Health Consultation

Evaluation of Health Implications of Potential Chemical Exposures in a Private Domestic Well

Ignacio/Durango Domestic Well
Ignacio, Colorado

JULY 2, 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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Prepared By:

The Colorado Department of Public Health and Environment
Under cooperative agreement with the
Agency for Toxic Substances and Disease Registry

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 authors of this document:

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PURPOSE

The purpose of this health consultation is to evaluate the public health implications associated with residential exposure to a contaminated groundwater well located on a private estate near Ignacio in southwestern Colorado. To this end, the available site background and groundwater data collected to date was reviewed; an exposure assessment was conducted; and exposure doses were estimated and compared to benchmarks for non-cancer and cancer health effects. An evaluation of potential contamination sources has not been conducted by CDPHE.

BACKGROUND AND STATEMENT OF ISSUES

The Colorado Cooperative Program for Environmental Health Assessments (CCPEHA) was contacted on June 3, 2008 by the Agency for Toxic Substances and Disease Registry's (ATSDR) Region 8 representative regarding a private domestic groundwater well contaminated with volatile organic compounds (VOCs). The well under investigation is located on a private estate approximately 5 miles west of Ignacio and 15 miles south of Durango, Colorado. Property utilities are run strictly on solar power and the contaminated well serves as the sole source of water for household use. The closest municipal water supply is roughly 5 miles away in Ignacio. The family that owns the property consists of two adults and two small children.

The owners requested that Elm Ridge Exploration, sample the domestic well water because they planned to install a gas well approximately ¼ mile from the property. Elm Ridge Exploration responded and collected the first water sample in August 2005. Field personnel collecting the samples noted a hydrocarbon odor in the well water; however, no laboratory analyses were conducted for hydrocarbons at this time. The domestic well was sampled again in February 2008 by the operator and was tested for benzene, toluene, ethylbenzene, and xylenes (BTEX) when the hydrocarbon odor was noted again. All BTEX constituents were identified during this sampling round. Upon notification of the impacts, the Colorado Oil and Gas Conservation Commission (COGCC) conducted two additional sampling rounds in March and May of 2008. The analysis of these samples detected BTEX compounds along with a number of other VOCs. No semi-VOCs were identified.

The owners have been told a number of things regarding the contamination including the substances in the well are dangerous and at unsafe levels (particularly benzene), and not to bathe their children with the contaminated water. However, the owners are interested in learning more about the actual risk associated with using the well water. This letter health consultation seeks to answer some of the owners concerns regarding the potential health risks associated with using the contaminated water. Identifying the source of contamination

is outside the scope of this evaluation based on the currently available information and environmental data set.

DISCUSSION

To determine the Contaminants of Potential Concern (COPCs), the maximum detected concentration of contaminants in the owner's domestic well were screened with the Environmental Protection Agency (EPA) Region 9 Preliminary Remediation Goals (PRGs) for residential exposure to tap water. PRGs are conservative, health-based screening values that consider multiple pathways of exposure to a particular environmental medium. In this case, the PRGs account for residential tap water use over a period of 30 years including ingestion of drinking water and inhalation of VOCs while showering/bathing. For additional information on PRGs, see EPA 2004a. Residential exposure to contaminant levels below the PRG value are not likely to result in adverse health effects and were dropped from further analysis. If the concentration of a contaminant exceeds the screening value, it does not necessarily indicate a health hazard, only that further investigation needs to be conducted.

The maximum concentration of a number of VOCs exceeded the respective screening value as shown in Table 1. In addition, the levels of benzene and total trihalomethanes exceed the regulatory drinking water standard for municipal water systems (Maximum Contaminant Level).

The first sampling round that showed evidence of VOC contamination (February 2008) was analyzed by EPA Method 8021B, an abbreviated groundwater analysis method used to identify BTEX compounds only. Benzene and the combined xylenes exceeded the screening value in this sample. Ethylbenzene and toluene were also detected, but at levels below the screening value and were dropped from further consideration. The second round of groundwater sampling, conducted in late March 2008, was analyzed by EPA Method 8260B for the complete suite of VOCs. Benzene and the xylenes were also detected though the concentration of xylenes was slightly below the screening value this time. In addition, naphthalene; tetrachloroethene (PCE); 1,3,5-trimethylbenzene; and 1,2,4-trimethylbenzene were also selected as COPCs since the concentration exceeded the screening value. The third round of sampling, conducted in May 2008, also indicated the presence of the aforementioned COPCs. Some were above the screening value and others were below. More importantly, all of the trihalomethanes were detected in this sample at relatively high concentrations when they had not been detected previously. These trihalomethanes could be due to a sanitation activity conducted by the owners about 5 days before this sampling event. The groundwater data from all sampling events was combined and the maximum value was taken as the exposure point concentration for estimating exposure doses. Overall, the COPCs listed in Table 1 were selected for further evaluation based on the maximum detected concentration in any sample exceeding the screening value.

