Health Consultation

HAZEN RESEARCH, INC.

JEFFERSON COUNTY, COLORADO

SEPTEMBER 5, 2008

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

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

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

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HEALTH CONSULTATION

HAZEN RESEARCH, INC.

JEFFERSON COUNTY, COLORADO

Prepared By:

The Colorado Department of Public Health and Environment
Under Cooperative Agreement with the
U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry

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Foreword

The Colorado Department of Public Health and Environment's (CDPHE) Environmental Epidemiology Section has prepared this health consultation in cooperation with the Agency for Toxic Substances and Disease Registry (ATSDR). ATSDR is part of the US Department of Health and Human Services and is the principal federal public health agency responsible for the health issues related to hazardous waste. This health consultation was prepared in accordance with the methodologies and guidelines developed by ATSDR.

The purpose of this health consultation is to identify and prevent harmful health effects resulting from exposure to hazardous substances in the environment. Health consultations focus on health issues associated with specific exposures so that the state or local department of public health can respond quickly to requests from concerned citizens or agencies regarding health information on hazardous substances. The Colorado Cooperative Program for Environmental Health Assessments (CCPEHA) of the Environmental Epidemiology Section (EES) evaluates sampling data collected from a hazardous waste site, determines whether exposures have occurred or could occur in the future, reports any potential harmful effects, and then recommends actions to protect public health. The findings in this report are relevant to conditions at the site during the time this health consultation was conducted and should not necessarily be relied upon if site conditions or land use changes in the future.

For additional information or questions regarding the contents of this health consultation or the Environmental Epidemiology Section, please contact the author of this document:

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Summary and Statement of Issues

In the fall of 2007, a chlorinated solvent contaminant plume was discovered in the groundwater beneath the Fairmont neighborhood of Golden, CO. The available data to date suggests that one source of the contaminant plume is Hazen Research Incorporated (Hazen), an industrial research and development firm, located up-gradient of the Fairmont neighborhood. The Colorado Cooperative Program for Environmental Health Assessments (CCPEHA) was initially contacted in July of 2007 to assist with community concerns regarding the consumption of fruits and vegetables from domestic gardens that are irrigated with contaminated groundwater. After a preliminary investigation of the available environmental data, it was decided that a health consultation should be conducted to address the potential public health hazards associated with exposure to groundwater contaminants. This health consultation focuses on residential exposures to groundwater contaminants in the Fairmont neighborhood. Additional public health activities may be conducted in the future as additional data becomes available.

After reviewing the available environmental data, it was determined that theoretical cancer risks estimated for all exposures to perchloroethylene (PCE) constitute an indeterminate public health hazard because the actual exposure duration and the concentration of contaminants over time are unknown. However, if the groundwater has been contaminated for a period of 30 years at the currently identified concentrations, it would represent a public health hazard since the theoretical cancer risks are above the acceptable cancer risk range. Significant non-cancer health effects are not likely to be occurring because all estimated non-cancer health hazards are below a level of concern assuming 30 years of exposure at the currently identified concentrations of contaminants. It is however, important to note that the potential for non-cancer adverse health effects cannot be evaluated completely since the actual concentration of contaminants in the past (prior to July 2007) is unknown. Overall, it is recommended that a sampling and analysis plan be developed to better characterize the groundwater contaminant plume beneath the Fairmont neighborhood and also identify the sources of contamination. In addition, Hazen officials should continue with the remedial actions discussed in the Integrated Corrective Action Plan to reduce or remove the contaminant plume on their property.

Background

Site Description and History

Hazen Research Incorporated (Hazen) is an industrial research and development firm located in Golden, Colorado. Hazen was founded in 1961 and currently offers a variety of services for clients in the mineral, chemical, energy, and environmental fields. Specific site activities include development of hydrometallurgical, pyrometallurgical, and mineral benefication processes from most commercial metals and industrial minerals as well as for inorganic compounds (HWS 2007). The facility currently consists of 17 buildings overall including an onsite commercial analytical laboratory. 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. In April 2007, Hazen officials contacted the Colorado Department of Public Health and Environment's (CDPHE) Hazardous Waste and Waste Management Division, the Fairmont Fire Department, and the president of the Fairmont Homeowners Association to inform them of the incident and to seek further guidance.

CDPHE Hazardous Waste and Waste Management Division officials recommended the installation of onsite groundwater monitoring wells to identify any contaminant releases that may have occurred via the leaking floor trench. In May 2007, Hazen installed onsite groundwater monitoring wells and the initial sampling results revealed elevated concentrations of 3 halogenated organic solvents including tetrachloroethene (PCE), trichloroethene (TCE), and chloroform. PCE was found in the majority of the samples at the highest concentrations and appears to be the primary contaminant of concern. It should be noted that PCE was not used in the onsite analytical laboratory and has not historically been used in large quantities at the facility. However, Hazen officials indicated that small amounts of PCE were used in the 1960's and 1970's for flotation experiments conducted in building 6 (currently the analytical laboratory). The highest concentration of groundwater contaminants identified to date is in the immediate vicinity of building 6.

The subsurface investigation continued to expand into August of 2007 and currently includes the following data set:

- 41 groundwater samples from 23 onsite monitoring wells
- 46 passive soil gas samples from 38 onsite locations
- 49 offsite groundwater samples from 40 domestic wells in the Fairmont neighborhood
- 8 fruit and vegetable samples from domestic gardens of 3 Fairmont residents
- 24 active soil gas samples in the Fairmont neighborhood and one sample on the Hazen facility
- 5 indoor air samples from 3 houses in the Fairmont neighborhood

The available data indicates that contaminants are migrating off the Hazen facility from a source in the vicinity of the analytical laboratory. However, the contaminant plume is not clearly defined at this point in time. It is possible that other sources are contributing to the contaminant plume beneath the Fairmont neighborhood. For example, it appears that Ball Container is also contributing low levels of PCE to the groundwater plume. As mentioned, the primary groundwater contaminant appears to be PCE. However, TCE, chloroform, and vinyl chloride (VC), have also been detected sporadically at lower concentrations.

The Colorado Cooperative Program for Environmental Health Assessments (CCPEHA) was initially contacted in July 2007 to assist with community concerns regarding the consumption of fruits and vegetables from domestic gardens being irrigated with contaminated groundwater. At that time, CCPEHA recommended that fruit and vegetable samples be collected and analyzed and also determined that a health consultation should be performed to address the potential public health hazards associated with exposure to groundwater contaminants once additional data was collected. This evaluation focuses on residential exposures in the Fairmont neighborhood since this population is the most likely to be exposed to groundwater contaminants. An additional health consultation may be conducted in the future to analyze other potential exposure pathways to construction/utility workers operating onsite and in the Fairmont neighborhood.

Demographics

According to U.S. Census data (2000), there are 370 individuals occupying 139 homes in the area currently under investigation (2.7 people per household). The population consists of slightly more males (52%) than females (48%) with a median age of 42 years. Approximately 7% of this population is under the age of 5 years and nearly 6% (5.7%) is over the age of 65 years. Language data is not available at this resolution. However, the data does show a small Hispanic/Latino (4%) and Asian (1.1%) subpopulation indicating that multilingual materials may be needed to communicate public health information.

Community Health Concerns

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.

Discussion

Environmental Data

The available environmental data pertinent to this evaluation consists of domestic groundwater well samples, fruit and vegetable samples from domestic gardens, and indoor air samples from homes in the Fairmont neighborhood. Each environmental medium used in this health consultation is described in more detail below. Additional onsite data is available that was not used in this document since Fairmont residents are the primary population of concern at this time. A detailed description of the current onsite data is available in the Integrated Corrective Action Plan (HWS 2007).

Residential Groundwater Data

A residential groundwater survey was conducted by Hazen through the Colorado State Engineers Office to determine potentially affected domestic wells in the Fairmont neighborhood. In addition, Hazen personnel contacted each household in the Fairmont neighborhood in May 2007 to determine any additional wells that may not have been identified in the well survey and to determine the actual use of those wells. A total of 40 domestic wells were identified in the neighborhood, 29 of which are used for agricultural/domestic irrigation and 11 that are used for drinking water.

A total of forty-nine groundwater samples from the 40 groundwater wells identified were collected and analyzed in July, August, and September of 2007. The samples were sent to Evergreen Analytical Laboratory, a certified analytical laboratory, located in Wheat Ridge, CO. The samples were analyzed for Volatile Organic Compounds (VOCs) by the Environmental Protection Agency's (EPA) Method 524.2 and Method 8260B. A summary of the residential groundwater data is shown below in Table 1 and the complete data set is contained in Table 5. PCE was detected in the majority of the samples (65%) at concentrations ranging from 0.53 parts contaminant per billion parts water (ppb) to 140 ppb. As mentioned, TCE, chloroform, and VC were also detected, but less frequently and at lower concentrations.

