Health Consultation

IRON KING MINE & HUMBOLDT SMELTER

An Update for Water Sampling Results

DEWEY-HUMBOLDT, YAVAPAI COUNTY, ARIZONA

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Summary

INTRODUCTION

In the *Iron King Mine and Humboldt Smelter: An Update for Water Sampling Results*, the Arizona Department of Health Services' (ADHS') top priority is to ensure that the community and residents have the best information possible to safeguard their health.

This report was written in response to a request from the U.S. Environmental Protection Agency (EPA). In September 2008, the Iron King Mine-Humboldt Smelter was added to the National Priority List (NPL) due to elevated levels of arsenic and lead in the area. Local residents have voiced concern about levels of heavy metals in ambient air during high wind events. EPA conducted an ambient air sampling program to evaluate the potential migration of airborne contaminants from the site. During the investigation, additional water and residential soil samples were collected.

The Arizona Department of Health Services (ADHS) planned to produce a series of reports to address contaminants in the air, water, and soil as well as the cumulative health risks. In 2013, ADHS and the Agency for Toxic Substances and Disease Registry (ATSDR) published a health consultation entitled "Evaluation of Ambient Air Sampling Results" to address the airborne contaminants.

ADHS used groundwater samples collected by EPA and public drinking water samples collected by Arizona Department of Environmental Quality (ADEQ). The EPA groundwater samples comprise public drinking water supply wells, private drinking water wells, monitoring wells, and wells in the mine areas. In this health consultation, ADHS evaluated the potential health impact associated with exposure to wells and from water plant storage tanks that can be (potentially) used for potable purposes.

CONCLUSIONS AND BASIS FOR DECISION FOR THIS REPORT (WATER EXPOSURE)

Based on the available information, ADHS reached the following conclusions regarding current and potential future exposure to groundwater and public drinking water in the study area:

<u>Exposure to Contaminants in ADEQ Public Drinking Water Samples:</u>

- *Past Exposure (before 2015): Exposure to arsenic levels found in public drinking water could harm the health of adults and children*. The water samples were not collected directly from the public drinking water supply wells. They were collected after processing and storage in the water plant but before the first customer at the entry point to the distribution system.

Basis for Decision: This conclusion was reached because the estimated cancer risk due to arsenic exposure (2.6×10^{-4}) exceeded the upper limit of EPA target cancer risk range (10^{-6} to 10^{-4}). That means that there will about 3 additional cancer cases in 10,000 exposed individuals (10^{-4}).

- *Current Exposure (after 2015): Exposure to public drinking water is not expected to harm the health of adults and children.* The Humboldt Public Water System has installed an arsenic treatment system and has received the required approval from ADEQ in 2015. The water currently meets the arsenic standard and the Public Water System (PWS) is in compliance with the standard.

<u>Exposure to EPA Groundwater Samples:</u>

- *Exposure to arsenic, lead, magnesium, manganese, nitrate, and/or sulfate in some of the groundwater wells could harm the health of children and adults*.

  Basis for Decision:

  - Arsenic: the estimated daily exposure doses for 17 wells were associated with increased chance of developing dermal effects among children (Table 4-1). The estimated cancer risk for 29 wells exceeded EPA's upper target cancer risk range value (Table 4-2).
  - Lead: based on the Integrated Exposure Uptake Biokinetic (IEUBK) model prediction, children who drink water from wells GW-999928 and GW-999953 will have equal or greater than a 5% chance to exceed the blood lead level of 5 µg/dL.
  - Magnesium: young children (0-1 year old) who consume water from well GW-999947 may experience gastrointestinal discomfort because the estimated daily intake exceeded the upper intake level.
  - Manganese: an elevated level was detected in well GW-999917. The estimated daily exposure doses for children were associated with increased chance of developing neurological effects.
  - Nitrate: elevated levels were detected in well GW-999947 and well GW-999953. The estimated daily exposure doses were associated with increased chance of developing methoglobinemia in children, especially infants.

- Sulfate: concentrations detected in well GW-999914 and well GW-999947 exceeded the concentration associated with laxative effects, especially infants since they are more susceptible to diarrheal water loss.

Limitation of the Evaluation: For groundwater samples in the EPA RI/FS report, due to the limited amount of data available (one sample was collected from each well location/household), ADHS conducted this evaluation assuming the concentrations detected would remain at these levels (i.e. chemical concentrations do not change over time). For blood lead concentration estimation, ADHS used air monitoring data from Iron-King Mine, Humboldt-In-Town, Humboldt Smelter, and background stations based on the groundwater sampling location. No residential-specific soil concentrations were available, so the highest detected background concentrations were used in the prediction; therefore, the true exposure levels may be over- or under-estimated.

NEXT STEPS

- ADHS will continue to work with EPA and ADEQ to evaluate the potential health effects associated with soil exposure.
- ADHS will continue to attend additional public meetings, make presentations, develop handout literature, and engage in other actions to notify the property owners and residents in the area of the findings of this health consultation.
- ADHS will notify EPA and ADEQ regarding the findings of this report and work with both agencies to evaluate the protectiveness of remedial action plans.
- ADHS will continue to review and evaluate data provided for this site.

ADHS also made the following recommendations to local residents to reduce chemical exposure from groundwater and the site.

- For groundwater wells containing arsenic above the Maximum Contaminant Level (MCL) of 10 ppb (parts per billion): residents are advised to install a treatment system that can effectively remove arsenic. Meanwhile, residents are advised to use an alternative water source, such as bottled water, for drinking and cooking.
- All residents in the Dewey-Humboldt area are advised to have their well water tested for metals, bacteria, and nitrates promptly after a new groundwater well is drilled. If any parameter is found to be above the recommended levels, a confirmation sample needs to be collected before any decision can be made regarding water treatment.
- All residents in the Dewey-Humboldt area who use private well

water for drinking or cooking are advised to have their well water tested yearly for bacteria and nitrates, and every 5 years for contaminants including arsenic, fluoride, radon, uranium, lead, and copper. If any parameter is found to be above the recommended levels (MCL etc.) a confirmation sample needs to be collected before any decision can be made regarding water treatment.

- Children living in Dewey-Humboldt should receive individual risk assessments from their physicians to determine if they are at an increased risk for lead poisoning. Parents are encouraged to contact their physician to discuss whether there is a need for a blood test.
- Residents are encouraged to attend public meetings and public education activities to obtain more information on ways to minimize the amount of exposure.

CONCLUSIONS FROM PREVIOUS HEALTH CONSULTATION REPORT (AIR EXPOSURE)

PM_{10}: *Short-Term Exposure* (usually over a 24-hour period, but possibly as short as one hour): $PM_{2.5}$ (Particulate Matter less than 2.5 microns in width) is not expected to harm human health at the Iron King Mine and Humboldt-In-Town areas. During high wind events, the PM_{10} levels may harm people's health at the Humboldt Smelter area. *Long-Term Exposure*: PM_{10} was used to estimate the concentration of $PM_{2.5}$ (Particulate Matter less than 2.5 microns in width). The predicted concentration of $PM_{2.5}$ is not expected to harm human health at the study areas (i.e. Iron King Mine, Humboldt Smelter and Humboldt-In-Town).

Metals: Regardless of wind condition, the metal concentrations detected in the ambient air alone are not likely to be harmful to the public.

FOR MORE INFORMATION

If you have concerns about your health, you should contact your health care provider. Please call ADHS at 602-364-3118 and ask for more information on the Iron King Mine Humboldt Smelter Site.

Purpose

In September 2008, the Iron King Mine-Humboldt Smelter was added to the National Priority List (NPL) due to elevated levels of arsenic and lead in the area. The Arizona Department of Health Services (ADHS) conducted a health consultation to evaluate the health risks associated with exposure to contaminated soil and water based on samples collected from 2002 to 2006 (ADHS 2009). Additional samples were collected during the Remedial Investigation/Feasibility Study (RI/FS) conducted in 2008. ADHS and the Agency for Toxic Substances and Disease Registry (ATSDR) were requested to evaluate the sampling results to see if the contaminants are at levels harmful to human health.

ADHS planned to conduct a series of reports to address the contaminants detected in air, water, and soil samples, as well as the cumulative health risks. A 2012 ADHS health consultation focused on the exposure to airborne particles, and determined that the detected metal concentrations in the ambient air are not likely to be harmful to the public. This health consultation focused on the samples collected from groundwater and the public drinking water system. It only evaluated detected chemicals in the water samples. The next planned health consultation will address the chemicals in soil samples and the cumulative health risks from all exposure pathways.