The next step in the evaluation process is to determine if the owners are being exposed to the contaminated water and through which exposure pathways. The assumption that the

residents are currently using the well as the sole source of tap water in the household was made based on current information. Three primary routes of exposure to tap water exist: ingestion of drinking water, inhalation of VOCs while showering/bathing, and dermal exposure to contaminants while showering/bathing. These pathways are considered complete and relevant for this evaluation. In addition to these primary pathways, VOCs also have the ability to migrate from groundwater, through the soil vadose zone, and into the home. No data are available for the indoor air at this time. Therefore, vapor intrusion is considered an indeterminate pathway in this evaluation at this time.

To determine if adverse health effects are likely to occur from these exposures, an estimated dose must first be calculated for each COPC for both non-cancer and cancer health endpoints. The exposure dose calculations are standardized equations, established by the ATSDR and the EPA. A number of assumptions must be made regarding the variables of the equation such as, frequency of exposure, duration of exposure, body weight, and ingestion/inhalation rates. The assumptions used in this evaluation are the standard exposure assumptions used by the CCPEHA for residential exposures that account for 350 days of exposure over a 30-year period. The remaining assumptions used are described in detail in the EPA Exposure Factors Handbook (EPA 1997). Generally speaking, these assumptions are based on relatively high-end exposure rates in order to remain conservative for public health. However, the actual health risks to any one individual could be higher or lower than described below.

Exposure doses were estimated for each pathway to identify the individual risk contribution from each activity. Non-cancer exposure doses are compared to the health-based guidelines such as the ATSDR Minimal Risk Levels (MRLs) and EPA Reference Doses (RfDs). Health guidelines are considered to be protective of human health and are developed for both cancer and non-cancer effects. According to ATSDR, health guidelines for non-cancer effects are derived from human or experimental animal data and modified, as necessary, by a series of "uncertainty" factors (or "safety factors") to ensure that health guidelines are set at levels below those, which could result in adverse health effects. Health guidelines for cancer effects are derived by the EPA and represent hypothetical estimates of cancer risk at low levels of exposure. Comparison of the estimated exposure doses to the non-cancer health-based guidelines is used to determine which chemicals should be further evaluated. To facilitate this comparison in this evaluation, the estimated exposure dose is divided by the health-based guideline and this ratio is called a Hazard Quotient (HQ). HQs greater than 1 require further evaluation since the health-based guideline for that contaminant has been exceeded, while HQs less than 1 are dropped from further analysis. The HQs for each exposure pathway were then combined to evaluate cumulative health hazards from all pathways.

Theoretical cancer risks were also estimated by exposure pathway and then combined to evaluate cumulative cancer risks resulting from exposure to the COPCs in the groundwater well. The evaluation of cancer risks is slightly different than the non-cancer evaluation in that cancer doses are averaged over a lifetime (70 yrs.) as opposed to averaging over the exposure duration of 30 years for adults and 6 years for young children. In addition, the theoretical

cancer risks are compared to the CDPHE long-term cancer risk goal of one in a million and EPA's acceptable cancer risk range of $1 * 10^{-6} – 1 * 10^{-4}$ (literal meaning: no more than one to one hundred excess cancer cases per one million exposed individuals) to determine the likelihood of cancer risks.

As shown in Table 2, the estimated exposure doses significantly exceed the health-based guidelines for a number of COPCs including naphthalene, trimethylbenzenes, xylenes, and chloroform (i.e., these COPCs have HQs significantly greater than 1). The elevated cumulative non-cancer HQs are primarily due to the inhalation of COPCs while showering/bathing for 50 minutes/day (i.e., 35 minutes shower time+15 minutes post shower time in bathroom). These findings indicate that the estimated exposure doses enter a range of potential concern for non-cancer adverse health effects. Non-cancer estimated exposure doses for the drinking water (2L/day for 30 years for adults and 1L/day for 6 years for children) and dermal exposure during showering/bathing (about 35 minutes/day) pathways are well below the non-cancer health-based guideline for all COPCs; thereby indicating that these individual exposure pathways are not likely to result in significant non-cancer adverse health effects.