Table 1. Summary of Residential Groundwater Data

Contaminants	Minimum (µg/L)	Mean (µg/L)	Maximum (µg/L)	Percent Detected	Number of Samples
Chloroform	0.52	2.83	10	30.6 %	49
Tetrachloroethene	0.53	20.29	140	55.1 %	49
Trichloroethene	0.54	2.14	6.8	20.4 %	49
Vinyl Chloride	0.72	1.01	1.30	4.1 %	49

µg/L: micrograms contaminant per liter of water

Fruit and Vegetable Data

Fruits and vegetables were collected and analyzed from 3 domestic gardens in the Fairmont neighborhood that were irrigated with contaminated groundwater. Eight fruits and vegetables were collected in September 2007 and sent to EAL for VOC analysis by Method 8260B. Acetone and 2-Butanone were the only contaminants detected in the vegetation samples. These contaminants are not thought to be related to the groundwater contaminant plume under investigation and were dropped from further investigation. Both contaminants could possibly be related to laboratory contamination. However, it is known that some fruits and vegetables naturally produce acetone.

Residential Indoor Air Data

Five indoor and one outdoor air samples were collected from 3 homes in the Fairmont neighborhood where some of the highest concentrations of PCE in groundwater were found. The samples were collected using the approved method of evacuated 6-Liter Summa canisters, fitted with regulators to control air flow over a 24-hour period. The samples were sent to Test America laboratory for VOC analysis by EPA Method TO-15 with Select Ion Monitoring Mode (SIM). SIM is an analytical technique, which enables the laboratory to identify compounds at relatively low concentrations. PCE and its degradation byproducts, 1,1-Dichloroethene (DCE), cis-1,2-DCE, trans-1,2-DCE, and vinyl chloride (VC) were selected for SIM analysis. The analytical results revealed PCE and TCE in the indoor air of the 3 homes sampled. All other contaminants that were analyzed for were not detected. It should be noted that PCE and TCE are also found in many household products, which can also contribute to indoor air contaminants. Thus, it is not possible to determine if the indoor air contaminants identified in this evaluation are strictly related to the groundwater contamination. The indoor air data is summarized below in Table 2 and presented in full in Table 7.

Table 2. Summary of Residential Indoor Air Data

Sample Date	House Number	Tetrachloroethene ($\mu g/m^3$)	Trichloroethene ($\mu g/m^3$)
11/6/2007	House #24	3.8	0.14
11/6/2007	House #28	9.9	0.089
11/6/2007	House #23	2.1	0.074

$\mu g/m^3$: micrograms contaminant per cubic meter of air

Selection of Contaminants of Potential Concern (COPC)

To screen the available environmental data for contaminants of potential concern, the Colorado Cooperative Program for Environmental Health Assessment of the CDPHE uses the ATSDR Comparison Values (CVs), the EPA's Region 9 Preliminary Remediation Goals (PRGs) and/or EPA's Region 3 Risk Based Concentrations (RBCs). These CVs are conservative values based on health-based guidelines with built-in orders of protection. The appropriate CV is compared with the maximum detected concentration of the contaminant in groundwater and indoor air to determine if further evaluation is necessary. Contaminant levels below the PRG are not likely to result in adverse or harmful health effects and are dropped from further analysis. Contaminants that exceed the screening values are evaluated further. However, exceeding the comparison value does not necessarily indicate that adverse health effects are likely to occur, only that more analysis is necessary.

In groundwater, chloroform, PCE, TCE, and VC were all found at levels above the screening value (Table 6). PCE is the primary COPC since it was detected the most frequently at the highest concentrations in all domestic well data. Chloroform, PCE, TCE, and VC were carried to the next step of the evaluation process. However, VC was considered a COPC only for irrigation wells because it was not detected in domestic wells. In indoor air, only PCE and TCE were detected above the comparison value and carried forward (Table 7). PCE is also the primary COPC in indoor air.

Exposure Assessment

The next step of the evaluation process consists of identifying the ways that individuals could come into contact with site-related contaminants. The conceptual site model describes the primary contaminants of potential concern, contaminated sources, and the potential exposure pathways by which different types of populations (e.g. residents) might come into contact with contaminated media. Exposure pathways are classified as either complete, potential, or eliminated. Only complete exposure pathways can be fully evaluated and characterized to determine the public health implications. A complete exposure pathway consists of five elements: a source, a contaminated environmental medium and transport mechanism, a point of exposure, a route of exposure, and a receptor population.

Three primary routes of exposure to domestic groundwater exist: ingestion of drinking water, inhalation of VOCs during showering and/or bathing, and dermal exposure to contaminated water during showering, bathing, hand washing, etc. It is likely that residents with contaminated groundwater wells are, or have been in the past, exposed to COPCs through each of these exposure routes to some degree. In addition, contaminated groundwater can affect indoor air by vapor intrusion from the aquifer, through the vadose zone, and into the building (i.e. house). Inhalation is the only relevant route of exposure for contaminated indoor air. The conceptual site model for residents of the Fairmont neighborhood is shown below.

Conceptual Site Model

Source	Contaminated Environmental Medium	Point of Exposure	Route of Exposure	Timeframe of Exposure
Groundwater	Residential Domestic water	Buildings (Houses)	Ingestion	Past, Current, and Future
			Inhalation of VOCs	
			Dermal Absorption	
Groundwater	Residential Indoor Air	Buildings (Houses)	Inhalation	Past, Current, and Future
Groundwater	Fruits and Vegetables	Domestic Gardens	Ingestion	Past, Current, and Future

During the investigation of the groundwater plume, contaminants were found in both domestic wells, used for drinking water and other household purposes and agricultural/domestic irrigation wells. It is possible for contaminated irrigation wells to transfer chemicals to soil, crops, and the outdoor air. The VOCs under consideration in this evaluation are not expected to contaminate soil to a significant degree because of the relatively low concentrations observed to date and the fact that heat and volatilization would transfer most of the contamination to the atmosphere. The effect on the atmosphere (outdoor air) is also expected to be miniscule considering the relatively low concentrations and the huge volume of air. Thus, the use of contaminated domestic wells for irrigation purposes is not likely to result in significant exposures from soil or outdoor air and both media are not considered further in this assessment.

The available fruit and vegetable samples collected from domestic gardens in the Fairmont neighborhood have not shown any contaminants thought to be related to the groundwater plume under investigation. These samples were collected from gardens irrigated with some of the most highly contaminated wells known. This does not necessarily mean that no chemicals have been transferred to any crops that are currently being irrigated with contaminated groundwater. VOCs appear to accumulate to varying degrees depending on the species of the crop. It is possible that some crops have been affected, but have not been sampled or the sampling method was inadequate for detecting the presence of PCE. However, the probability of contaminated crops seems low for the same reasons identified above. In absence of any further evidence, this pathway will not be considered further at this time (i.e. relatively low concentrations and volatilization).

Public Health Implications

The overall purpose of this evaluation is to determine whether exposures to the identified groundwater and indoor air COPCs (PCE, TCE, and chloroform) might be associated with adverse health effects. This requires a calculation of site-specific exposure doses and comparison with an appropriate toxicity value (or health guideline) as described in Appendix A. Assumptions must be made on the exposure duration, exposure frequency, body weight, and other parameters that are also explained in detail in Appendix A. Very little is known about the source and spread of the current contaminant plume beneath the Fairmont neighborhood. The environmental data collected to date indicates that one possible source of contamination is the Hazen Research facility. Hazen officials maintain that PCE has not been used on their property since the 1960's and early 1970's. If this is the case, and Hazen is indeed the source of the contamination, then it is possible that the groundwater plume has existed for 30 years or more. It is expected that there would be a lag period between the time PCE was released to the environment, leached through the soil to groundwater, and then spread throughout the aquifer to the current placement. However, it is currently impossible to determine how long it would have taken for this scenario to materialize and what the concentrations of contaminants were over time. The first set of groundwater samples from private wells that indicated the presence of PCE in the Fairmont neighborhood were collected in July 2007. The exposure assumptions used in this evaluation are the CCPEHA standard default exposure parameters for residential scenarios as recommended by the ATSDR guidance manual. General assumptions include 350 days of exposure (2 weeks off for vacation/year) over a 30-year period (upper percentile length of time in one home), which are appropriate for use in this case even though the actual time of exposure is unknown.

As discussed in the conceptual site model, three relevant pathways to household groundwater exist. Eleven households were identified as using their domestic well for potable, household use in the well surveys conducted by Hazen. Three homes were also selected for indoor air sampling based on the high concentration of PCE found in those wells. Thus, exposure doses for drinking water and showering exposures (dermal and inhalation) were calculated at 11 homes. Exposure to contaminated indoor air outside of the bathroom was also calculated at the 3 homes where data was available. The exposure dose results for each pathway are presented in Appendix Tables A3-A9. The estimated exposure doses for non-cancer health effects were compared to health-based guidelines such as the ATSDR MRLs and EPA RfDs to determine the potential non-cancer health hazards. Theoretical cancer risks, which are averaged over a lifetime (70 yrs.), were calculated and compared to the EPA and CDPHE acceptable cancer risk range of $1 * 10^{-6} – 1 * 10^{-4}$. Literally, the acceptable cancer risk range is no more than 1 theoretical excess cancer case per 1,000,000 exposed individuals to 100 excess cancer cases per 1,000,000 exposed individuals.