Background

Site Location: The Iron King Mine and the Humboldt Smelter facilities have contaminated groundwater and soil with chemicals attributable to the mine and smelter sources. Both the mine and smelter are located in industrial, commercial, and/or residential areas of Dewey-Humboldt, Arizona. The Iron King Mine, located just west of the town of Humboldt, Arizona, is approximately 90 miles northwest of Phoenix and 20 miles southeast of Prescott. The mine is situated in the Agua Fria River basin. The Humboldt Smelter is located near the intersection of 3rd street and Main Street (Figure 1).

Operation History: The Iron King Mine covers approximately 153 acres. It was an active mine from 1904 until 1969; however, some of the residents who lived in the vicinity of Prescott the longest say the Iron King Mine was originally established in 1880. Sometime after the end of World War I the mine was closed. The Iron King Mine was expanded in 1936 to extract ore containing lead, gold, silver, zinc, and copper from the underlying Pre-Cambrian schist. Since this is an underground mine, with drifts and tunnels, ore was removed by an elevator. A 140-ton mill was erected on the site to crush the ore and was expanded to 225-ton capacity in 1938. A cyanide processing plant was added to the site in 1940 to treat the mill tailings to enhance metal recovery. Waste rock and tailings were deposited in large piles adjacent to actual mine property boundaries. The mine has been inactive since 1969. Operators utilize parcels of the former mine site for mineral recovery to be used in the production of iron-rich fertilizer. This fertilizer was bagged under the trade name, Ironite. Today, the Iron King Mine site is mainly covered by tailings and waste rock piles, although there are some facilities that exist within the property boundaries, such as a junk yard and a recycling plant for biosolids.

The Humboldt Smelter occupies approximately 182 acres. This area is covered in approximately 763,800 square feet of yellow-orange tailings, over 1 million square feet of grey smelter ash, and 456,000 square feet of slag. The Humboldt Smelter operated from the late 1800s until the early 1960s. The original smelter was burned down in 1904, and in 1906 a new smelter was built that processed 1,000 tons of ore per day. This smelter operated full-time until 1918 and then intermittently between 1922 and 1927. The smelter returned to full-time operation in 1930 until 1969.

Site Activity: Arsenic and lead have been detected at levels above health based standards in soil from several residential yards. As a result, a removal action was initialized in 2006 to remove contaminated soil from four off-site residential properties. The removal of the contaminants was conducted by a contractor on behalf of the Ironite Products Company under EPA oversight.

Portions of this site were regulated under the ADEQ Voluntary Remediation Program. In September 2007, EPA received a response from Arizona Governor Napolitano consenting to the placement of the Site on the National Priority List (NPL), commonly called the Superfund List. On March 19, 2008, EPA proposed listing the Iron King Mine-Humboldt Smelter Site to the NPL. In September 2008, EPA formally added the site to the NPL. ADHS conducted a health consultation to evaluate the health risks associated with exposure to contaminated soil and water based on samples collected from 2002 to 2006 (ADHS 2009).

In October 2008, EPA started the Remedial Investigation/Feasibility Study (RI/FS) to further assess the nature and extent of the contaminants. This investigation helped EPA determine possible cleanup actions for the site. As part of the RI/FS, EPA collected additional soil, water and air samples.

In 2011, EPA completed an interim removal action that addressed 12 residential properties located in the vicinity of the Humboldt Smelter. EPA removed soil with elevated levels of arsenic and lead (Pb) from these properties and replaced it with clean fill. The removed soil were placed in a location on top of the Iron King Mine Main Tailings Pile to address fugitive dust emissions from the top of the Iron King Mine. Hydroseed was also applied on top of the soils to promote vegetation growth. EPA also removed the Small Tailings Pile, located adjacent to the Chaparral Gulch. Additionally, EPA applied a temporary fixative agent to address fugitive dust emissions from the Humboldt Smelter Ash Piles.

Statement of Issues

Local residents have concerns about levels of heavy metals detected in the air, water, and soil. The local residents want to know how the detected contaminants could affect the health of the community members, especially children. Evidence showing the impacts of the mine and smelter on groundwater used for drinking became under investigation. EPA released a RI/FS report in October 2016. This report concluded that soil hot spots resulting from a combination of site-related and non-site-related sources of arsenic and lead are resulting in risks above EPA risk management thresholds in select yards. Many of these yards are located north of the former Humboldt Smelter property in Humboldt Proper, along the historic Smelter Spur, and along areas of tailings deposition in Chaparral Gulch.

Local residents can be exposed to contaminants from using well water for drinking and other domestic purposes. Many people have private wells in the area. Groundwater is also a source for the public drinking water system (sample ID: GW-999951 and GW-999952). The arsenic concentration in one of the supply wells (GW-999952) had a concentration higher than the Maximum Contaminant Level of 10 microgram per liter (µg/L). The groundwater from the two wells is blended prior to entering the water distribution system. To address the increasing community concern, ADHS evaluated the potential health effects associated with exposures to arsenic and nitrate in public drinking water.

ADHS/ATSDR Region 9 contacted EPA to help clarify if the groundwater wells are used for potable purposes. The results indicated that:

a) The following are not drinking water wells: MW-01-S (monitoring well), MW-02-S (monitoring well), MW-03-S (monitoring well), MW-04-S (monitoring well), MW-05-S (monitoring well), MW-06-D (monitoring well), GW-999954 (surface depression produced by block caving in underground mining in the mine), GW-999948 (on the smelter), GW-551459 (in the mine tailing pile), GW-SW-08, and GW-592720 (on the mine tailing area).
b) The following may be non-potable wells but still have a good chance of being potable wells: GW-999901, GW-999908, GW-999935, GW-999944, GW-999951, and GW-586144.
c) No information was found for the following wells: GW-573389, and GW-999943.
d) The rest of the sampling wells are likely residential potable wells.

In this health consultation, ADHS evaluated the potential public health impacts associated with the wells that can be potentially used for drinking, cooking or personal hygiene (i.e. statements b, c and d listed above).

Discussion

General Assessment Methodology

ADHS generally follows a three-step methodology to assess public health issues related to environmental exposures. First, ADHS obtains representative environmental data for the site of concern and compiles a comprehensive list of site-related contaminants. Second, ADHS identifies exposure pathways, and then uses health-based comparison values to find those contaminants that do not have a realistic possibility of causing adverse health effects. For the remaining contaminants, ADHS reviews recent scientific studies to determine if exposures are sufficient to impact public health.

Available Environmental Data

(1) EPA groundwater samples:

ADHS conducted the assessment based on the Iron King Mine-Humboldt Smelter Superfund Site Remedial Investigation (RI) Report (EA Engineering, Science, and Technology, Inc 2010) provided by EPA. This report indicated that groundwater samples were collected from private and municipal taps, as well as monitoring wells, a historical groundwater well, a cistern, and a pump near Old Mine Shaft No. 7 (see Appendix A for detailed information). These samples were analyzed for target analyte list (TAL) metals, volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), explosives, perchlorates, anions, cations, total dissolved solids (TDS), nitrates, nitrite, and sulfate.

(2) ADEQ Public drinking water samples:

For assessment of the public drinking water system, ADHS used the water sampling results provided by ADEQ. Arsenic and nitrate are chemicals of concern because elevated levels have been detected in the system in the past. The latest analytical results showed that all other chemicals are within compliance of public drinking water systems. All water sampling results can be accessed from: http://azsdwis.azdeq.gov/DWW_EXT/JSP/WaterSystemDetail.jsp?tinwsys_is_number=2709&tinwsys_st_code=AZ&wsnumber=AZ0413052

The water samples were not collected directly from the municipal supply wells. They were collected after processing and storage in the water plant but before the first customer at the entry point to the distribution system (EPDS). These are not well water samples. They are water samples collected directly from the water plant after they are processed and before they are sent to the customers.

Exposure Pathway Analysis

Identifying exposure pathways is important in a health consultation because adverse health impacts can only happen if people are exposed to contaminants. The presence of a contaminant in the environment does not necessarily mean that people are actually coming into contact with that contaminant. Exposure pathways have been divided into three categories: completed, potential, and eliminated.

