingestion	Maximum	2.18E-06	---	9.77E-08
		Minimum	1.42E-07	---	1.68E-08
Private Well #4	Dermal	Maximum	5.83E-05	---	7.23E-07
		Minimum	9.56E-06	---	1.08E-07
	Incidental Ingestion	Maximum	1.86E-06	---	1.12E-07
		Minimum	3.05E-07	---	1.68E-08
Private Well #5	Dermal	Maximum	2.81E-04	3.83E-06	3.28E-06
		Minimum	1.24E-04	2.14E-07	1.08E-07
	Incidental Ingestion	Maximum	8.98E-06	3.36E-07	5.09E-07
		Minimum	3.97E-06	1.88E-08	1.68E-08
Private Well #6	Dermal	Maximum	5.10E-04	3.59E-06	7.88E-06
		Minimum	2.81E-04	2.14E-07	3.55E-06
	Incidental Ingestion	Maximum	1.63E-05	3.15E-07	1.22E-06
		Minimum	8.95E-06	1.88E-08	5.50E-07

mg/kg-day = milligrams of contaminant per kilogram day

Table A7. Age-adjusted Theoretical Cancer Exposure Doses

Well Number	Exposure Pathway	Exposure Level	Tetrachloroethene Cancer Dose (mg/kg-day)	Trichloroethene Cancer Dose (mg/kg-day)	Chloroform Cancer Dose (mg/kg-day)
Private Well #1	Dermal	Maximum	2.65E-05	1.08E-06	9.00E-07
		Minimum	4.99E-06	2.44E-07	5.31E-08
	Incidental Ingestion	Maximum	1.28E-06	1.43E-07	2.11E-07
		Minimum	2.41E-07	3.24E-08	1.24E-08
Private Well #2	Dermal	Maximum	2.78E-05	1.22E-06	1.11E-06
		Minimum	5.23E-06	2.76E-07	6.55E-08
	Incidental Ingestion	Maximum	2.96E-04	4.26E-06	3.22E-06
		Minimum	1.56E-05	1.02E-06	1.54E-07
Private Well #3	Dermal	Maximum	1.43E-05	---	7.53E-07
		Minimum	7.53E-07	---	3.61E-08
	Incidental Ingestion	Maximum	3.11E-04	---	3.97E-06
		Minimum	1.64E-05	---	1.90E-07
Private Well #4	Dermal	Maximum	1.54E-05	---	1.10E-08
		Minimum	2.53E-06	---	1.64E-09
	Incidental Ingestion	Maximum	1.38E-06	---	8.28E-08
		Minimum	2.26E-07	---	1.24E-08
Private Well #5	Dermal	Maximum	1.68E-05	1.87E-06	9.38E-08
		Minimum	2.75E-06	1.05E-07	1.41E-08
	Incidental Ingestion	Maximum	1.38E-04	1.87E-06	1.61E-06
		Minimum	6.09E-05	1.05E-07	5.31E-08
Private Well #6	Dermal	Maximum	6.64E-06	2.49E-07	3.77E-07
		Minimum	2.94E-06	1.39E-08	1.24E-08
	Incidental Ingestion	Maximum	1.44E-04	2.12E-06	1.98E-06
		Minimum	6.38E-05	1.19E-07	6.55E-08

mg/kg-day = milligrams of contaminant per kilogram day

Appendix B. Toxicological Evaluation

The basic objective of a toxicological evaluation is to identify what adverse health effects a chemical causes, and how the appearance of these adverse effects depends on dose. The toxic effects of a chemical also depend on the route of exposure (oral, inhalation, dermal), the duration of exposure (acute, subchronic, chronic or lifetime), the health condition of the person, the nutritional status of the person, and the life style and family traits of the person. In this evaluation, chronic oral exposures were evaluated.

The U.S. Environmental Protection Agency (EPA) and the Agency for Toxic Substances and Disease (ATSDR) have established oral reference doses (RfD) and minimal risk levels (MRL) for non-cancer effects. An RfD is the daily dose in humans (with uncertainty spanning perhaps an order of magnitude), including sensitive subpopulations, that is likely to be without an appreciable risk of non-cancer adverse health effects during a lifetime of exposure to a particular contaminated substance. An MRL is the dose of a compound that is an estimate of daily human exposure that is likely to be without an appreciable risk of adverse non-cancer effects of a specified duration of exposure. The acute, intermediate, and chronic MRLs address exposures of 14 days or less, 14 days to 365 days, and 1-year to lifetime, respectively. The health-based guidelines for the contaminants of potential concern for this evaluation are listed below.