All of the pathways analyzed in this evaluation occur simultaneously for residents. Thus, the evaluation of cumulative health impacts associated with all pathways of exposure was the primary focus of this consultation. Non-cancer health hazards and theoretical cancer risks for each pathway were combined to evaluate the cumulative health impacts of the typical household exposure. The cumulative non-cancer health hazards and theoretical cancer risks from the combined exposure pathways are shown below in Tables 3 and 4.

Non-Cancer Hazards

As shown in Table 3, the estimated non-cancer exposure doses from the combined exposures of drinking, showering, and indoor air inhalation are above the health-based guideline for PCE at 3 homes in the Fairmont neighborhood. Non-cancer health hazards from chloroform and TCE are not considered further since the combined estimated exposure doses for all pathways analyzed in this assessment are below the applicable health-based guidelines. In addition, the estimated exposure doses for the remaining 8 homes for which data was available are below the non-cancer health based guidelines for all COPCs.

To determine if a public health hazard exists from exposure to PCE at the 3 homes with elevated estimated exposure doses, the estimated doses from each household were compared to known health effects levels such as the No Observed Adverse Effect Level (NOAEL) and the Lowest observed Adverse Effect Level (LOAEL) that are described in scientific literature. The combined estimated exposure doses are well below both the NOAEL and LOAEL values for all contaminants, indicating that adverse health effects are not likely to occur. Overall, significant non-cancer adverse health effects from both routes of exposure are not likely to occur since the largest estimated doses are well below the known health effect levels following exposure to PCE. However, there is uncertainty associated with this conclusion since the oral and inhalation health effect levels in humans are not well defined and the EPA IRIS is in the process of re-evaluating the toxicity potential of PCE. In addition, the actual contaminant levels over time are unknown. Thus, the potential non-cancer health hazards cannot be completely evaluated.

Table 3. Comparison of combined exposure doses for all exposure pathways with health guidelines as indicated by Non-Cancer Hazard Quotients

Sample ID	Chloroform Hazard Quotient		Tetrachloroethene Hazard Quotient		Trichloroethene Hazard Quotient	
	Child	Adult	Child	Adult	Child	Adult
House #24	2.18E-01	5.37E-02	5.67E+00	1.41E+00	8.57E-01	3.37E-01
House #23	4.34E-02	1.07E-02	1.28E+00	3.29E-01	2.33E-01	9.15E-02
House #2	1.12E-02	2.76E-03	1.07E-01	2.61E-02	6.93E-02	2.73E-02
House #7	1.12E-02	2.76E-03	1.52E-02	3.71E-03	6.93E-02	2.73E-02
House #8	1.12E-02	2.76E-03	6.22E-02	1.52E-02	6.93E-02	2.73E-02
House #26	1.12E-02	2.76E-03	4.45E-02	1.08E-02	6.93E-02	2.73E-02
House #27	2.33E-02	5.73E-03	3.23E-02	7.87E-03	6.93E-02	2.73E-02
House #33	1.12E-02	2.76E-03	1.52E-02	3.71E-03	6.93E-02	5.13E-03
House #36	2.60E-02	6.39E-03	1.52E-02	3.71E-03	6.93E-02	2.73E-02
House #38	1.12E-02	2.76E-03	1.52E-02	3.71E-03	6.93E-02	2.73E-02
House #25	4.30E-02	1.06E-02	1.31E+00	3.18E-01	1.97E-01	7.75E-02

Hazard Quotients (HQs) are calculated by dividing the non-cancer health based guideline by the estimated exposure dose. Please see Appendix Table A1-A11 for estimated exposure doses.
HQs > 1, which are highlighted in red, require further evaluation since the “safe” dose level has been exceeded.
HQs < 1 are dropped from further evaluation since the estimated dose is less than the “safe” dose level.

Theoretical Cancer Risks

The total theoretical cancer risks estimated from each pathway evaluated are above the acceptable cancer risk range at 3 out of 11 homes in the Fairmont neighborhood (Table 4). The highest estimated theoretical cancer risk is $1 * 10^{-3}$ or 1,000 excess cancer cases per 1,000,000 exposed individuals. Theoretical cancer risks above the acceptable cancer risk range are generally considered a public health hazard. In this case, the estimated cancer risks are considered to constitute an indeterminate public health hazard due to the uncertainties associated with the available data for the following reasons: (a) actual duration of exposure to PCE in groundwater and indoor air is unknown; and (b) limited sampling data are available for groundwater, vegetables, and indoor air. The exposure duration has a profound effect on the theoretical cancer risk equation because lower exposure durations correspond with lower theoretical cancer risks. In this evaluation, theoretical cancer risks were based on the default value of 30 years of exposure duration. Additionally, in 2007, the three homes with theoretical cancer risks above $1 * 10^{-4}$ were provided with bottled water and in March 2008, these residents were connected to the municipal water system. Therefore, these exposure pathways were eliminated by March 2008. The remaining 8 households are not likely to be of significant concern since the theoretical cancer risks are within the acceptable cancer risk range based on exposure to contaminants at the currently measured concentrations over a period of thirty years.

Table 4. Cumulative Theoretical Cancer Risks for Potable Use Water

Sample ID	Age-Adjusted Theoretical Cancer Risk Chloroform	Age-Adjusted Theoretical Cancer Risk Tetrachloroethene	Age-Adjusted Theoretical Cancer Risk Trichloroethene
House #24	3.36E-05	1.04E-03	1.32E-04
House #23	6.69E-06	2.20E-04	3.79E-05
House #2	1.72E-06	2.05E-05	1.01E-05
House #7	1.72E-06	2.91E-06	1.01E-05
House #8	1.72E-06	1.19E-05	1.01E-05
House #26	1.72E-06	8.51E-06	1.01E-05
House #27	3.59E-06	6.18E-06	1.01E-05
House #33	1.72E-06	2.91E-06	1.01E-05
House #36	4.00E-06	2.91E-06	1.01E-05
House #38	1.72E-06	2.91E-06	1.01E-05
House #25	6.62E-06	2.49E-04	2.87E-05

Values highlighted in red indicate theoretical cancer risks above the acceptable cancer risk range

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. A child's lower body weight and higher relative 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. Two important considerations for small children and the developing fetus in regards to PCE exposure are the ability of PCE that has been transferred into breast milk and the ability of PCE to cross the placenta. 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. For example, infants can be exposed to PCE that has been transferred into breast milk. Additionally, PCE can also cross the placenta. Therefore, the developing fetus and infants should be considered a susceptible population for exposure to PCE.

Child exposures to PCE were evaluated in this consultation. The estimated exposure doses for children are higher than the doses estimated for adults. Thus, the overall conclusions discussed in the text are based upon child exposures. Non-cancer health hazards for children are below a level of concern since the estimated doses are below known health effect levels. The age-adjusted theoretical cancer risks account for exposures during childhood as well as adulthood. The theoretical carcinogenic risks described above are considered an indeterminate public health hazard for past, current, and future exposures.

Conclusions

After a through review of the available environmental data, the following conclusions have been made regarding the groundwater contaminant plume in the Fairmont neighborhood:

- The estimated theoretical cancer risks at 3 homes in the Fairmont neighborhood are above the high-end of the acceptable theoretical cancer risk level of 100 excess cancer cases in a million for current and future exposures over a period of 30 years, based on the currently available data. Generally, theoretical cancer risks at this level would be considered a public health hazard. However, the exposures for all homes evaluated in this consultation are considered to constitute an indeterminate public health hazard because the actual exposure duration and the concentrations of VOCs over time are unknown. In addition, actions have been taken to reduce exposure at the homes with the highest theoretical cancer risks (e.g. bottled water and municipal water tap).

- Significant non-cancer health effects are not likely to occur because all estimated non-cancer health hazards are below a level of concern, assuming a 30 year exposure duration at the currently identified concentrations of contaminants.

Recommendations

To reduce the health hazards associated with residential exposures to groundwater contaminants, the following recommendations should be implemented:

- Hazen officials should continue with the remediation plans described in the ICAP to reduce and/or prevent future exposures from contaminated groundwater and indoor air to residents in the Fairmont neighborhood.

- A groundwater sampling plan should be developed and carried out not only to evaluate the effectiveness of remedial activities, but also to further characterize the groundwater plume.

- The vapor intrusion pathway should be further evaluated in the areas above the plume to identify any potential hazards associated with contaminated indoor air.