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

1) a source of contamination
2) a medium such as soil or ground water through which the contaminant is transported
3) a point of exposure where people can contact the contaminant
4) a route of exposure by which the contaminant enters or contacts the body
5) a receptor population

Completed pathways exist when all five elements are present and indicate that exposure to a contaminant has occurred in the past and/or is occurring presently. In a potential exposure pathway, one or more elements of the pathway cannot be identified, but it is possible that the element might be present or might have been present. In eliminated pathways, at least one of the five elements is or was missing, and will never be present. Completed and potential pathways, however, may be eliminated when they are unlikely to be significant. ADHS identified three potential/completed exposure pathways: air inhalation, water ingestion, and incidental soil ingestion.

The following summarizes the possible scenarios via different exposure pathways. This health consultation evaluated the exposure to groundwater. ADHS evaluated health risks associated with the exposure to each individual well. ADHS will consider all exposure pathways and estimate cumulative health risks.

Exposure to Air: This exposure pathway was evaluated in a previous health consultation[1]. Nearby residents can also breathe in contaminated dust during moderate to high wind events. The meteorological data show that the prevailing wind directions, in general, are from the northwest during November and January, and from the southeast for the rest of the year. Surface soil and mine tailings from the Iron King Mine and Humboldt Smelter are not covered; therefore, the dust particles can be blown to nearby residential areas throughout the year. High wind events usually occur from March to May, and also from July to August. This health consultation concluded that metal particles in the air are not likely to harm people's health. The data showed that sometimes, during windy conditions, particles in the air near the Humboldt Smelter could reach levels high enough to be a health concern to sensitive individuals. High levels of dust were not found near the Iron King Mine or Humboldt-In-Town.

Exposure to Groundwater/Public Drinking Water: This exposure pathway is evaluated in this health consultation. Local residents can be exposed to contaminants from using well water for domestic purposes. Many people have private wells in the area. Groundwater is also a source for the public drinking water system. Typical potable and municipal supply well exposures to contaminants include dermal exposures from bathing and showering, and ingestion exposures from drinking and using water for cooking. Metals tend not to be absorbed through the skin, and are not likely to be inhaled by people as aerosol while showering because they are not volatile (i.e. do not evaporate). Therefore, dermal and inhalation exposures from bathing and showering are not considered in this evaluation.

In this health consultation, ADHS evaluated measurements of wells that may be (potentially) used for potable purposes. Measurements of monitoring wells and wells in the smelter areas were not considered because the public is not likely to have direct contact with chemical in these wells through inhalation, ingestion, or dermal contact.

Exposure to Soil: This exposure pathway will be evaluated in the next planned health consultation. Residents may come in contact with the constituent chemicals of the soil in the residential area (i.e. yard). Chemicals from the mine tailings could potentially be carried to the residential area through air dispersion. Human exposure to the soil in the residential area could result in exposure to the natural constituents of the soil and any additional chemicals that may have been carried by the wind from the mine tailings. People can accidentally ingest soil when eating food with their hands or putting their fingers in their mouths, because soil or dust particles can adhere to food, cigarettes, and hands. Children are particularly sensitive, because they are

[1] http://www.atsdr.cdc.gov/HAC/pha/IronKingMineAir/IronKingMineAirHC02072013.pdf

likely to ingest more soil than adults during a normal phase of childhood in which they exhibit hand-to-mouth behavior. ADHS is conducting an evaluation to address the chemicals found in soil samples.

ADHS further evaluated the completed and potential exposure pathways to determine whether realistic exposures are sufficient in magnitude, duration or frequency to result in adverse health effects (Table 1).

Comparison to Health-based Comparison Values for Groundwater Well Samples

Health-based comparison values (CVs) are screening tools used to evaluate environmental data relevant to exposure pathways. These comparison values are quite conservative, and usually include uncertainty factors to help protect the most sensitive populations. Adverse health effects are not expected to occur if an exposure concentration/dose is below a CV. However, an exposure concentration/dose at or above the CV doesn't mean adverse effects will occur: rather, it means that there is a need to conduct a site-specific exposure scenario evaluation. The health risk for an individual depends on individual human factors (e.g. personal habits, occupation, and/or overall health), and site-specific environmental exposure factors (e.g. duration and amount of exposure). Therefore, the comparison values should not be used to predict the occurrence of adverse health effects without looking at site-specific conditions.

ADHS typically uses comparison values as follows: if a contaminant is not found at levels greater than its CV, ADHS concludes the levels of corresponding contamination do not pose a risk to human health. If, however, a contaminant is found at levels that are greater than its comparison value, ADHS designates the pollutant as a *contaminant of concern* and examines potential human exposures in greater detail.

During this investigation, naturally occurring minerals (e.g. calcium and iron) were also detected in the groundwater samples and the possible harmful effects associated with these substances were also evaluated. ADHS considered these substances found in drinking water as nutrients, and focused the assessments around estimated dietary intake. These assessments specifically utilized adequate intakes[2] (AI) and the tolerable upper intake levels[3] (UL) recommended by the Institute of Medicine (IOM).

A number of substances (i.e. arsenic, bromide, cobalt, iron, lead, magnesium, manganese, nitrate as N, sulfate and total dissolved solids) were found in samples collected from the public drinking water system (ADEQ samples) and/or EPA groundwater wells. If a substance was found in exceedance of its respective health-based CV, it was labeled as a "contaminant of concern" and investigated further (Table 2-1 and Table 2-2).

To evaluate potential public health implications for the contaminants of interest, exposure estimates are based on a daily intake of 2 liters of water/day and a 70 kg body weight for adults.

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[2] Adequate Intakes (AI): AIs meet or exceed the amount needed to maintain a nutritional state of adequacy in nearly all members of a specific age and gender group. An AI is set when there is insufficient scientific data available to establish a recommended dietary allowance (RDA) for specific age/gender groups.
[3] Tolerable Upper Intake Levels (UL): the maximum daily intake unlikely to result in adverse health effects.

For a child, two exposure doses were calculated, including (1) daily intake of 1 liter of water/day and a 16 kg body weight to represent 1-6 year old children, and (2) daily intake of 1 liter of water/day and a 10 kg body weight to represent 0-1 year old children.

For samples in the RI/FS report, due to the limited amount of data available (one sample was collected from each well location), ADHS conducted this evaluation assuming the concentrations detected would remain at these levels (i.e. chemical concentrations do not change over time). Therefore, a chronic exposure evaluation along with an evaluation of potential acute exposure impacts was performed for these data. Table 3 provides a well-by-well summary of the chemical constituent of potential public health concern. The detailed review of potential health effects for all of the chemicals of interest follows. For samples collected from the public drinking water system, an average concentration was used in the chronic exposure evaluation (Table 2-2).

Public Health Implications*: This section will provide general toxicological information and site-specific exposure evaluation for each contaminant of interest. In this health consultation, ADHS evaluated the potential public health impacts associated with groundwater wells that can be potentially used for drinking, cooking or personal hygiene. When calculating chronic (long-term) exposure doses, ADHS used the exposure parameters (such as exposure duration, exposure frequency, and averaging time) listed in the ADHS Deterministic Risk Assessment Guidance.*

Arsenic:

Arsenic is a naturally occurring element widely distributed in the earth's crust and can be found in air, water and soil. In Arizona, the average concentrations of arsenic around the state are: 10 mg/kg for soil, and 28–40 µg/L for groundwater (AAC 2004; Radden 2005). Arsenic exists as inorganic arsenic, organic arsenic, and arsine gas. In general, organic arsenic is less toxic than inorganic arsenic. The general population is likely to be exposed to arsenic through food and water ingestion. The average dietary exposures to total arsenic are 50.6 µg/day for females and 58.5 µg/day for males. Fish and seafood contain the highest concentrations of arsenic; however, most of this is the less toxic organic form of arsenic (ATSDR 2007).

Non-Cancerous Health Effects

<u>Short-term Exposure (0-14 days)</u>:

Overview: Drinking water containing high levels of arsenic (60 mg/L) can result in death. Drinking lower levels of arsenic-containing water (0.3–30 mg/L) can cause irritation to the stomach and intestines, with symptoms such as stomach ache, nausea, vomiting, and diarrhea (ATSDR 2007). Mizuta et al. (1956) reported an arsenic poisoning incident in Japan. Two hundred and twenty poisoned individuals were exposed to arsenic-contaminated soy sauce (100 mg/L, probably as calcium arsenate, an inorganic form of arsenic) for approximately 2–3 weeks. The initial primary symptoms were edema of the face, gastrointestinal (nausea, vomiting and diarrhea) and upper respiratory symptoms, followed by skin lesions and neuropathy in some patients. The estimated consumption of arsenic for Mizuta et al. (1956) was about 3 mg/day (i.e. 0.05 mg/kg/day, assuming 55-kg body weight for the Asian population). ATSDR established an acute minimal risk level[4] (MRL) of 0.005 mg/kg/day based on the characteristics of the initial poisoning reported in Mizuta et al. (1956), and an uncertainty factor of 10 for using the Lowest Observed Adverse Effect Level (LOAEL)[5] (ATSDR 2007).