Table B1. Oral Health-based Guidelines for the contaminants of potential concern

Contaminant Of Potential Concern	Oral Health-based Guideline (mg/kg-day)	Source of Oral Health-based Guideline	Oral Slope Factor (mg/kg-day^{-1})	Source of Oral Slope Factor
Chloroform	1.00E-02	ATSDR Chronic MRL	3.10E-02	California EPA
cis-1,2-Dichloroethene	1.00E-02	EPA PPRTV	N/a	N/a
Tetrachloroethene	1.00E-02	EPA IRIS	5.40E-01	California EPA
Trichloroethene	3.00E-04	EPA NCEA	5.90E-03	California EPA

Note: The same values were used for the dermal exposure pathway without adjustment for gastrointestinal absorption in accordance with EPA RAGs Part E.
mg/kg-day = milligrams of contaminant per kilogram day
MRL = Minimal Risk Level
N/a = Not applicable
IRIS = Integrated Risk Information System
NCEA = National Center for Environmental Health Assessment
PPRTV = Provisional Peer Reviewed Toxicity Value

It should be noted that the toxicity values for trichloroethene have been in limbo the past few years and there is little agreement on which values are appropriate for assessing the toxic potential of this compound. However in this document, the varying toxicity values are not of high importance because the concentration of TCE is low in all private wells that were evaluated. To assess the potential health risks for TCE, a range of cancer risk was calculated with CDPHE's interim slope factor of 0.4 mg/kg-day^{-1} (high-end). For example, the maximum concentration of TCE was found in private well #2 at 7.5 parts per billion. The corresponding age-adjusted cancer dose of TCE for the combined pool exposure equals $4.82 * 10^{-6}$ mg/kg-day (Table A7, private well #2). With the high-end oral slope factor, the theoretical cancer risks in this well are 1.93 excess cancer cases per million exposed individuals. However, this value is still at the low-end of the acceptable cancer risk range. Thus, the overall effect of the range in toxicity values is of little importance in this health consultation.

Appendix C. Public Health Statement for Tetrachloroethene

Public Health Statement for Tetrachloroethylene

CAS# 127-18-4

This Public Health Statement is the summary chapter from the Toxicological Profile for tetrachloroethylene. It is one in a series of Public Health Statements about hazardous substances and their health effects. A shorter version, the ToxFAQs™, is also available. This information is important because this substance may harm you. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present. For more information, call the ATSDR Information Center at 1-888-422-8737.

This public health statement tells you about tetrachloroethylene and the effects of exposure.

The Environmental Protection Agency (EPA) identifies the most serious hazardous waste sites in the nation. These sites make up the National Priorities List (NPL) and are the sites targeted for long-term federal cleanup. Tetrachloroethylene has been found in at least 771 of the 1,430 current or former NPL sites. However, it's unknown how many NPL sites have been evaluated for this substance. As more sites are evaluated, the sites with tetrachloroethylene may increase. This is important because exposure to this substance may harm you and because these sites may be sources of exposure.

When a substance is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment. This release does not always lead to exposure. You are exposed to a substance only when you come in contact with it. You may be exposed by breathing, eating, or drinking the substance or by skin contact.

If you are exposed to tetrachloroethylene, many factors determine whether you'll be harmed. These factors include the dose (how much), the duration (how long), and how you come in contact with it. You must also consider the other chemicals you're exposed to and your age, sex, diet, family traits, lifestyle, and state of health.

What is tetrachloroethylene?

Tetrachloroethylene is a synthetic chemical that is widely used for dry cleaning of fabrics and for metal-degreasing operations. It is also used as a starting material (building block) for making other chemicals and is used in some consumer products. Other names for tetrachloroethylene include perchloroethylene, PCE, perc, tetrachloroethene, perclene, and perchlor. It is a nonflammable liquid at room temperature. It evaporates easily into the air and has a sharp, sweet odor. Most people can smell tetrachloroethylene when it is present in the

air at a level of 1 part in 1 million parts of air (ppm) or more. In an experiment, some people could smell tetrachloroethylene in water at a level of 0.3 ppm.

What happens to tetrachloroethylene when it enters the environment?

Tetrachloroethylene enters the environment mostly by evaporating into the air during use. It can also get into water supplies and the soil during disposal of sewage sludge and factory waste and when leaking from underground storage tanks. Tetrachloroethylene may also get into the air, soil, or water by leaking or evaporating from storage and waste sites. It can stay in the air for several months before it is broken down into other chemicals or is brought back down to the soil and water by rain.

Much of the tetrachloroethylene that gets into water and soil will evaporate into the air. However, because tetrachloroethylene can travel through soils quite easily, it can get into underground drinking water supplies. If it gets into underground water, it may stay there for many months without being broken down. If conditions are right, bacteria will break down some of it and some of the chemicals formed may also be harmful. Under some conditions, tetrachloroethylene may stick to the soil and stay there. It does not seem to build up in animals that live in water, such as fish, clams, and oysters. We do not know if it builds up in plants grown on land.