- In order to reduce exposure to COPCs, residents should ensure that indoor sources of VOCs (e.g., paints, and household cleaners) are stored in sealed containers preferably outside the home (e.g., garage). In addition, dry-cleaned clothes should not be stored in plastic bagging for extended periods of time and should also be kept in well-ventilated areas.

Public Health Action Plan

The Public Health Action Plan describes the actions that are necessary to reduce exposure to site-related contaminants and how these actions can be executed.

Current and Future Activities:

- Present the findings of this consultation in a public meeting.
- Produce a fact sheet, which can be easily distributed to all stakeholders.
- Review the available soil gas data.
- Determine if an additional health consultation is necessary on vapor intrusion.
- Review any additional groundwater or other environmental data as necessary or upon request.

Past Activities:

- In the summer of 2007, CCPEHA recommended that fruit and vegetable sampling be conducted to address community concerns regarding the consumption of crops grown in domestic gardens irrigated with contaminated groundwater. Hazen official conducted sampling in September 2007.
- CCPEHA health education and health assessment staff participated in the planning of public meeting as well as attended the meeting to provide technical support for health related questions.

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References

Agency for Toxic Substances and Disease Registry (ATSDR 2005). *Public Health Assessment Guidance Manual,* Revised January 2005. Available on the Internet at: http://www.atsdr.cdc.gov/HAC/PHAManual/toc.html, accessed November 2007.

Agency for Toxic Substances and Disease Registry (ATSDR 2007a). *Toxicological Profile on Tetrachloroethene,* September 2007. Available on the Internet at: http://www.atsdr.cdc.gov/toxprofiles/tp18.html, Accessed May 2008.

Agency for Toxic Substances and Disease Registry (ATSDR 2007b). *Toxicological Profile on Trichloroethene,* September 2007. Available on the Internet at: http://www.atsdr.cdc.gov/toxprofiles/tp19.html, Accessed May 2008.

Agency for Toxic Substances and Disease Registry (ATSDR 2007c). *Toxicological Profile on Chloroform,* September 2007. Available on the Internet at: http://www.atsdr.cdc.gov/toxprofiles/tp6.html, Accessed May 2008.

U.S. Environmental Protection Agency, Region 9 (EPA 2004a). *Preliminary Remediation Goals*, last update October 2004. Available on the Internet at: http://www.epa.gov/region09/waste/sfund/prg/, Accessed April 2008.

U. S. Environmental Protection Agency, Region 3 (EPA 2007a). *Human Health Risk Assessment, Risk-Based Concentration Table,* last update October 11, 2007. Available on the Internet at: http://www.epa.gov/reg3hwmd/risk/human/index.htm, Accessed April 2008.

U.S. Environmental Protection Agency, Integrated Risk Information System (EPA 2002). *Chloroform Profile 0025*, last update March 2002. Available on the Internet at: http://www.epa.gov/ncea/iris/subst/0025.htm, Accessed May 2008.

U.S. Environmental Protection Agency, Integrated Risk Information System (EPA 1998). *Tetrachloroethene Profile 0106*, last update January 1998. Available on the Internet at: http://www.epa.gov/ncea/iris/subst/0106.htm, Accessed May 2008.

U.S. Environmental Protection Agency, Integrated Risk Information System (EPA 2004b). *Trichloroethene Profile 0199*, last update June 2004. Available on the Internet at: http://www.epa.gov/ncea/iris/subst/0199.htm, Accessed May 2008.

U.S. Environmental Protection Agency, National Center for Environmental Assessment (EPA 1997). *Exposure Factors Handbook*, last update August 1997. Available on the Internet at: http://www.epa.gov/ncea/efh/, Accessed May 2008.

U.S. Environmental Protection Agency, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk*

Assessment) (EPA 2004c), last update July 2004. Available on the Internet at: http://www.epa.gov/oswer/riskassessment/ragse/index.htm, Accessed May 2008.

Additional Tables and Figures

Table 5. Groundwater Data for Residential Wells in the Fairmont Neighborhood

Sample Date	Sample ID	Drinking Water Well	Chloroform µg/L	Tetrachloroethene µg/L	Trichloroethene µg/L	Vinyl Chloride µg/L
7/24/2007	House #1		0.25	2.17	0.25	0.25
8/1/2007	House #2	DW	0.25	1.72	0.25	0.25
7/23/2007	House #2	DW	0.25	1.76	0.25	0.25
8/1/2007	House #3		1	5.2	1	1
8/1/2007	House #4		10	120	6.8	1
7/24/2007	House #5		0.98	0.25	0.25	0.72
8/1/2007	House #6		2.8	17	1	1
8/1/2007	House #7	DW	0.25	0.25	0.25	0.25
7/23/2007	House #8	DW	0.25	1.02	0.25	0.25
8/1/2007	House #9		1	1	1	1
7/24/2007	House #10		0.79	1.65	0.25	0.25
8/14/2007	House #11		4.2	0.25	0.25	0.25
8/1/2007	House #12		1	1	1	1
7/24/2007	House #13		0.25	2.04	0.25	0.25
8/1/2007	House #14		1	1	1	1.3
7/24/2007	House #15		2.15	1.48	0.25	0.25
8/1/2007	House #16		1	1	1.2	1
8/14/2007	House #17		0.25	5.2	0.25	0.25
7/24/2007	House #18		0.25	0.25	1.69	0.25
7/23/2007	House #19		0.25	2.84	0.25	0.25
8/14/2007	House #20		0.25	7.5	0.25	0.25
7/24/2007	House #21		0.25	3.09	0.25	0.25
9/10/2007	House #22		0.25	8.8	0.25	0.25
8/14/2007	House #23	DW	0.97	18.3	0.54	0.25
8/1/2007	House #23	DW	1	16.4	0.82	0.25
7/23/2007	House #23	DW	0.9	15	0.7	0.25
8/1/2007	House #24	DW	4.87	88.2	2.92	0.25
7/23/2007	House #24	DW	3.94	50.4	3.05	0.25
8/14/2007	House #25	DW	0.25	9	0.25	0.25
8/14/2007	House #25	DW	0.96	21.4	0.71	0.25
8/1/2007	House #26	DW	0.25	0.73	0.25	0.25
8/1/2007	House #27	DW	0.25	0.25	0.25	0.25
7/24/2007	House #27	DW	0.52	0.53	0.25	0.25
8/1/2007	House #28		7.8	140	3	1
8/1/2007	House #29		1	5.3	1	1
7/24/2007	House #30		0.25	1.02	0.25	0.25
8/1/2007	House #31		1	1	1	1
8/1/2007	House #32		1	1	1	1
7/24/2007	House #33	DW	0.25	0.25	0.25	0.25
7/24/2007	House #33	DW	0.25	0.25	0.25	0.25
7/24/2007	House #34		0.25	0.25	0.25	0.25
7/24/2007	House #35		0.25	0.25	0.25	0.25
8/1/2007	House #36	DW	0.25	0.25	0.25	0.25
7/24/2007	House #36	DW	0.58	0.25	0.25	0.25
7/24/2007	House #37		0.25	0.25	0.25	0.25
8/1/2007	House #38	DW	0.25	0.25	0.25	0.25
7/23/2007	House #38	DW	0.25	0.25	0.25	0.25
7/24/2007	House #39		0.25	0.25	0.25	0.25
7/24/2007	House #40		0.25	0.25	0.25	0.25

Values in red denote the surrogate value for non-detected samples equal to ½ the detection limit
DW = Drinking Water Well

Table 6. Summary of Residential Groundwater Data

Contaminants	Maximum (µg/L)	Percent Detected	Number of Samples	ATSDR CV (µg/L)	EPA Region 9 PRG (µg/L)	EPA Maximum Contaminant Levels (µg/L)	COPC
Chloroform	10	30.6 %	49	70	0.17	80	X
Tetrachloroethene	140	55.1 %	49	10	0.1	5	X
Trichloroethene	6.8	20.4 %	49	NA	0.028	5	X
Vinyl Chloride	1.30	4.1 %	49	0.03	0.02	2	X

µg/L: micrograms contaminant per liter of water

Table 7. Indoor and Outdoor Air Results and Selection of Contaminants of Potential Concern (COPC)

Analytes	House #23	House #24 (Upstairs)	House #24 (Downstairs)	House #24 (Duplicate)	Outdoor	House #28	Region 3 RBC	COPC
Tetrachloroethene	2.1	3.8	3.1	3.0	0.2	9.9	0.31	X
Trichloroethene	0.074	0.14	0.095	0.095	0.03	0.089	0.016	X
1,1-Dichloroethene	0.020	0.020	0.020	0.020	0.020	0.020	5.0	
cis-1,2-Dichloroethene	0.10	0.10	0.10	0.10	0.10	0.10	37	
trans-1,2-Dichloroethene	0.020	0.020	0.020	0.020	0.020	0.020	62	
Vinyl Chloride	0.010	0.010	0.010	0.010	0.010	0.010	0.072	

All concentrations are expressed in $\mu g/m^3$ or micrograms contaminant per cubic meter of air
Values in red are surrogate values for non-detected contaminants equal to ½ the reporting limit of the analytical method.