Discussion for EPA Groundwater Samples: ADHS calculated the short-term exposure doses for each sample using the detected concentrations. The estimated exposure doses for the highest concentration (0.041 mg/L) did not exceed the acute MRL[6]. Therefore, ADHS does not expect to see symptoms associated with acute exposure among people using the well water for domestic purposes (i.e. drinking, cooking, and personal hygiene).

Discussion for ADEQ Public Drinking Water Samples: ADHS calculated the short-term exposure doses for each sample using the detected concentrations. None of the estimated exposure doses exceeded the ATSDR acute MRL of 0.005 mg/kg/day. The highest exposure dose was 0.002 mg/kg/day. Therefore, acute adverse effects are not expected to occur among the exposed population.

<u>Long-term Exposure (> 365 days)</u>:

Overview: In humans, skin is the most sensitive target organ after ingesting arsenic for a long period of time. Typical effects include hyperkeratosis (patches of hardened skin, especially on the palms of the hands and soles of the feet), hyperpigmentation of the skin, and changes in the blood vessels of the skin. These symptoms typically begin to manifest at exposure levels of about 0.002–0.02 mg/kg/day. Ingestion of arsenic can also result in effects on other organs such as cardiovascular and respiratory organ systems. Nausea, vomiting and diarrhea are also common symptoms in humans after repeated exposure to low doses of arsenic; their effects are due to a direct irritation of the gastrointestinal mucosa (ATSDR 2007).

ATSDR established a chronic MRL of 0.0003 mg/kg/day based on the incidence of Blackfoot Disease and dermal lesions (hyperkeratosis and hyperpigmentation) in a population exposed to high levels of arsenic well water in Taiwan. The control-, low-, medium-, and high-exposure levels correspond to doses of 0.0008, 0.014, 0.038, and 0.065 mg/kg/day, respectively. The identified No Observed Adverse Effect Level (NOAEL) is 0.0008 mg/kg/day was divided by an uncertainty factor of 3 for human variability. Hyperpigmentation and keratosis of the skin (less serious Lowest Observed Adverse Effect Level (LOAEL)) were observed in the low-level exposure group, and increased incidences of dermal lesions were observed in the medium- and high-level exposure groups. The identified NOAEL is limited by the fact that the majority of the

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[4] Minimal Risk Level (MRL): The daily dose of a chemical that people could be exposed to for a specific period of time without experiencing adverse health effects. There should be no risk for developing non-cancer health effects at an exposure dose less than the MRL. If the MRL is exceeded, further evaluation is needed to determine if health effects may occur.

[5] Lowest Observed Adverse Effect Level (LOAEL): The lowest exposure level found in a study at which there are biologically significant increases in frequency or severity of adverse effects between the exposed population and its appropriate control group.

[6] Sample calculation to estimate arsenic short term exposure doses (mg/kg/day) for adult: $\frac{0.041\frac{mg}{L} \times \frac{2L}{day}}{70\ kg} = 0.001$; 1-6 yr old child: $\frac{0.041\frac{mg}{L} \times \frac{1L}{day}}{16\ kg}$ = 0.003; 0-1 yr old child: $\frac{0.041\frac{mg}{L} \times 1\frac{L}{day}}{10\ kg} = 0.004$

population was <20 years of age and the incidence of skin lesions increased as a function of age, and because the estimates of water intake and dietary arsenic intake are highly uncertain (ATSDR 2007). The NOAEL would be doubled (0.0016 mg/kg/day) by using the arsenic dietary intakes from rice and yams based on the food analyses conducted by Schoof et al (1998).

Discussion for EPA Groundwater Samples: Arsenic was detected in all groundwater samples. Twenty samples had arsenic concentrations that exceeded the ATSDR Environmental Media Evaluation Guidelines (EMEGs) of 11 ppb (0.011 mg/L). ADHS estimated the daily exposure dose for long term exposure for children and adults. The estimated values were compared to health guideline values (i.e. MRL) to determine if the groundwater users were at risk for non-cancer health effects. There should be no risk for developing non-cancer health effects at an exposure dose less than the MRL. If the MRL is exceeded, further evaluation is needed to determine if health effects may occur. There could be concern if the estimated exposure dose approaches the LOAEL[7]. Table 4-1 shows groundwater samples containing elevated levels of arsenic that may increase the chance of non-cancerous health effects (dermal toxicity) among the exposed population. Table 3 shows possible health effects due to exposure to contaminant levels detected in individual groundwater samples.

Discussion for ADEQ Public Drinking Water Samples: Eight samples were collected from 3/10/07 to 7/18/13. The detected concentrations of arsenic ranged from 3.8 ppb to 21.8 ppb. Six of the eight samples exceeded the ATSDR EMEG. Based on our analysis of the available data, the average concentration of the samples was 15 ppb, which was used in the evaluation. The same approach and exposure parameters were used to estimate the exposure doses, which were 0.0004 mg/kg/day for adults, 0.0009 mg/kg/day for 16-kg children, and 0.0014 mg/kg/day for 10-kg children. The estimated exposure doses for adults and children were at least an order of magnitude lower than the LOAEL of 0.014 mg/kg/day. Therefore, ADHS does not expect to see adverse noncancerous effects among the exposed population.

Cancerous Health Effects

Overview: Arsenic has been identified as a known human carcinogen. Ingestion of arsenic can increase the risk for developing cancer in the skin, lung, bladder, and to a less extent, kidney, liver and prostate (ATSDR 2007). EPA has calculated an oral cancer slope of 1.5 $(mg/kg/day)^{-1}$ (EPA 2012). ADHS conducted a cancer risk evaluation to determine if drinking the water in these wells over many years could result in an increased risk for cancer. A cancer risk is estimated by using EPA's cancer slope factor with the estimated exposure dose (Appendix B).

These calculated values may not represent actual risk, but allow regulatory and public health officials to identify potential cancer risks. Cancer risks are explained in terms of the likelihood that an additional case of cancer will occur in a population of a given size. For example, one

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[7] Sample calculation to estimate long term non-cancerous arsenic exposure doses (mg/kg/day) for adult: $\frac{0.041\frac{mg}{L}\times\frac{2L}{day}\times 350\frac{day}{yr}\times 30\ yr}{70\ kg\times 10950\ day} = 0.001$; 1-6 yr old child: $\frac{0.041\frac{mg}{L}\times\frac{1L}{day}\times 350\frac{day}{yr}\times 5\ yr}{16\ kg\times 1825\ day} = 0.002$; 0-1 yr old child: $\frac{0.041\frac{mg}{L}\times 1\frac{L}{day}\times 350\frac{day}{yr}\times 1\ yr}{10\ kg\times 365\ day} = 0.004$

additional cancer case in 1,000,000 exposed individuals indicates that there is a very low cancer risk. Cancer is a common illness, with many different forms that result from a variety of causes; not all are fatal. According to the American Cancer Society, men have almost a 1 in 2 lifetime risk of developing cancer, and for women the risk for developing cancer during their lifetimes is a little more than 1 in 3. This translates to about 500,000 men and a little more than 333,333 women in a population of one million people. Lifetime risk refers to the probability that an individual, over the course of a lifetime, will develop cancer. EPA has established a target excess lifetime cancer risk range of 1 in 1,000,000 to 10,000 (10^{-6} to 10^{-4}) for hazardous waste sites. For example, 10^{-4} excess lifetime cancer risk indicates that there can be one additional cancer case (due to the exposure to the contaminant) in 10,000 exposed individuals.

Discussion for EPA Groundwater Samples: ADHS conducted a cancer risk evaluation by using the measured arsenic concentrations and the EPA's standard cancer risk evaluation methodology. Table 4-2 shows the estimated additional cancer risks from consuming arsenic-contaminated groundwater for 30 years[8]. The estimated long-term cancer risks for 29 groundwater samples were more than 4 in 10,000, which is higher than EPA's target risk range (10^{-6} to 10^{-4}).