How might I be exposed to tetrachloroethylene?

People can be exposed to tetrachloroethylene from environmental and occupational sources and from consumer products. Common environmental levels of tetrachloroethylene (called background levels) are several thousand times lower than levels found in some workplaces. Background levels are found in the air we breathe, in the water we drink, and in the food we eat. The chemical is found most frequently in air and, less often, in water. Tetrachloroethylene gets into air by evaporation from industrial or dry cleaning operations. It is also released from areas where chemical wastes containing it are stored. It is frequently found in water. For example, tetrachloroethylene was found in 38% of 9,232 surface water sampling sites throughout the United States. There is no similar information on how often the chemical is found in air samples, but we know it is widespread. We do not know how often it is found in soil, but in one study, it was found in 5% of 359 sediment samples.

In general, tetrachloroethylene levels in air are higher in cities or industrial areas where it is in use more than in more rural or remote areas. You can smell it at levels of 1 ppm in air. However, the background level of tetrachloroethylene in air is usually less than 1 part in 1 billion parts of air (ppb). The air close to dry cleaning shops and chemical waste sites has levels of tetrachloroethylene higher than background levels. These levels are usually less than 1 ppm, the level at which you can smell it. Water, both above and below ground, may contain tetrachloroethylene. Levels in water are also usually less than 1 ppb. Levels in contaminated water near disposal sites are higher than levels in water far away from those sites. Water polluted with this chemical may have levels greater than 1 ppm. In soil, background levels are probably 100–1,000 times lower than 1 ppm. You can also be exposed to tetrachloroethylene by using certain consumer products. Products that may contain it include water repellents, silicone lubricants, fabric finishers, spot removers, adhesives, and wood

cleaners. Although uncommon, small amounts of tetrachloroethylene have been found in food, especially food prepared near a dry cleaning shop. When you bring clothes home from the dry cleaners, the clothes may release small amounts of tetrachloroethylene into the air. The full significance to human health of these exposures to small amounts of tetrachloroethylene is unknown, but to date, they appear to be relatively harmless. Tetrachloroethylene can also be found in the breast milk of mothers who have been exposed to the chemical.

The people with the greatest chance of exposure to tetrachloroethylene are those who work with it. According to estimates from a survey conducted by the National Institute for Occupational Safety and Health (NIOSH), more than 650,000 U.S. workers may be exposed.

For the general population, the estimated amount that a person might breathe per day ranges from 0.08 to 0.2 milligrams. The estimated amount that most people might drink in water ranges from 0.0001 to 0.002 milligrams per day. These are very small amounts.

How can tetrachloroethylene enter and leave my body?

Tetrachloroethylene can enter your body when you breathe air containing it. How much enters your body in this way depends on how much of the chemical is in the air, how fast and deeply you are breathing, and how long you are exposed to it. Tetrachloroethylene may also enter your body when you drink water or eat food containing the chemical. How much enters your body in this way depends on how much of the chemical you drink or eat. These two exposure routes are the most likely ways people will take in tetrachloroethylene. These are also the most likely ways that people living near areas polluted with the chemical, such as hazardous waste sites, might be exposed to it. If tetrachloroethylene is trapped against your skin, a small amount of it can pass through into your body. Very little tetrachloroethylene in the air can pass through your skin into your body.

Most tetrachloroethylene leaves your body from your lungs when you breathe out. This is true whether you take in the chemical by breathing, drinking, eating, or touching it. A small amount of the tetrachloroethylene is changed by your body (especially your liver) into other chemicals that are removed from your body in urine. Most of the changed tetrachloroethylene leaves your body in a few days. Some of it that you take in is found in your blood and other tissues, especially body fat. Part of the tetrachloroethylene that is stored in fat may stay in your body for several days or weeks before it is eliminated.

How can tetrachloroethylene affect my health?

To protect the public from the harmful effects of toxic chemicals and to find ways to treat people who have been harmed, scientists use many tests.

One way to see if a chemical will hurt people is to learn how the chemical is absorbed, used, and released by the body; for some chemicals, animal testing may be necessary. Animal testing may also be used to identify health effects such as cancer or birth defects. Without laboratory animals, scientists would lose a basic method to get information needed to make wise decisions to protect public health. Scientists have the responsibility to treat research

animals with care and compassion. Laws today protect the welfare of research animals, and scientists must comply with strict animal care guidelines.