Table 8. Non-Cancer Hazard Quotients for Drinking Water Ingestion

Sample ID	Chloroform Hazard Quotient		Tetrachloroethene Hazard Quotient		Trichloroethene Hazard Quotient	
	Child	Adult	Child	Adult	Child	Adult
House #24	3.11E-02	1.33E-02	5.64E-01	2.42E-01	6.50E-01	2.79E-01
House #23	6.20E-03	2.66E-03	1.17E-01	5.01E-02	1.75E-01	7.49E-02
House #2	1.60E-03	6.85E-04	1.13E-02	4.82E-03	5.33E-02	2.28E-02
House #7	1.60E-03	6.85E-04	1.60E-03	6.85E-04	5.33E-02	2.28E-02
House #8	1.60E-03	6.85E-04	6.52E-03	2.79E-03	5.33E-02	2.28E-02
House #26	1.60E-03	6.85E-04	4.67E-03	2.00E-03	5.33E-02	2.28E-02
House #27	3.32E-03	1.42E-03	3.39E-03	1.45E-03	5.33E-02	2.28E-02
House #33	1.60E-03	6.85E-04	1.60E-03	6.85E-04	5.33E-02	6.85E-04
House #36	3.71E-03	1.59E-03	1.60E-03	6.85E-04	5.33E-02	2.28E-02
House #38	1.60E-03	6.85E-04	1.60E-03	6.85E-04	5.33E-02	2.28E-02
House #25	6.14E-03	2.63E-03	1.37E-01	5.86E-02	1.51E-01	6.48E-02

Hazard Quotients (HQs) are calculated by dividing the non-cancer health based guideline by the estimated exposure dose.
HQs > 1, which are highlighted in red, require further evaluation since the “safe” dose level has been exceeded.
HQs < 1 are dropped from further evaluation since the estimated dose is less than the “safe” dose level.

Table 9. Theoretical Cancer Risks for Drinking Water

Sample ID	Age-Adjusted Theoretical Cancer Risk Tetrachloroethene	Age-Adjusted Theoretical Cancer Risk Trichloroethene
House #24	7.18E-04	1.84E-05
House #23	1.49E-04	4.94E-06
House #2	1.43E-05	1.51E-06
House #7	2.03E-06	1.51E-06
House #8	8.30E-06	1.51E-06
House #26	5.94E-06	1.51E-06
House #27	4.31E-06	1.51E-06
House #33	2.03E-06	1.51E-06
House #36	2.03E-06	1.51E-06
House #38	2.03E-06	1.51E-06
House #25	1.74E-04	4.28E-06

Theoretical cancer risks were not calculated for oral exposures to chloroform.
Chloroform is only carcinogenic by the inhalation pathway.

Table 10. Non-cancer Hazard Quotients for Dermal Exposures while Showering

Sample ID	Chloroform Hazard Quotient		Tetrachloroethene Hazard Quotient		Trichloroethene Hazard Quotient	
	Child	Adult	Child	Adult	Child	Adult
House #24	8.32E-04	4.86E-04	9.86E-02	5.76E-02	3.30E-02	1.93E-02
House #23	1.66E-04	9.68E-05	2.05E-02	1.20E-02	8.87E-03	5.19E-03
House #2	4.27E-05	2.50E-05	1.97E-03	1.15E-03	2.71E-03	1.58E-03
House #7	4.27E-05	2.50E-05	2.80E-04	1.63E-04	2.71E-03	1.58E-03
House #8	4.27E-05	2.50E-05	1.14E-03	6.67E-04	2.71E-03	1.58E-03
House #26	4.27E-05	2.50E-05	8.16E-04	4.77E-04	2.71E-03	1.58E-03
House #27	8.88E-05	5.19E-05	5.93E-04	3.46E-04	2.71E-03	1.58E-03
House #33	4.27E-05	2.50E-05	2.80E-04	1.63E-04	2.71E-03	1.58E-03
House #36	9.91E-05	5.79E-05	2.80E-04	1.63E-04	2.71E-03	1.58E-03
House #38	4.27E-05	2.50E-05	2.80E-04	1.63E-04	2.71E-03	1.58E-03
House #25	1.64E-04	9.58E-05	2.39E-02	1.40E-02	7.68E-03	4.49E-03

Hazard Quotients (HQs) are calculated by dividing the non-cancer health based guideline by the estimated exposure dose.
HQs > 1, which are highlighted in red, require further evaluation since the “safe” dose level has been exceeded.
HQs < 1 are dropped from further evaluation since the estimated dose is less than the “safe” dose level.

Table 11. Theoretical Cancer Risks of Dermal Exposure While Showering

Sample ID	Age-Adjusted Theoretical Cancer Risk Chloroform	Age-Adjusted Theoretical Cancer Risk Tetrachloroethene	Age-Adjusted Theoretical Cancer Risk Trichloroethene
House #24	N/a	1.52E-04	1.13E-06
House #23	N/a	3.16E-05	3.05E-07
House #2	N/a	3.04E-06	9.29E-08
House #7	N/a	4.32E-07	9.29E-08
House #8	N/a	1.76E-06	9.29E-08
House #26	N/a	1.26E-06	9.29E-08
House #27	N/a	9.16E-07	9.29E-08
House #33	N/a	4.32E-07	9.29E-08
House #36	N/a	4.32E-07	9.29E-08
House #38	N/a	4.32E-07	9.29E-08
House #25	N/a	3.70E-05	2.64E-07

Theoretical cancer risks were not calculated for oral exposures to chloroform.
Chloroform is only carcinogenic by the inhalation pathway.

Table 12. Non-cancer Hazard Quotients from Inhalation Exposure while Showering

Sample ID	Chloroform Hazard Quotient		Tetrachloroethene Hazard Quotient		Trichloroethene Hazard Quotient	
	Child	Adult	Child	Adult	Child	Adult
House #24	1.86E-01	3.99E-02	4.72E+00	1.01E+00	1.63E-01	3.50E-02
House #23	3.71E-02	7.94E-03	9.79E-01	2.10E-01	4.39E-02	9.40E-03
House #2	9.55E-03	2.05E-03	9.41E-02	2.02E-02	1.34E-02	2.87E-03
House #7	9.55E-03	2.05E-03	1.34E-02	2.87E-03	1.34E-02	2.87E-03
House #8	9.55E-03	2.05E-03	5.46E-02	1.17E-02	1.34E-02	2.87E-03
House #26	9.55E-03	2.05E-03	3.90E-02	8.37E-03	1.34E-02	2.87E-03
House #27	1.99E-02	4.26E-03	2.83E-02	6.07E-03	1.34E-02	2.87E-03
House #33	9.55E-03	2.05E-03	1.34E-02	2.87E-03	1.34E-02	2.87E-03
House #36	2.22E-02	4.75E-03	1.34E-02	2.87E-03	1.34E-02	2.87E-03
House #38	9.55E-03	2.05E-03	1.34E-02	2.87E-03	1.34E-02	2.87E-03
House #25	3.67E-02	7.86E-03	1.14E+00	2.45E-01	3.80E-02	8.14E-03

Hazard Quotients (HQs) are calculated by dividing the non-cancer health based guideline by the estimated exposure dose.
HQs > 1, which are highlighted in red, require further evaluation since the "safe" dose level has been exceeded.
HQs < 1 are dropped from further evaluation since the estimated dose is less than the "safe" dose level.

Table 13. Theoretical Cancer Risks of Inhalation Exposure while Showering

Sample ID	Age-Adjusted Theoretical Cancer Risk Chloroform	Age-Adjusted Theoretical Cancer Risk Tetrachloroethene	Age-Adjusted Theoretical Cancer Risk Trichloroethene
House #24	3.36E-05	1.58E-04	1.04E-04
House #23	6.69E-06	3.27E-05	2.79E-05
House #2	1.72E-06	3.15E-06	8.51E-06
House #7	1.72E-06	4.47E-07	8.51E-06
House #8	1.72E-06	1.82E-06	8.51E-06
House #26	1.72E-06	1.31E-06	8.51E-06
House #27	3.59E-06	9.48E-07	8.51E-06
House #33	1.72E-06	4.47E-07	8.51E-06
House #36	4.00E-06	4.47E-07	8.51E-06
House #38	1.72E-06	4.47E-07	8.51E-06
House #25	6.62E-06	3.83E-05	2.42E-05

Values in red denote theoretical cancer risks outside of the acceptable cancer risk range (i.e. greater than 1E-04)

Table 14. Total Non-cancer Hazard Quotients While Showering (Includes Dermal and Inhalation Exposures)