Discussion for ADEQ Public Drinking Water Samples: Based on the available data, the averaged arsenic concentration (15 ppb) was used in the estimation of cancer health risk. The estimated additional cancer risk from consuming arsenic-contaminated drinking water for 30 years was 2.6×10^{-4}. This value was more than 4 in 10,000; which is above EPA's target risk range.

Bromide:

Overview: Bromide is a naturally occurring element, and commonly exists as a soluble salt with either sodium or potassium. Bromide concentrations range from 65 mg/L to over 80 mg/L in sea water, and from trace amounts to about 0.5 mg/L in fresh water. In the US, people eat about 2–8 mg of bromide per day from grains, nuts, and fish. Bromide and chloride are always present in bodily fluid in animals and are excreted readily. Increased chloride intake will increase the excretion of bromide (WHO 2009).

The Joint Food and Agriculture Organization /World Health Organization (FAO/WHO) meeting on Pesticide Residues (JMPR) in 1996[9] recommended an acceptable daily intake of inorganic bromide of 0–1 mg/kg. This level was reaffirmed with new data in 1988, and in a subsequent second human study. An Average Daily Intake (ADI) of 0.4 mg/kg/day was derived based on a NOAEL (for marginal effect within normal limits of electroencephalograms in females at 9 mg/kg/day) of 4 mg/kg/day with a safety factor of 10 for population diversity (WHO 2009).

Discussion for EPA Groundwater Samples: The groundwater sample GW-999947 had the highest bromide concentration (4.1 mg/L). It exceeded the WHO Acceptable Daily Intake of 2 mg/L for children. The estimated exposure doses from consuming groundwater with the highest

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[8] Sample calculation to estimate arsenic exposure doses used for cancer risk calculation (mg/kg/day) :

$$\frac{0.041\frac{mg}{L}\times\frac{2L}{day}\times 350\frac{day}{yr}\times 30\,yr}{70\,kg\times 25550\,day} = 0.0005;\text{ excess lifetime cancer risk}= 0.0005\left(\frac{\frac{mg}{kg}}{day}\right)\times 1.5\,(\frac{\frac{mg}{kg}}{day})^{-1} = 7.2\times10^{-4}$$

[9] http://www.who.int/water_sanitation_health/dwq/chemicals/bromide.pdf

detected bromide concentrations are: 0.11 mg/kg/day for adults, 0.25 mg/kg/day for 16-kg children, and 0.39 mg/kg/day for 10-kg children[10]. The estimated daily intakes were below the ADI and NOAEL. Therefore, the detected bromide concentrations in groundwater well samples are not likely to result in adverse effects.

Lead:

Overview: The most common pathways through which people are exposed to lead are by breathing air, drinking water, eating foods, or swallowing dust or dirt contaminated with lead. Elevated blood lead levels (EBLLs) can cause serious, irreversible damage to the nervous system. Children's nervous systems are still developing and are more susceptible to long-term damage than adults'. In addition to cognitive side effects, lead exposure may cause weakness in fingers, wrists, or ankles, small increases in blood pressure, anemia, kidney damage, and seizures. Extremely high blood lead levels may cause miscarriages, can damage the organs responsible for sperm production, and ultimately may cause death (ATSDR 2007).

Lead-contaminated soil affects children ages 0-6 more than other age groups because young children are more likely to play in dirt and place their hands and other contaminated objects in their mouths. This age group is more likely to absorb lead through their gastrointestinal tract than adults and to exhibit the types of nutritional deficiencies, such as anemia, that facilitate the absorption of lead. The public health significance of childhood lead poisoning prevention has lead the EPA to develop an Integrated Exposure Uptake Biokinetic (IEUBK) model to estimate the blood lead levels in children exposed to environmental lead. It predicts the chance that a Blood Lead Level exceeds a level of interest. The IEUBK model is a mathematical model that estimates the percentage of children under the age of seven that exceed a specific blood lead level from environmental exposures. Further investigation is warranted when environmental lead concentrations from all sources result in more than a 5% chance of exceeding the CDC blood lead reference level (5 µg/dL).

The follow-up level for lead exposures differs for adults and children. Blood lead levels ≥ 10 µg/dL are considered elevated in adults, while blood lead levels ≥5 µg/dL are considered elevated in children. The reason that children have lower follow-up blood lead level than adults is because their brain and neural system are still developing. Therefore, having a lower screening level is more protective of health. On January 2012, the CDC's Advisory Committee on Childhood Lead Poisoning Prevention (ACCLPP) recommended that children with blood lead levels at or above 5 µg/dL be offered limited case management services, potentially including health education and possible environmental investigations, to mitigate the effects of lead exposure (CDC 2012a). CDC adopted this recommendation in 2012.

Discussion for EPA Groundwater Samples: The IEUBK model combines exposure assumptions (e.g., daily amount of water ingestion) along with physiologically based assumptions (e.g., the

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[10] Sample calculation to estimate long term non-cancerous bromide exposure doses (mg/kg/day) for adult: $\frac{4.1\frac{mg}{L}\times\frac{2L}{day}\times 350\frac{day}{yr}\times 30\ yr}{70\ kg\times 10950\ day} = 0.11$; 1-6 yr old child: $\frac{4.1\frac{mg}{L}\times\frac{1L}{day}\times 350\frac{day}{yr}\times 5\ yr}{16\ kg\times 1825\ day}$ = 0.25; 0-1 yr old child: $\frac{4.1\frac{mg}{L}\times 1\frac{L}{day}\times 350\frac{day}{yr}\times 1\ yr}{10\ kg\times 365\ day} = 0.39$

relationship between lead uptake and blood lead levels) to predict blood lead concentrations in young children exposed to lead from several sources and by several routes. ADHS ran the IEUBK model to predict the blood lead levels using a combination of EPA's default parameters and site-specific measurements, including individual groundwater results, air monitoring data and background soil concentration. Air monitoring data from Iron-King Mine, Humboldt-In-Town, Humboldt Smelter, and background stations were assigned to each resident based on their location. No residential-specific soil concentrations were available, so the highest area background concentrations (83 mg/kg) were used in the prediction. ADHS will reevaluate the blood lead level when individual lead levels in the yards of the persons with lead in the drinking water are available.

Using the above assumptions and the CDC reference value of 5 µg/dL, the predicted results showed that children who drink water from wells GW-999928 and GW-999953 may have elevated blood lead level above 5 µg/dL (Table 5).

Magnesium:

Overview: Magnesium is an essential element for good health. It is needed to maintain muscle and nerve function, keep heart rhythms steady, support the immune system, and keep bones strong (NIH 2012). People can get magnesium from a variety of foods, such as green vegetables, nuts, and whole grains. The recommended dietary allowances[11] (RDAs) are: 80 mg/day for 1-3 year old children, 130 mg/day for 3-8 year old children, 240 mg/day for 14-18 year old children, 420 mg/day for adult males, and 320 mg/day for adult females (IOM 1999).

There are no known health risks associated with dietary magnesium. However, eating too much magnesium in supplements can cause diarrhea and abdominal cramping. Mild diarrhea was observed in a small percentage of adults who eat about 360-365 mg of magnesium per day. The diarrheal incidence is generally higher in 1-3 year old children (NIH 2012, ECSCF 2001). The tolerable upper intake levels (UL) for supplemental magnesium are: 65 mg/day for 1-3 year old children, 110 mg/day for 4-8 year old children, and 350 mg/day for > 9 years old individuals (IOM 1999). Adverse health effects, such as hypotension or muscular weakness, can be seen in people who eat more than 2,500 mg magnesium per day (ECSCF 2001).

Discussion for EPA Groundwater Samples: For groundwater sample GW-999947[12], the estimated daily intake for 0-1 year old children (10-kg) was above the recommended UL. Therefore, children less than one year old may experience gastrointestinal discomfort if they consume water from sampling location GW-999947.

[11] Recommended Dietary Allowance (RDA): The average daily intake that is sufficient to meet the nutrient requirement of nearly all (97%-98%) healthy people.

[12] Sample calculation for magnesium exposure dose (mg/day): adults: $94.7 \left(\frac{mg}{L}\right) \times 2 \left(\frac{L}{day}\right) = 189.4$; 1-6 yr old child: $94.7 \left(\frac{mg}{L}\right) \times 1 \left(\frac{L}{day}\right) = 94.7$; 01- yr old child: $94.7 \left(\frac{mg}{L}\right) \times 1 \left(\frac{L}{day}\right) = 94.7$

Manganese:

Overview: Manganese is a naturally occurring element found in many types of rocks and soil. Persons living near a coal or oil-burning factory may be exposed to higher levels of manganese since it is released into air when fossil fuels are burned. Manganese can be found in groundwater as a result of its use in the production of batteries, pesticides, and fertilizers. The average level of manganese in drinking water ranges from 4 to 32 µg/L (ATSDR 2008).