For the COPCs in which the estimated exposure doses exceeded health guideline (i.e., HQs >1), a more in-depth analysis is needed to understand the public health significance of the exposure level. It should, however, be noted that because of the uncertainties regarding exposure conditions and the adverse health effects associated with environmental levels of exposure, definitive answers on whether health effects actually will occur or will not occur are not possible. The in-depth analysis only serves as a means of gaining a better perspective on how strongly the available toxicological information in the scientific literature suggests potential for harmful exposures (i.e., public health hazard[1]). Thus, the estimated non-cancer exposure doses were compared with the known health effect levels that serve as the basis for the health-based guideline. The non-cancer health effect levels are referred to as the No Observable Adverse Effect Level (NOAEL) and the Lowest Observed Adverse Effect Level (LOAEL). In each case, the estimated non-cancer exposure dose was below the known health effects level (Table 4). The highest estimated dose/health effect ratio is 0.1 (chloroform). This means that the concentration of chloroform in the well water would have to be 10 times greater than what has been identified to date for the estimated non-cancer doses to be equal to the LOAEL of chloroform. Thus, it appears that significant non-cancer adverse health effects are not likely for both children and adults based on what is currently known about the toxic potential of these compounds. However, it is important to note that the estimated exposure doses enter a range of potential concern for non-cancer adverse health effects based on the significant exceedance of health-based guidelines for multiple chemicals (e.g., HQs ranging from 1.5 to 22.0).

[1] ATSDR defines "public health hazard" as a category used in ATSDR's public health assessments for sites that pose a public health hazard because of long-term exposures (greater than 1 year) to sufficiently high levels of hazardous substances that could result in harmful health effects

Theoretical cancer risks (Table 3), on the other hand, appear to be of concern. Specifically, the theoretical cancer risks for the trihalomethanes (bromodichloromethane, chloroform, and dibromochloromethane) are slightly above the high end of the acceptable risk range, with values of $1.7 * 10^{-4}$, $2.7 * 10^{-4}$, and $2.4 * 10^{-4}$, respectively (i.e., 170 to 270 excess cancer cases predicted per one million exposed individuals). The theoretical cancer risks for PCE, benzene, and bromoform are also at the high end of the acceptable cancer risk range (up to $5 * 10^{-5}$). When combined, the cumulative cancer risks are significantly above the acceptable risk range ($7.74* 10^{-4}$ or 774 excess cases per one million exposed). Thus, current and future exposures are considered a public health hazard as a result of excessive cumulative theoretical cancer risks. The theoretical cancer risks calculated in this assessment are based on the age-adjusted exposure dose equation (includes child & adult) with an exposure duration of 30 years. If it is assumed that the domestic well was free of contamination in August 2005 (1st well sample), but became contaminated shortly thereafter (data gap between 2005-2008), then a maximum of 3 years of exposure seems reasonable to evaluate past exposures. In this case, the theoretical cancer risks for past exposures would be 10 times less than the cancer risks calculated for this evaluation. The highest theoretical cancer risk for past exposures is $2.7 * 10^{-5}$ (chloroform) based on a 3-year exposure duration, which is well within the acceptable cancer risk range. However, past exposures are still technically considered an indeterminate public health hazard for the following reasons: 1) small number of available samples, 2) the actual exposure duration is unknown, and 3) the possibility that trihalomethanes have been present in the past, but have not been analyzed for.

It is important to note that the estimated cumulative cancer risks are from chemicals for which the weight-of-evidence for the carcinogenic potential varies from the "possible" to "known" human carcinogen classification. For example, benzene is classified as a known human carcinogen by the EPA based on the adequate evidence in humans. Whereas, chloroform, bromoform, bromodichloromethane, and tetrachloroethene are considered to be probable human carcinogens based on sufficient evidence of carcinogenicity in animal studies, and dibromochloromethane is classified as a possible human carcinogen based on limited evidence of carcinogenicity in animal studies.