Sample ID	Chloroform Hazard Quotient		Tetrachloroethene Hazard Quotient		Trichloroethene Hazard Quotient	
	Child	Adult	Child	Adult	Child	Adult
House #24	1.87E-01	4.04E-02	4.82E+00	1.07E+00	1.96E-01	5.42E-02
House #23	3.72E-02	8.04E-03	9.99E-01	2.22E-01	5.27E-02	1.46E-02
House #2	9.59E-03	2.07E-03	9.61E-02	2.13E-02	1.61E-02	4.45E-03
House #7	9.59E-03	2.07E-03	1.37E-02	3.03E-03	1.61E-02	4.45E-03
House #8	9.59E-03	2.07E-03	5.57E-02	1.24E-02	1.61E-02	4.45E-03
House #26	9.59E-03	2.07E-03	3.99E-02	8.84E-03	1.61E-02	4.45E-03
House #27	2.00E-02	4.31E-03	2.89E-02	6.42E-03	1.61E-02	4.45E-03
House #33	9.59E-03	2.07E-03	1.37E-02	3.03E-03	1.61E-02	4.45E-03
House #36	2.23E-02	4.81E-03	1.37E-02	3.03E-03	1.61E-02	4.45E-03
House #38	9.59E-03	2.07E-03	1.37E-02	3.03E-03	1.61E-02	4.45E-03
House #25	3.68E-02	7.95E-03	1.17E+00	2.59E-01	4.57E-02	1.26E-02

Hazard Quotients (HQs) are calculated by dividing the non-cancer health based guideline by the estimated exposure dose.
HQs > 1, which are highlighted in red, require further evaluation since the "safe" dose level has been exceeded.
HQs < 1 are dropped from further evaluation since the estimated dose is less than the "safe" dose level.

Table 15. Total Theoretical Cancer Risks While Showering (Includes Dermal and Inhalation Exposures)

Sample ID	Age-Adjusted Theoretical Cancer Risk Chloroform	Age-Adjusted Theoretical Cancer Risk Tetrachloroethene	Age-Adjusted Theoretical Cancer Risk Trichloroethene
House #24	3.36E-05	3.10E-04	1.05E-04
House #23	6.69E-06	6.43E-05	2.82E-05
House #2	1.72E-06	6.19E-06	8.61E-06
House #7	1.72E-06	8.79E-07	8.61E-06
House #8	1.72E-06	3.59E-06	8.61E-06
House #26	1.72E-06	2.57E-06	8.61E-06
House #27	3.59E-06	1.86E-06	8.61E-06
House #33	1.72E-06	8.79E-07	8.61E-06
House #36	4.00E-06	8.79E-07	8.61E-06
House #38	1.72E-06	8.79E-07	8.61E-06
House #25	6.62E-06	7.52E-05	2.44E-05

Values in red denote theoretical cancer risks outside of the acceptable cancer risk range (i.e. greater than 1E-04)

Table 16. Non-Cancer Household Inhalation Hazard Quotients

Sample ID	Tetrachloroethene Hazard Quotient		Trichloroethene Hazard Quotient	
	Child	Adult	Child	Adult
House # 24	2.92E-01	1.04E-01	1.07E-02	3.84E-03
House #28	7.59E-01	2.71E-01	6.83E-03	2.44E-03
House #23	1.61E-01	5.75E-02	5.68E-03	2.03E-03

Hazard Quotients (HQs) are calculated by dividing the non-cancer health based guideline by the estimated exposure dose.
HQs > 1, which are highlighted in red, require further evaluation since the “safe” dose level has been exceeded.
HQs < 1 are dropped from further evaluation since the estimated dose is less than the “safe” dose level.

Table 17. Theoretical Cancer Risks of Household Inhalation

Sample ID	Tetrachloroethene Age-adjusted Cancer Risk	Trichloroethene Age-adjusted Cancer Risk
House # 24	1.27E-05	8.94E-06
House #28	3.32E-05	5.68E-06
House #23	7.04E-06	4.73E-06

Appendices

Appendix A. Detailed Information on Exposure Dose Calculations

Public Health Evaluation Process

To identify the public health implications of contaminants of potential concern, exposure doses are estimated and compared to known health-based guidelines such as the ATSDR Minimal Risk Levels (MRL) and EPA's Reference Doses (RfD). MRLs and RfDs are conservative health-based guidelines with built in safety factors based on the uncertainty regarding a contaminant's toxicity and the available scientific literature. MRLs and RfDs are considered "safe" doses. That is, if the estimated exposure doses are below the applicable health-based guideline for a particular contaminant, no adverse health effects are likely to occur from the exposure. If the estimated exposure dose is above the health-based guideline, the contaminant is analyzed in further detail including a review of the available scientific literature on that contaminant and a comparison with known adverse health effect levels such as the No Observable Adverse Effect Level (NOAEL) and the Lowest Observable Adverse Effect Level (LOAEL). Estimated exposure doses below known health effects levels are critically evaluated to determine if adverse health effects are likely to occur. Estimated exposure doses that exceed known health effect levels are generally considered a public health hazard.

Exposure Dose Calculations

Exposure doses were calculated for the three primary pathways identified in this evaluation including: 1) Drinking contaminated water, 2) Breathing air affected by vapor intrusion of VOCs from contaminated groundwater, and 3) exposure to contaminants while showering and bathing, which includes inhalation and dermal contact. Exposure doses were calculated for non-carcinogenic health endpoints for both children and adults. The carcinogenic exposure dose calculation for each pathway is based on an age-adjusted equation that includes exposure to children and adults averaged over a lifetime. Due to the low number of groundwater and indoor air samples currently available, the maximum detected concentration was used as the exposure point concentration (Table X below). The exposure dose calculation for each pathway is discussed in greater detail below.

Table A1. Indoor Air Exposure Point Concentrations.

Sample ID	Tetrachloroethene ($\mu g/m^3$)	Trichloroethene ($\mu g/m^3$)
House # 24 (Upstairs)	3.8	0.14
House #28	9.9	0.089
House #23	2.1	0.074

$\mu g/m^3$ = micrograms of contaminant per cubic meter of air

Table A2. Groundwater Exposure Point Concentrations

Sample ID	Chloroform (in µg/L)	Tetrachloroethene (in µg/L)	Trichloroethene (in µg/L)
House #24	4.87	88.2	3.05
House #23	0.97	18.3	0.82
House #2	0.25	1.76	0.25
House #7	0.25	0.25	0.25
House #8	0.25	1.02	0.25
House #26	0.25	0.73	0.25
House #27	0.52	0.53	0.25
House #33	0.25	0.25	0.25
House #36	0.58	0.25	0.25
House #38	0.25	0.25	0.25
House #25	0.96	21.4	0.71

Values in red are surrogate values for non-detected samples equal to ½ the detection limit of the analytical method.
µg/L = micrograms of contaminant per liter of groundwater

Drinking Water Ingestion

Drinking water ingestion is a relatively straightforward calculation based on the average amount of water-ingested daily for children and adults; reported body weights, and the frequency and duration of exposure. The values and basis for each exposure parameter is contained within the EPA Exposure Factor Handbook (EPA 1997).

Non-Cancer Drinking Water Ingestion Dose

Non-Cancer Dose = $\mathbf{(C_{GW} * IRW * F * ED * CF) / (BW * AT)}$

Age-Adjusted Water Ingestion Cancer Dose

Age-Adjusted Cancer Dose = $\mathbf{(C_{GW} * IRW_{adj} * CF * EF) / 25{,}550\ Days}$

Drinking Water Ingestion Exposure Parameters

Exposure Parameter	Units	Child	Adult
Groundwater Concentration (C_{GW})	μg/L	Chemical-specific	Chemical-specific
Body Weight (BW)	kg	15	70
Exposure Frequency (EF)	days/yr	350	350
Exposure Duration$_{Non-cancer}$ ($ED_{Non-cancer}$)	years	6	30
Exposure Duration$_{Cancer}$ (ED_{Cancer})	years	6	30
Averaging Time$_{Non-cancer}$ ($AT_{Non-cancer}$)	days	2190	10950
Averaging Time$_{Cancer}$ (AT_{Cancer})	days	N/a	25550*
Ingestion Rate$_{Non-cancer}$ ($IRW_{Non-cancer}$)	L/day	1.0	2.0
Ingestion Rate$_{Age-adjusted\ Cancer}$ (IRW_{adj})	L*yr/kg*day	N/a	1.1

Inhalation of Household VOCs

Estimated exposure doses for inhalation of VOCs in household air were calculated for the 3 homes where indoor air data was collected. The exposure dose calculation for this pathway is also relatively straightforward and is based on the amount of air inhaled over a certain period of time.