Manganese is an essential element needed by the body in small amounts. Not eating enough manganese can lead to slow blood clotting, skin problems, changes in hair color, lowered cholesterol levels, and other alterations in metabolism. The WHO estimated the average daily intake ranges from 2 to 8.8 mg/L (WHO 1973). The Food and Nutrition Board of the National Research Council established the "Estimated Safe and Adequate Daily Dietary Intake" (ESADDI) of manganese ranges from 0.3 mg/day for infants to 5 mg/day for adults (NRC 1989). Manganese in food or water can enter our body through the digestive tract and most of it will leave the body in feces within a few days (ATSDR 2008).

For most people, food is the primary source of manganese exposure. The EPA estimated that the typical human intake of manganese from food is 3.8 mg/day (ATSDR 2008). The IOM set the tolerable upper intake levels for manganese from all sources, including food, water and supplements. These levels are 2-3 mg/L for 1-8 year old children, 6 mg/L for 9-13 year old children, 9 mg/L for 14-18 year old children and 11 mg/L for adults (IOM 2001). No upper intake level is set for infants due to lack of data on the adverse effects and concerns regarding their inability to handle an excess amount (IOM 2001). Children appear to be more susceptible to high levels of manganese, possibly because they have immature and developing organs, as well as a longer retention time of manganese in their bodies than adults (ATSDR 2008).

Exposure to high levels of manganese can be harmful to human health. The central nervous system is the primary target for toxicity. Kondakis (1989) showed a statistically significant difference in neurological test scores between people consuming well water containing high (1.8 to 2.3 mg/L) and low (< 0.25 mg/L) manganese. However, this study could not be used to establish a quantitative dose-response relationship for the toxicity due to other limitations. Kawamura et al. (1941) reported an outbreak of manganese-like symptoms in a group of six Japanese families exposed to a high level of manganese (14 mg/L) in their well water for about 2-3 months.

Discussion for EPA Groundwater Samples: EPA established a Reference Dose (RfD) of 0.14 mg/kg/day considering manganese from all sources. ADHS applied a modifying factor of 3 (i.e. 0.05 mg/kg/day) to evaluate the exposure from drinking water as recommended by EPA (EPA 2012). Using the reported concentrations, children may experience adverse health effects if they consume water from GW-999917 (0.05 mg/kg/day for 1− 6 years old children, and 0.08 mg/kg/day for 0 − 1 years old children)[13].

Nitrate as Nitrogen:

Overview: Nitrate is a naturally occurring inorganic ion, and is part of the nitrogen cycle. Nitrates (e.g. potassium nitrate and ammonium nitrate) are common ingredients in fertilizer. The most serious health concern caused by nitrate in drinking water is methemoglobinemia, or "blue-baby" syndrome. It is a condition where the blood cannot carry enough oxygen to body cells or tissues.

Infants, especially those under 4 months of age, are more susceptible to health effects from nitrate exposure due to underdeveloped digestive systems favoring the growth of nitrate-reducing bacteria. These bacteria can convert ingested nitrate (NO_3^-) to nitrites (NO_2^-). Nitrites can react with hemoglobin, the oxygen carrier in the blood found in red blood cells, to form methemoglobin (an abnormal form of hemoglobin incapable of carrying oxygen) (ATSDR 2011). Oxygen deficiency can cause the baby to look blue, slate-grey, or chocolate brown (cyanosis) because there is too much methemoglobin (10-20% of total hemoglobin) in the blood. Other adverse reactions include labored breathing, headache, dizziness, nausea, vomiting, and diarrhea at methemoglobin levels between 20-45% of total hemoglobin. If concentrations of methemoglobin increase even further (45-55% of total hemoglobin), irregular heartbeat, shock, convulsions, or coma may result. At methemoglobin levels greater than 70%, death may result. Little is known about possible long-term health effects of drinking water with elevated nitrate levels. Some studies suggested that nitrate may play a role in thyroid disorders and birth defects (ATSDR 2007).

Most adults and older children (> 6 months) will not be affected by nitrate because their red blood cells will quickly convert back to normal. However, some people may have conditions that make them more susceptible to elevated levels of nitrate in drinking water. They include: (1) individuals who do not have enough stomach acids, which promotes the conversion of nitrates to nitrites; (2) individuals with an inherited lack of methemoglobin reductase (enzyme that converts affected red blood cells back to normal) or an abnormal hemoglobin molecule as in hemoglobin M; and (3) pregnant women around the 30th week of pregnancy because their methemoglobin level naturally increases (ATSDR 2007, EPA 2012).

Discussion for EPA Groundwater Samples: The EPA RfD of 1.6 mg/kg/day is based on various studies of infant methemoglobinemia. It was derived from the NOAEL of 10 mg/L (1.6 mg/kg/day) with an uncertainty factor of one (1). EPA also determined the LOAEL to be 11-20

[13] Sample calculation to estimate long term non-cancerous manganese exposure doses (mg/kg/day) for adult: $\frac{0.84\frac{mg}{L}\times\frac{2L}{day}\times 350\frac{day}{yr}\times 30\,yr}{70\,kg\times 10950\,day} = 0.023$; 1-6 yr old child: $\frac{0.84\frac{mg}{L}\times\frac{1L}{day}\times 350\frac{day}{yr}\times 5\,yr}{16\,kg\times 1825\,day}$ = 0.05; 0-1 yr old child: $\frac{0.84\frac{mg}{L}\times 1\frac{L}{day}\times 350\frac{day}{yr}\times 1\,yr}{10\,kg\times 365\,day} = 0.08$

mg/L (1.8-3.2 mg/kg/day). Two groundwater samples (GW-999953 and GW-999947) had nitrate levels above the CV. Results from the estimated daily intakes[14] showed that:

1) Infants less than 12 months old may experience adverse health effects if they consume the water. The estimated exposure doses are 4.3 mg/kg/day and 5.7 mg/kg/day for GW-999953 and GW-999947, respectively.
2) Children (1-6 years old) may experience adverse health effects if they consume the water. The estimated exposure doses are 2.7 mg/kg/day and 3.5 mg/kg/day for GW-999953 and GW-999947, respectively; and
3) Healthy adults and older children are not likely to experience adverse effects if they consume the water. The estimated exposure doses are 1.2 mg/kg/day and 1.6 mg/kg/day for GW-999953 and GW-999947, respectively.

Discussion for ADEQ Public Drinking Water Samples: Eighteen (18) samples were collected from 4/25/06 to 7/18/13. The detected concentrations ranged from 3.97 mg/L to 11.4 mg/L. Two out of the 18 samples exceeded the MCL of 10 mg/L. The average concentration of the samples was 6.31 mg/L, which were used in the evaluation. Since the average nitrate concentration was below the MCL, ADHS does not expect to see adverse effects among people using the public drinking water for domestic purposes.

Sulfate:

Overview: Sulfate is found in the natural waters. Previous studies showed the sulfate concentration in seawater is about 2,700 mg/L (Hitchcock 1975), and ranges from 3 to 30 mg/L in freshwater lakes (Katz 1977). There is no RfD or chronic MRL set for sulfate since it is not associated with chronic disease or cancer risks.

The EPA established a secondary drinking water standard of 250 mg/L for sulfate based on the unpleasant taste and odor. The secondary standards are not enforceable by the federal government (EPA 1999, EPA 2003). The health concern associated with exposure to sulfate is a laxative effect (i.e. soft stool or diarrhea), and this effect only occurs at concentrations > 500 mg/L; therefore, EPA established a health advisory of 500 mg/L for acute exposure (EPA 1999, EPA 2003). Chronic exposure to sulfate may not have the same laxative effect as an acute exposure because humans may develop a tolerance to high sulfate concentration in drinking water (Schofield and Hsieh 1983).