As mentioned previously, it is beyond the scope of this evaluation to determine the source of the contamination in the owner's domestic well. The COGCC has concluded from its evaluation of this matter, including a soil gas analysis completed by an independent contractor, that the nearby gas operations are not the source of this contamination. At this time, CDPHE has no information to cause it to disagree with this conclusion. In fact, the trihalomethanes and PCE are not likely to be associated with the nearby gas production activities because the trihalomethanes (chloroform, bromodichloromethane, bromoform, and dibromochloromethane) are commonly known disinfection byproducts following chlorination. PCE is an organic solvent; most commonly associated with dry cleaners, but is also used in a number of commercial and household products. Regardless of the source, the well water samples contain levels of chemicals that could be of potential public health concern and these levels need to be reduced.

CHILD HEALTH CONSIDERATION

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.

Health effects for children were considered in this evaluation and were found to be a concern, especially, for non-cancer hazards.

CONCLUSIONS

The following conclusions have been made regarding the contamination found in the domestic well:

- Current and future exposures over a period of 30 years constitute a "public health hazard" based on the cumulative theoretical cancer risks from various chemicals exceeding the high end of acceptable cancer risk range (i.e., greater than 100 in a million).

- Past exposures to COPCs are considered an "indeterminate public health hazard"[2] based on uncertainties regarding contaminant levels over time (particularly trihalomethanes).

- Significant non-cancer health hazards are not likely to occur since the estimated exposure doses for 30 years are below the known health effect level for all COPCs. It is, however, important to note that the estimated exposures for non-cancer hazards enter a range of potential concern based on the exceedance of health-based guidelines for both children and adults.

- Significant non-carcinogenic and cancer health effects are not likely to occur from only drinking the well water.

[2] The category used in ATSDR's public health assessment documents when a professional judgment about the level of health hazard cannot be made because information critical to such a decision is lacking.

- Bottled water may not be an effective risk reduction strategy since the majority of the health hazards determined in this evaluation are based on showering exposures.

- The exact source of contamination is not currently known. The COGCC has concluded from its evaluation of this matter that the nearby gas operations are not the source of this contamination. At this time, CDPHE has no information to cause it to disagree with this conclusion.

RECOMMENDATIONS

To reduce the exposure levels and potential for cancer and non-cancer health effects associated with domestic use of the owner's well water, the following recommendations should be implemented:

- The owners should reduce exposures to contaminated well water by adopting various strategies until contaminant levels in the well have been reduced. Some exposure reduction strategies may include: reducing or discontinuing use of domestic well for potable household purposes; reducing shower times; thoroughly ventilating house, particularly the bathroom while showering; using alternate water supply; and implementing advanced technologies to remove VOCs.

- A sampling and analysis plan may be warranted to monitor future groundwater contaminant levels. In addition, indoor air sampling to confirm the absence of the vapor intrusion pathway would be useful.

- If VOCs continue to be detected in the owner's well, an investigation to confirm the source of the contamination to enable remedial efforts and, subsequently, reduce the contaminant levels in the groundwater.

- CCPEHA should and will review any additional groundwater data as requested and/or necessary.

PUBLIC HEALTH ACTION PLAN

- The CCPEHA will share this health consult with the owners and will also review and evaluate any additional groundwater data as requested and/or necessary.

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TABLES

Table 1. Contaminants of Potential Concern

Contaminant of Potential Concern	Concentration Range (in μg/L)	EPA Region 9 Preliminary Remediation Goal (in μg/L)	EPA Maximum Contaminant Levels (MCLs) (in μg/L)
Naphthalene	6 - 11	6.2	N/A
Tetrachloroethene	ND - 3.5	0.1	5
1,3,5-Trimethylbenzene	15 - 45	12	N/A
1,2,4-Trimethylbenzene	34 - 68	12	N/A
Benzene	7.9 - 12	0.35	5
Combined Xylenes	151 - 220	210	10000
Bromodichloromethane	ND - 24	0.18	80*
Bromoform	ND - 22	8.5	80*
Chloroform	ND - 350	0.17	80*
Dibromochloromethane	ND - 25	0.13	80*

ND = Not Detected
N/A = Not Available
* The MCL value is based on total trihalomethanes (bromodichlormethane, bromoform, chloroform, dibromochloromethane)