Non-Cancer Inhalation Dose

Dose = $\mathbf{(C_{IA} * IRA * F * ED * CF) / (BW * AT)}$

Age-Adjusted Inhalation Cancer Dose

Age-Adjusted Cancer Dose = $\mathbf{(C_{IA} * IRA_{adj} * CF * F * D) / \ 25{,}550\ Days}$

Household Indoor Air Exposure Parameters

Exposure Parameter	Units	Child	Adult
Indoor Air Concentration (C_{IA})	$\mu g/m^3$	Chemical-specific	Chemical-specific
Body Weight (BW)	kg	15	70
Exposure Frequency (EF)	days/yr	350	350
Exposure Duration$_{Non-cancer}$ ($ED_{Non-cancer}$)	years	6	30
Exposure Duration$_{Cancer}$ (ED_{Cancer})	years	6	30
Averaging Time$_{Non-cancer}$ ($AT_{Non-cancer}$)	days	2190	10950
Averaging Time$_{Cancer}$ (AT_{Cancer})	days	N/a	25550*
Inhalation Rate$_{Non-cancer}$ ($IRA_{Non-cancer}$)	mg/day	12	20
Inhalation Rate$_{Age-adjusted\ Cancer}$ (IRA_{adj})	mg*yr./kg*day	N/a	11.3
Conversion Factor (CF)	unitless		

Showering Exposures

Individuals are exposed to VOCs while showering through two routes of exposure, dermal and inhalation. The exposure dose for inhalation of VOCs while showering and bathing is calculated by estimating the concentration of VOCs that have volatilized from the water and determining the amount inhaled by standardized inhalation rates over the total time spent in the bathroom. This model, provided by ATSDR, is based on experimental data from several studies (Andelman, 1985; Andelman, 1990; Jo *et al*., 1990; McKone, 1987; McKone 1991). The volatilization rate that has been established for VOCs is 0.6 (i.e. 60% of VOCs will volatilize to air while showering). The bathroom air concentration is calculated by the chemical concentration, the volatilization rate, water flow rate, shower duration, and volume of air in the bathroom with the following equation.

Bathroom Air Concentration

$$\boxed{C_{Air\ Max} = (C_w) * (CF) * (k) * (F_w) * (T_s) / (V_a)}$$

After the air concentration in the bathroom has been calculated, the standard indoor air equation described above is used to estimate the exposure doses for non-cancer and carcinogenic health endpoints.

Bathroom Air Exposure Parameters

Exposure Parameter	**Units**	**Child**	**Adult**
Shower Water Concentration (C_W)	µg/L	Chemical-specific	Chemical-specific
Body Weight (BW)	kg	15	70
Exposure Frequency (EF)	days/yr	350	350
Exposure Duration$_{Non-cancer}$ ($ED_{Non-cancer}$)	years	6	30
Exposure Duration$_{Cancer}$ (ED_{Cancer})	years	6	30
Averaging Time$_{Non-cancer}$ ($AT_{Non-cancer}$)	days	2190	10950
Averaging Time$_{Cancer}$ (AT_{Cancer})	days	N/a	25550*
Inhalation Rate$_{Non-cancer}$ ($IRA_{Non-cancer}$)	m^3/hour	0.6	0.6
Inhalation Rate$_{Age-adjusted\ Cancer}$ (IRA_{adj})	m^3*yr./kg*day	N/a	0.37
Conversion Factor (CF)	unitless	0.000001	0.000001
Water Run Time	minutes	35	35
Time Spent in Bathroom After Shower	minutes	15	15
Total Bathroom Time (T_s)	hours	0.83	0.83
Water Flow Rate (F_w)	liters/minute	8	8
Volume of Bathroom Air (V_a)	liters	10000	10000

The exposure dose calculation for dermal exposure to contaminants while showering is provided by EPA Risk Assessment Guidance Manual, Part E (EPA 2004). This calculation requires the use chemical-specific physical properties of the contaminants, which describe the rate of absorption and time it takes for the contaminant to cross the skin barrier.

Non-Cancer Dermal Absorbed Dose

$$\textbf{DA event (DAev)} = 2\ FA * K_p * C_w * 0.4 * CF\ \sqrt{\left(6\tau ev * tev \div \pi\right)}$$

$$\textbf{DAD (mg/cm}^2\textbf{-event)} = \frac{DAev * ED * EF * SA}{BW * AT}$$

Age-Adjusted Dermal Absorption Cancer Dose

Age-Adjusted Cancer Dose = $(C_s * IRS_{adj} * CF * EF) / 25{,}550$ **Days**

Where: $IRS_{adj} = [(ED_{child} * IRS_c) / BW_c] + [(ED_{adult} * IRS_a) / BW_a]$

Table A3. Non-Cancer Drinking Water Exposure Dose Results

Sample ID	Chloroform Dose (mg/kg-day)		Tetrachloroethene Dose (mg/kg-day)		Trichloroethene Dose (mg/kg-day)	
	Child	Adult	Child	Adult	Child	Adult
House #24	3.11E-04	1.33E-04	5.64E-03	2.42E-03	1.95E-04	8.36E-05
House #23	6.20E-05	2.66E-05	1.17E-03	5.01E-04	5.24E-05	2.25E-05
House #2	1.60E-05	6.85E-06	1.13E-04	4.82E-05	1.60E-05	6.85E-06
House #7	1.60E-05	6.85E-06	1.60E-05	6.85E-06	1.60E-05	6.85E-06
House #8	1.60E-05	6.85E-06	6.52E-05	2.79E-05	1.60E-05	6.85E-06
House #26	1.60E-05	6.85E-06	4.67E-05	2.00E-05	1.60E-05	6.85E-06
House #27	3.32E-05	1.42E-05	3.39E-05	1.45E-05	1.60E-05	6.85E-06
House #33	1.60E-05	6.85E-06	1.60E-05	6.85E-06	1.60E-05	6.85E-06
House #36	3.71E-05	1.59E-05	1.60E-05	6.85E-06	1.60E-05	6.85E-06
House #38	1.60E-05	6.85E-06	1.60E-05	6.85E-06	1.60E-05	6.85E-06
House #25	6.14E-05	2.63E-05	1.37E-03	5.86E-04	4.54E-05	1.95E-05

Table A4. Dermal Absorbed per Showering Event

Sample ID	Chloroform DAev (mg/cm2-event)	Tetrachloroethene DAev (mg/cm2-event)	Trichloroethene DAev (mg/cm2-event)
House #24	1.97E-08	2.34E-06	2.35E-08
House #23	3.93E-09	4.85E-07	6.31E-09
House #2	1.01E-09	4.67E-08	1.92E-09
House #7	1.01E-09	6.63E-09	1.92E-09
House #8	1.01E-09	2.70E-08	1.92E-09
House #26	1.01E-09	1.93E-08	1.92E-09
House #27	2.11E-09	1.40E-08	1.92E-09
House #33	1.01E-09	6.63E-09	1.92E-09
House #36	2.35E-09	6.63E-09	1.92E-09
House #38	1.01E-09	6.63E-09	1.92E-09
House #25	3.89E-09	5.67E-07	5.46E-09

Table A5. Non-cancer Dermal Exposure Dose Results (Showering)

Sample ID	Chloroform Dose (mg/kg-day)		Tetrachloroethene Dose (mg/kg-day)		Trichloroethene Dose (mg/kg-day)	
	Child	Adult	Child	Adult	Child	Adult
House #24	8.32E-06	4.86E-06	9.86E-04	5.76E-04	9.90E-06	5.79E-06
House #23	1.66E-06	9.68E-07	2.05E-04	1.20E-04	2.66E-06	1.56E-06
House #2	4.27E-07	2.50E-07	1.97E-05	1.15E-05	8.12E-07	4.74E-07
House #7	4.27E-07	2.50E-07	2.80E-06	1.63E-06	8.12E-07	4.74E-07
House #8	4.27E-07	2.50E-07	1.14E-05	6.67E-06	8.12E-07	4.74E-07
House #26	4.27E-07	2.50E-07	8.16E-06	4.77E-06	8.12E-07	4.74E-07
House #27	8.88E-07	5.19E-07	5.93E-06	3.46E-06	8.12E-07	4.74E-07
House #33	4.27E-07	2.50E-07	2.80E-06	1.63E-06	8.12E-07	4.74E-07
House #36	9.91E-07	5.79E-07	2.80E-06	1.63E-06	8.12E-07	4.74E-07
House #38	4.27E-07	2.50E-07	2.80E-06	1.63E-06	8.12E-07	4.74E-07
House #25	1.64E-06	9.58E-07	2.39E-04	1.40E-04	2.31E-06	1.35E-06