Discussion for EPA Groundwater Samples: Groundwater samples GW-999947 and GW-999914 contain 4,700 mg/L and 1,100 mg/L of sulfate, respectively. Residents may experience unpleasant taste and laxative effects if they consume water from the sampling locations. Water from these locations should not be used to prepare formula since infants are more susceptible to diarrheal water loss than adults due to differences in gastrointestinal structure and function (EPA

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[14] Sample calculation to estimate long term non-cancerous exposure nitrate as nitrogen doses (mg/kg/day) for adult: $\frac{45\,\frac{mg}{L}\times\frac{2L}{day}\times 350\frac{day}{yr}\times 30\,yr}{70\,kg\times 10950\,day} = 1.2$; 1-6 yr old child: $\frac{45\,\frac{mg}{L}\times\frac{1L}{day}\times 350\frac{day}{yr}\times 5\,yr}{16\,kg\times 1825\,day}$ = 2.7; 0-1 yr old child: $\frac{45\,\frac{mg}{L}\times 1\frac{L}{day}\times 350\frac{day}{yr}\times 1\,yr}{10\,kg\times 365\,day} = 4.3$

2003). The use of an alternate low-mineral-content water source is recommended for preparing infant formula or powdered nutritional supplements.

Total Dissolved Solids:

Overview: Total dissolved solids (TDS) are the inorganic salts or organic matter in water that cannot be removed by a traditional filter. The major components are calcium, magnesium, sodium, potassium, carbonate, hydrogen carbonate, chloride, sulfate, and nitrate anions. The taste of water is affected by the level of TDS. Water containing TDS concentrations less than 1,000 mg/L is usually acceptable to consumers (WHO 1996).

Discussion EPA Groundwater Samples: TDS can give water a murky appearance and detract from the taste quality of the water. EPA established a secondary MCL (SMCL) of 500 mg/L for TDS for aesthetic or cosmetic quality of the water. Groundwater samples containing TDS concentrations above the SMCL (GW-999953, GW-999949, GW-999947, and GW-999945) may affect the taste of water, and result in excessive scaling in water pipes, water heaters, and boilers, but is not expected to result in adverse health effects.

Cumulative Exposures

Multiple Chemical Exposures through Water Exposure: Provide an evaluation of the combined risks due to exposure to multiple chemicals at the same time.

Noncancerous Health Effects:

Overview: Additivity is the default assumption for evaluating health effects of simultaneous exposure to multiple chemicals (i.e. the combined toxic effect of multiple chemicals is the same as the sum of the individual toxic effects). However, sometimes the joint (combined) toxic effect can be greater than the sum of the individual toxic effects. For example, the joint toxic effects on the neurological system due to exposure to a mixture of lead and arsenic mixture are greater than the additive for the effect of arsenic and lead. ATSDR (2004) provides guidance on evaluating the joint toxic effects from arsenic, cadmium, chromium, and lead.

The critical adverse health effects[15] of exposure to these individual compounds are the endpoints of concern, which include neurological, dermal, renal, cardiovascular, hematological, testicular, and carcinogenic effects. Studies showed that the impacts of interactions are greater than additive for neurological and testicular effects, and lower than additive for renal and hematological effects. Interactions of the mixture have little impact on the additive of the cardiovascular end-point specific toxicity. Interactions of the mixture on the dermal toxicity cannot be determined (ATSDR 2004).

[15] The critical effect is the first adverse effect that occurs when the threshold concentration is reached at the most sensitive organ under the specified exposure conditions and for a given population.

According to the ATSDR guidance, no further assessment of joint toxic action is needed if only one or none of the metals have a hazard quotient (HQ)[16] at or above 0.1 because additivity and/or interactions are not likely to result in a significant health hazard (ATSDR 2004). Therefore, cumulative exposure evaluation was conducted only for EPA groundwater samples. Multiple chemical exposure was not evaluated for ADEQ public drinking water samples.

Discussion for EPA Groundwater Samples:

ADHS calculated the HQs of critical health effects for arsenic, lead, cadmium and chromium. Fifty-three groundwater samples were tested and 30 out of 53 groundwater samples contained both arsenic and lead. The HQs of critical health effects for arsenic and lead exceeded 0.1 in the following 29 groundwater samples[17].

GW-999953	GW-999952	GW-999951	GW-999950	GW-999949	GW-999947	GW-999946	GW-999945
GW-999941	GW-999940	GW-999939	GW-999938	GW-999937	GW-999936	GW-999935	GW-999934
GW-999933	GW-999932	GW-999931	GW-999930	GW-999929	GW-999928	GW-999926	GW-999923
GW-999921	GW-999916	GW-999907	GW-999904	GW-573389			

The HQs of critical health effect of cadmium exceeded 0.1 in 1 of 7 groundwater samples detected (53 samples were tested): GW-999947.

The HQs of critical heath effect of chromium exceeded 0.1 in 10 of 30 groundwater samples detected (53 samples were tested).

GW-999947	GW-999946	GW-999939	GW-999936	GW-999935	GW-999928	GW-999922	GW-999917
GW-999910	GW-586144						

Neurological Effects: Neurological effects are common endpoints to lead, arsenic, cadmium and chromium (VI) exposure. Studies show that neurological toxicity is greater than additive for lead on arsenic, arsenic on lead, cadmium on lead, and chromium on arsenic; and less than additive for arsenic on chromium (VI). The combined results indicated that the potential health hazard may be greater than estimated by the endpoint-specific hazard index for neurological effects (ATSDR 2004).

ADHS calculated the endpoint hazard index (HI)[18] of neurological effects for children.

[16] Hazardous Quotient (HQ) is the ratio of the exposure estimate to an effects concentration (e.g. reference dose or reference concentration). A HQ value of 1 or less than 1 indicates that no adverse health effects (noncancer) are expected to occur.
[17] Blood lead concentration of 5 µg/dL was used in the calculation
[18] Sum of the hazard quotients for substances that affect the same target organ or organ system.

For 16-kg children (1-6 year old), the HI for neurotoxicity exceeded 1[19] in 27 of 53 groundwater tested.

GW-999953	GW-999952	GW-999951	GW-999950	GW-999949	GW-999947	GW-999946	GW-999945
GW-999941	GW-999940	GW-999939	GW-999938	GW-999937	GW-999936	GW-999935	GW-999934
GW-999933	GW-999932	GW-999931	GW-999930	GW-999928	GW-999926	GW-999923	GW-999916
GW-999907	GW-999904	GW-573389					

For 10-kg children (0-1 year old), the HI for neurotoxicity exceeded 1[20] in 29 of 53 groundwater tested

GW-999953	GW-999952	GW-999951	GW-999950	GW-999949	GW-999947	GW-999946	GW-999945
GW-999941	GW-999940	GW-999939	GW-999938	GW-999937	GW-999936	GW-999935	GW-999934
GW-999933	GW-999932	GW-999931	GW-999930	GW-999929	GW-999928	GW-999926	GW-999923
GW-999921	GW-999916	GW-999907	GW-999904	GW-573389			

Therefore, children may experience greater neurological toxicity (such as maladaptive classroom behavior, decreased reading and spelling performance) than additive due to the joint toxic action of exposure to lead and arsenic in the wells listed above.

Testicular Effects: The potential health effects can be higher than additive when the mixture contains high levels of cadmium and lead. Lead can cause the production of abnormal sperm and a reduction of total sperm count. Cadmium can cause damage on the seminferous tubule, increased testes weight, and decreased sperm count and motility (ATSDR 1999). There is one groundwater sample containing both lead and cadmium: GW-999947. The endpoint-specific HQs for cadmium exposures were below or equal to 0.1. Therefore, ADHS determined that interactions of lead and cadmium have little impact on the additivity of the testicular end-point specific toxicity.

ADHS calculated the endpoint hazard index (HI) of testicular effects for adults and children who consume water from GW-999947. The estimated HIs were: 0.13 for adults and 16-kg children, and 0.14 for 10-kg children. Therefore, residents are not expected to experience adverse testicular effects due to the exposure to cadmium and lead.

Cancerous Health Effects:

[19] Blood lead concentration of 5 µg/dL was used in the calculation
[20] Blood lead concentration of 5 µg/dL was used in the calculation

Overview: ADHS assumes that carcinogenic health effects are additive because no data are available regarding the effects of the mixture components on arsenic carcinogenicity (ATSDR 2004). Some information suggests that the effect of chromium (VI) on arsenic carcinogenicity may be greater than additive, but confidence in this assessment was low (ATSDR 2004).

Discussion for EPA Groundwater Samples: ADHS considered cumulative cancer risk from multiple chemicals. However, ADHS noted that the detected concentrations of chromium are very low; therefore, additive cancer effects are not expected. As a result, chromium (VI) was not considered in the cumulative cancer risk calculations. Essentially, the estimated cumulative cancer risk is equal to (the same as) the arsenic cancer risk.