Tetrachloroethylene has been used safely as a general anesthetic agent, so at high concentrations, it is known to produce loss of consciousness. When concentrations in air are high—particularly in closed, poorly ventilated areas—single exposures can cause dizziness, headache, sleepiness, confusion, nausea, difficulty in speaking and walking, unconsciousness, and death. Irritation may result from repeated or extended skin contact with the chemical. As you might expect, these symptoms occur almost entirely in work (or hobby) environments when individuals have been accidentally exposed to high concentrations or have intentionally abused tetrachloroethylene to get a "high." In industry, most workers are exposed to levels lower than those causing dizziness, sleepiness, and other nervous system effects. The health effects of breathing in air or drinking water with low levels of tetrachloroethylene are not definitely known. However, at levels found in the ambient air or drinking water, risk of adverse health effects is minimal. The effects of exposing babies to tetrachloroethylene through breast milk are unknown. Results from some studies suggest that women who work in dry cleaning industries where exposures to tetrachloroethylene can be quite high may have more menstrual problems and spontaneous abortions than women who are not exposed. However, it is not known for sure if tetrachloroethylene was responsible for these problems because other possible causes were not considered.

Results of animal studies, conducted with amounts much higher than those that most people are exposed to, show that tetrachloroethylene can cause liver and kidney damage and liver and kidney cancers even though the relevance to people is unclear. Although it has not been shown to cause cancer in people, the U.S. Department of Health and Human Services has determined that tetrachloroethylene may reasonably be anticipated to be a human carcinogen. The International Agency for Research on Cancer (IARC) has determined that tetrachloroethylene is probably carcinogenic to humans. Exposure to very high levels of tetrachloroethylene can be toxic to the unborn pups of pregnant rats and mice. Changes in behavior were observed in the offspring of rats that breathed high levels of the chemical while they were pregnant. Rats that were given oral doses of tetrachloroethylene when they were very young, when their brains were still developing, were hyperactive when they became adults. How tetrachloroethylene may affect the developing brain in human babies is not known.

Is there a medical test to determine whether I have been exposed to tetrachloroethylene?

One way of testing for tetrachloroethylene exposure is to measure the amount of the chemical in the breath, much the same way breath alcohol measurements are used to determine the amount of alcohol in the blood. This test has been used to measure levels of the chemical in people living in areas where the air is contaminated with tetrachloroethylene or those exposed to the chemical through their work. Because it is stored in the body's fat and is slowly released into the bloodstream, it can be detected in the breath for weeks following a heavy exposure. Tetrachloroethylene can be detected in the blood. Also, breakdown products of the chemical can be detected in the blood and urine of people exposed to tetrachloroethylene. Trichloroacetic acid (TCA), a breakdown product of

tetrachloroethylene can be detected for several days after exposure. These tests are relatively simple to perform. The breath, blood, or urine must be collected in special containers and then sent to a laboratory for testing. Because exposure to other chemicals can produce the same breakdown products in the urine and blood, the tests for breakdown products cannot determine if you have been exposed only to tetrachloroethylene.

What recommendations has the federal government made to protect human health?

The federal government develops regulations and recommendations to protect public health. Regulations can be enforced by law. Federal agencies that develop regulations for toxic substances include the EPA, the Occupational Safety and Health Administration (OSHA), and the Food and Drug Administration (FDA). Recommendations provide valuable guidelines to protect public health but cannot be enforced by law. Federal organizations that develop recommendations for toxic substances include the Agency for Toxic Substances and Disease Registry (ATSDR) and NIOSH.

Regulations and recommendations can be expressed in not-to-exceed levels in air, water, soil, or food that are usually based on levels that affect animals; then they are adjusted to help protect people. Sometimes these not-to-exceed levels differ among federal organizations because of different exposure times (an 8-hour workday or a 24-hour day), the use of different animal studies, or other factors.

Recommendations and regulations are also periodically updated as more information becomes available. For the most current information, check with the federal agency or organization that provides it. Some regulations and recommendations for tetrachloroethylene include the following:

The EPA maximum contaminant level for the amount of tetrachloroethylene that can be in drinking water is 0.005 milligrams tetrachloroethylene per liter of water (mg/L) (0.005 ppm). EPA has established regulations and procedures for dealing with tetrachloroethylene, which it considers a hazardous waste. Many regulations govern its disposal. If amounts greater than 100 pounds are released to the environment, the National Response Center of the federal government must be told immediately.

OSHA limits the amount of tetrachloroethylene that can be present in workroom air. This amount is limited to 100 ppm for an 8-hour workday over a 40-hour workweek. NIOSH recommends that tetrachloroethylene be handled as a chemical that might potentially cause cancer and states that levels of the chemical in workplace air should be as low as possible.

Where can I get more information?

For additional information on tetrachloroethylene, refer to the ATSDR Toxicological Profile at: http://www.atsdr.cdc.gov/toxprofiles/tp18.html

References

Agency for Toxic Substances and Disease Registry (ATSDR). 1997. Toxicological profile for tetrachloroethylene. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.