Table A6. Non-Cancer Inhalation Exposure Dose Results While Showering

Sample ID	Chloroform Dose (mg/kg-day)		Tetrachloroethene Dose (mg/kg-day)		Trichloroethene Dose (mg/kg-day)	
	Child	Adult	Child	Adult	Child	Adult
House #24	2.60E-03	5.58E-04	4.72E-02	1.01E-02	1.63E-03	3.50E-04
House #23	5.19E-04	1.11E-04	9.79E-03	2.10E-03	4.39E-04	9.40E-05
House #2	1.34E-04	2.87E-05	9.41E-04	2.02E-04	1.34E-04	2.87E-05
House #7	1.34E-04	2.87E-05	1.34E-04	2.87E-05	1.34E-04	2.87E-05
House #8	1.34E-04	2.87E-05	5.46E-04	1.17E-04	1.34E-04	2.87E-05
House #26	1.34E-04	2.87E-05	3.90E-04	8.37E-05	1.34E-04	2.87E-05
House #27	2.78E-04	5.96E-05	2.83E-04	6.07E-05	1.34E-04	2.87E-05
House #33	1.34E-04	2.87E-05	1.34E-04	2.87E-05	1.34E-04	2.87E-05
House #36	3.10E-04	6.65E-05	1.34E-04	2.87E-05	1.34E-04	2.87E-05
House #38	1.34E-04	2.87E-05	1.34E-04	2.87E-05	1.34E-04	2.87E-05
House #25	5.13E-04	1.10E-04	1.14E-02	2.45E-03	3.80E-04	8.14E-05

Table A7. Total Non-cancer Hazard Quotients While Showering (Dermal and Inhalation)

Sample ID	Chloroform Hazard Quotient		Tetrachloroethene Hazard Quotient		Trichloroethene Hazard Quotient	
	Child	Adult	Child	Adult	Child	Adult
House #24	1.87E-01	4.04E-02	4.82E+00	1.07E+00	1.96E-01	5.42E-02
House #23	3.72E-02	8.04E-03	9.99E-01	2.22E-01	5.27E-02	1.46E-02
House #2	9.59E-03	2.07E-03	9.61E-02	2.13E-02	1.61E-02	4.45E-03
House #7	9.59E-03	2.07E-03	1.37E-02	3.03E-03	1.61E-02	4.45E-03
House #8	9.59E-03	2.07E-03	5.57E-02	1.24E-02	1.61E-02	4.45E-03
House #26	9.59E-03	2.07E-03	3.99E-02	8.84E-03	1.61E-02	4.45E-03
House #27	2.00E-02	4.31E-03	2.89E-02	6.42E-03	1.61E-02	4.45E-03
House #33	9.59E-03	2.07E-03	1.37E-02	3.03E-03	1.61E-02	4.45E-03
House #36	2.23E-02	4.81E-03	1.37E-02	3.03E-03	1.61E-02	4.45E-03
House #38	9.59E-03	2.07E-03	1.37E-02	3.03E-03	1.61E-02	4.45E-03
House #25	3.68E-02	7.95E-03	1.17E+00	2.59E-01	4.57E-02	1.26E-02

Table A8. Total Theoretical Cancer Risks While Showering (Dermal and Inhalation)

Sample ID	Age-Adjusted Theoretical Cancer Risk Chloroform	Age-Adjusted Theoretical Cancer Risk Tetrachloroethene	Age-Adjusted Theoretical Cancer Risk Trichloroethene
House #24	3.36E-05	3.10E-04	1.05E-04
House #23	6.69E-06	6.43E-05	2.82E-05
House #2	1.72E-06	6.19E-06	8.61E-06
House #7	1.72E-06	8.79E-07	8.61E-06
House #8	1.72E-06	3.59E-06	8.61E-06
House #26	1.72E-06	2.57E-06	8.61E-06
House #27	3.59E-06	1.86E-06	8.61E-06
House #33	1.72E-06	8.79E-07	8.61E-06
House #36	4.00E-06	8.79E-07	8.61E-06
House #38	1.72E-06	8.79E-07	8.61E-06
House #25	6.62E-06	7.52E-05	2.44E-05

Table A9. Non-Cancer Household Inhalation Exposure Dose Results

Sample ID	Tetrachloroethene Dose (mg/kg-day)		Trichloroethene Dose (mg/kg-day)	
	Child	Adult	Child	Adult
House # 24	2.92E-03	1.04E-03	1.07E-04	3.84E-05
House #28	7.59E-03	2.71E-03	6.83E-05	2.44E-05
House #23	1.61E-03	5.75E-04	5.68E-05	2.03E-05

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 is dependant on dose. The toxic effects of a chemical frequently depend on the route of exposure (oral, inhalation, dermal) and the duration of exposure (acute, subchronic, chronic or lifetime). In general, acute and chronic neurological changes, and liver and kidney toxicity, have been observed in humans and animals exposed to PCE (See Appendix C for PCE health effect fact sheet). It is important to note that estimates of human health risks may be based on evidence of health effects in humans and/or animals depending upon the availability of data.

At the current time, the International Agency for Cancer Research (IARC) has classified PCE as a Group 2a carcinogen (IARC 1995). The USEPA has not established an inhalation reference concentration or a carcinogenicity assessment for lifetime exposures to PCE in the EPA Integrated Risk Information System (IRIS). In the absence of relevant values in IRIS, the USEPA Office of Solid Waste and Emergency Response (OSWER) recommends using the California EPA's carcinogenic inhalation cancer slope factor or toxicity factor per mg/kg/day of PCE (EPA, 2003, OSWER Directive No. 9285.7-75). CDPHE's Hazardous Waste and Waste Management Division also adopted the Cal EPA inhalation cancer slope factor, which results in RBC of 0.31 $\mu g/m^3$ as a screening value to guide remedial action in 2006.

The resulting RBC used in this assessment is based on age-adjusted theoretical cancer risks spanning 30 years from the time of birth to the age of 30. It accounts for exposure to PCE and TCE vapors for 350 days per year over the thirty-year time period and lower body weights and of children. Exposure to PCE at this duration and frequency of exposure is expected to result in no more than 1 theoretical cancer case per 1,000,000 people.

Noncancer health guidelines for PCE, TCE, and Chloroform are available from ATSDR, EPA draft risk assessment for TCE, and EPA Integrated Risk Information System (IRIS). These values are not discussed further here because the concentrations of these contaminants in indoor air are significantly below the health guidelines.

Appendix C. Tetrachloroethene Public Health Statement

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.

1.8 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.

Appendix C: ATSDR Public Health Hazard Categories

Category / Definition	Data Sufficiency	Criteria
A. Urgent Public Health Hazard This category is used for sites where short-term exposures (< 1 yr) to hazardous substances or conditions could result in adverse health effects that require rapid intervention.	This determination represents a professional judgment based on critical data which ATSDR has judged sufficient to support a decision. This does not necessarily imply that the available data are complete; in some cases additional data may be required to confirm or further support the decision made.	Evaluation of available relevant information* indicates that site-specific conditions or likely exposures have had, are having, or are likely to have in the future, an adverse impact on human health that requires immediate action or intervention. Such site-specific conditions or exposures may include the presence of serious physical or safety hazards.
B. Public Health Hazard This category is used for sites that pose a public health hazard due to the existence of long-term exposures (> 1 yr) to hazardous substance or conditions that could result in adverse health effects.	This determination represents a professional judgment based on critical data which ATSDR has judged sufficient to support a decision. This does not necessarily imply that the available data are complete; in some cases additional data may be required to confirm or further support the decision made.	**Evaluation of available relevant information* suggests that, under site-specific conditions of exposure, long-term exposures to site-specific contaminants (including radionuclides) have had, are having, or are likely to have in the future, an adverse impact on human health that requires one or more public health interventions. Such site-specific exposures may include the presence of serious physical or safety hazards.**
C. Indeterminate Public Health Hazard **This category is used for sites in which "*critical*" data are *insufficient* with regard to extent of exposure and/or toxicologic properties at estimated exposure levels.**	This determination represents a professional judgment that critical data are missing and ATSDR has judged the data are insufficient to support a decision. This does not necessarily imply all data are incomplete; but that some additional data are required to support a decision.	**The health assessor must determine, using professional judgment, the "criticality" of such data and the likelihood that the data can be obtained and will be obtained in a timely manner. Where some data are available, even limited data, the health assessor is encouraged to the extent possible to select other hazard categories and to support their decision with clear narrative that explains the limits of the data and the rationale for the decision.**
D. No Apparent Public Health Hazard This category is used for sites where human exposure to contaminated media may be occurring, may have occurred in the past, and/or may occur in the future, but the exposure is not expected to cause any adverse health effects.	This determination represents a professional judgment based on critical data which ATSDR considers sufficient to support a decision. This does not necessarily imply that the available data are complete; in some cases additional data may be required to confirm or further support the decision made.	Evaluation of available relevant information* indicates that, under site-specific conditions of exposure, exposures to site-specific contaminants in the past, present, or future are not likely to result in any adverse impact on human health.
E: No Public Health Hazard **This category is used for sites that, because of the absence of exposure, do NOT pose a public health hazard.**	**Sufficient evidence indicates that no human exposures to contaminated media have occurred, none are now occurring, and none are likely to occur in the future**	

CERTIFICATION

This Health Consultation was prepared by the Colorado Department of Public Health and Environment under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with approved methodology and procedures existing at the time the health consultation was begun. Editorial review was completed by the Cooperative Agreement partner.

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The Division of Health Assessment and Consultation, ATSDR, has reviewed this health consultation and concurs with its findings.

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