Table 2. Non-cancer hazard quotients by exposure pathway

Contaminant of Potential Concern	Child Dermal HQ	Child Shower Inhalation HQ	Child Drinking Water Ingestion HQ	Child Cumulative HQs	Adult Dermal HQ	Adult Shower Inhalation Hazard Quotient	Adult Drinking Water Ingestion HQ	Adult Cumulative HQs
Naphthalene	6.87E-03	**6.84E+00**	3.52E-02	**6.88E+00**	4.02E-03	**1.47E+00**	1.51E-02	**1.49E+00**
Tetrachloroethene	3.91E-03	1.87E-01	2.24E-02	2.13E-01	2.29E-03	4.01E-02	9.59E-03	5.20E-02
1,3,5-Trimethylbenzene	1.37E-02	**1.42E+01**	5.75E-02	**1.42E+01**	7.98E-03	**3.03E+00**	2.47E-02	**3.07E+00**
1,2,4-Trimethylbenzene	3.72E-02	**2.14E+01**	7.46E-01	**2.22E+01**	2.17E-02	**4.58E+00**	3.73E-02	**4.64E+00**
Benzene	8.61E-03	4.91E-01	1.92E-01	6.92E-01	5.03E-03	1.60E-01	8.22E-02	2.47E-01
Xylenes	1.34E-02	**4.06E+00**	7.03E-02	**4.14E+00**	7.84E-03	8.69E-01	3.01E-02	9.07E-01
Bromodichloromethane	1.72E-03	6.42E-01	7.67E-02	7.20E-01	1.00E-03	1.38E-01	3.29E-02	1.71E-01
Bromoform	1.44E-03	5.88E-01	7.03E-02	6.60E-01	8.39E-04	1.26E-01	3.01E-02	1.57E-01
Chloroform	5.98E-03	**1.34E+01**	2.24E-01	**1.36E+01**	3.49E-03	**2.87E+00**	9.59E-02	**2.96E+00**
Dibromochloromethane	1.78E-03	6.69E-01	7.99E-02	7.50E-01	1.04E-03	1.43E-01	3.42E-02	1.79E-01

Values in red indicate HQs > 1

Table 3. Age-adjusted Theoretical Cancer Risks by exposure pathway

Carcinogen	Dermal Age-Adjusted Cancer Risk	Shower Inhalation Age-Adjusted Cancer Risk	Ingestion Age-Adjusted Cancer Risk	Cumulative Age-Adjusted Cancer Risk
Tetrachloroethene	7.11E-06	6.98E-06	3.25E-05	4.66E-05
Benzene	6.37E-07	3.08E-05	1.14E-05	4.28E-05
Bromodichloromethane	7.17E-07	**1.41E-04**	2.56E-05	**1.68E-04**
Bromoform	7.63E-08	8.15E-06	2.99E-06	1.12E-05
Chloroform[1]	N/A	**2.69E-04**	N/A	**2.69E-04**
Dibromochloromethane	1.01E-06	**1.99E-04**	3.62E-05	**2.37E-04**
Total cancer risk	9.54E-06	**6.56E-04**	**1.09E-04**	**7.74E-04**

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

N/A- Not applicable

Table 4. Estimated Non-Cancer Exposure Doses and Health-Based Guidelines for Contaminants with Elevated Hazard Quotients

Contaminant of Potential Concern	Estimated Shower Inhalation Exposure Dose for Children (mg/kg-day)	Estimated Shower Inhalation Exposure Dose for Adults (mg/kg-day)	Applicable Health-Based Guideline [a] (mg/kg-day)	No Observable Adverse Effect Level (mg/kg-day)	Low Observable Adverse Effect Level (mg/kg-day)
Naphthalene	$5.9 * 10^{-3}$	$1.3 * 10^{-3}$	$8.6 * 10^{-4}$	N/A	0.3 [b]
1,3,5-Trimethylbenzene	$2.4 * 10^{-2}$	$5.2 * 10^{-3}$	$1.7 * 10^{-3}$	N/A	5.0
1,2,4-Trimethylbenzene	$3.6 * 10^{-2}$	$7.8 * 10^{-3}$	$1.7 * 10^{-3}$	6.2	N/A
Xylenes	$1.2 * 10^{-1}$	$2.5 * 10^{-2}$	$2.9 * 10^{-2}$	11.1	17.4
Chloroform	$1.9 * 10^{-1}$	$4.0 * 10^{-2}$	$1.4 * 10^{-2}$	N/A	2.8 [b]

*Applicable health-based guideline is the EPA Inhalation Reference Concentration
[b] based on ATSDR MRLs
N/A: Not available

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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