ATSDR Child Health Concern

ATSDR recognizes that the unique vulnerabilities of infants and children demand special emphasis in communities faced with contaminants in environmental media. A child's developing body systems can sustain permanent damage if toxic exposures occur during critical growth stages. Children ingest a larger amount of water relative to body weight, resulting in a higher burden of pollutants. Furthermore, children often engage in vigorous outdoor activities, making them more sensitive to pollution than healthy adults. All health analyses in this report take into consideration the unique vulnerability of children.

Conclusions

This health consultation evaluated the health risks associated with exposure to contaminants in groundwater samples collected by EPA, and public drinking water samples collected by ADEQ. The EPA groundwater samples comprise public drinking water supply wells, private drinking water wells, monitoring wells, water near an old mine shaft, groundwater within the tailings, and an old drinking water well (no longer in use). The ADEQ public drinking water samples were not collected directly from the public drinking water supply wells; rather, they were collected after processing and storage in the water plant but before the first customer at the entry point to the distribution system.

In this health consultation, ADHS evaluated the potential public health impacts associated with the wells that can be potentially used for domestic purposes because the complete well usage information is not available. For groundwater samples in the EPA RI/FS report, due to the limited amount of data available (one sample was collected from each well location/household), ADHS conducted this evaluation assuming the concentrations detected would remain at these levels (i.e. chemical concentrations do not change over time). For blood lead concentration estimation, ADHS used air monitoring data from Iron-King Mine, Humboldt-In-Town, Humboldt Smelter, and background stations based on the groundwater sampling location. No residential-specific soil concentrations were available, so the highest detected background concentrations were used in the prediction Therefore, the true exposure levels may be over- or under-estimated. Based on the available information, ADHS reached the following conclusions regarding current and potential future exposure to groundwater and public drinking water in the study area:

Exposure to ADEQ Public Drinking Water Samples:

- *Past Exposure (before 2015): Exposure to public drinking water could harm the health of adults and children*. The detected arsenic concentrations ranged from 3.8 ppb to 21.8 ppb. Six out of the eight samples exceeded the MCL of 10 ppb. The average concentration of the samples was 15 ppb, which was used in the evaluation. The conclusion was reached because the estimated cancer risk due to arsenic exposure (2.6×10^{-4}) exceeded EPA's upper target cancer risk range value of 10^{-4}. That means that there will about 3 additional cancer cases in 10,000 exposed individuals.

- *Current Exposure (after 2015): Exposure to public drinking water is not expected to harm the health of adults and children.* The Humboldt Public Water System (PWS) has installed an arsenic treatment system and has received the required approval from ADEQ in 2015. The water currently meets the arsenic standard and the PWS is in compliance with the standard.

Exposure to EPA Groundwater Samples:

- *Arsenic: Exposure to arsenic in some wells could harm the health of adults and children.* This conclusion was reached because the estimated non-cancerous health hazard for 17 wells were associated with increased chances of developing noncancerous health effects among children (see Table 4-1). In addition, the estimated cancer risks for 29 of the wells exceeded EPA upper target cancer risk range value of 10^{-4} (see Table 4-2).
- *Bromide: Exposure to bromide in groundwater wells will not harm the health of adults and children.* The conclusion was reached because the estimated daily intakes for adults and children were below the acceptable Average Daily Intake (ADI).
- *Lead: Exposure to lead in groundwater wells: GW-999928 and GW-999953 could harm the health of children*. This conclusion was reached because, based on the IEUBK model prediction, children who drink the water will have equal or greater than 5% chance to exceed the blood lead reference level of 5 µg/dL.
- *Magnesium: Exposure to magnesium in groundwater well: GW-999947 could harm the health of 0-1 year old children*. This conclusion was reached because the estimated daily intake exceeded the recommended upper intake level.
- *Manganese: Exposure to manganese in groundwater well: GW-999917 could harm the health of children.* This conclusion was reached because the estimated non-cancerous health hazard was associated with increased chances of developing noncancerous health effects.
- *Nitrate as Nitrogen: Exposure to nitrate in groundwater wells: GW-999953 and GW-999947 could harm the health of children.* This conclusion was reached because the estimated exposure doses were associated with increased chance of developing methoglobinemia.
- *Sulfate: Exposure to sulfate in groundwater wells: GW-999947 and GW-999914 could harm the health of adults and children*. This conclusion was reached because the

measured concentrations exceeded the concentration (>500 mg/L) associated with laxative effects, especially for infants since they are more susceptible to diarrheal water loss than adults.

- *Total Dissolved Solids (TDS)*: *Exposure to TDS in groundwater wells will not harm the health of adults and children*. High levels of TDS measured in groundwater wells (GW-999953, GW-999949, GW-999947, and GW-999945) may affect the taste of water, and result in excessive scaling in water pipes.

- *Exposure to multiple chemicals in the groundwater samples is not expected to increase the overall additional cancer risk.* This conclusion was reached because the detected concentrations of chromium are very low; therefore, additive cancer effects are not expected. As a result, chromium (VI) was not considered in the cumulative cancer risk calculations. Essentially, the estimated cumulative cancer risk is equal to the arsenic cancer risk.

Recommendations

- For groundwater wells containing arsenic above the Maximum Contaminant Level (MCL) of 10 ppb (parts per billion): Residents are advised to have a treatment system installed that can effectively remove arsenic. Meanwhile, residents are advised to use an alternative water source, such as bottled water, for drinking and cooking.
- All residents in the Dewey-Humboldt area are advised to have their well water tested for metals, bacteria, and nitrates promptly after a new groundwater well is drilled. If any parameter is found to be above the recommended levels, a confirmation sample needs to be collected before making any decisions regarding water treatment.
- All residents in the Dewey-Humboldt area who use private well water for drinking or cooking are advised to have their well water tested yearly for bacteria and nitrates, and every 5 years for chronic contaminants including arsenic, radon, uranium, lead, and copper. If any parameter is found to be above the recommended levels, a confirmation sample needs to be collected before making any decisions regarding water treatment.
- Children living in Dewey-Humboldt should receive an individual risk assessment from their physician to determine if they are at an increased risk for lead poisoning. Parents are encouraged to contact their physician to discuss whether there is a need for a blood test.
- Residents are encouraged to attend public meetings and public education activities to obtain more information on ways to minimize the amount of exposure to the contaminants.

Public Health Action Plan

- ADHS attended public meetings to discuss the process of preparing health consultations and community concerns. ADHS will continue to attend additional public meetings, make presentations, develop handout literature, and engage in other actions to notify the property owners and residents in the area of the findings of this health consultation.

- ADHS will notify EPA and ADEQ regarding the findings of this report and work with both agencies to evaluate the protectiveness of remedial action plans.

  On December 11, 2013 ADEQ Water Quality Enforcement Unit issued Consent Order DW-41-12 requiring Humboldt Water Systems, Inc. PWS #AZ0413052 to submit to ADEQ an administratively complete application for an Approval to Construct (ATC) for a treatment system using best available technology (BAT) or other approved method, including a blending plan, to achieve compliance with the MCL for nitrate and arsenic. On July 10, 2015, ADEQ inspector confirmed that the arsenic and nitrate treatment systems have been constructed. ADEQ terminated the Approval of Construction (AOC) in late November 2015. The treatment systems were installed and are in compliance[21].

- ADHS will continue to review and evaluate data provided for this site.

References/Information Sources

Arizona Administrative Code (AAC) (2004). Available at: http://www.azsos.gov/public_services/Table_of_Contents.htm. Last Access: 3/4/2013

Agency for Toxic Substances and Disease Registry (ATSDR) (2007). Toxicological profile for arsenic. ATSDR, Department of Health and Human Services.

Agency for Toxic Substances and Disease Registry (ATSDR) (2004). Interaction profile for arsenic, cadmium, chromium and lead. ATSDR, Department of Health and Human Services

Agency for Toxic Substances and Disease Registry (ATSDR) (2004). Interaction profile for cobalt. ATSDR, Department of Health and Human Services

Agency for Toxic Substances and Disease Registry (ATSDR) (2007). Toxicological profile for lead, update. ATSDR, Department of Health and Human Services.

Agency for Toxic Substances and Disease Registry (ATSDR) (2008). Toxicological profile for manganese. ATSDR, Department of Health and Human Services.

Agency for Toxic Substances and Disease Registry (ATSDR) (2011). ToxFAQs for Nitrate and Nitrites. Available at: http://www.atsdr.cdc.gov/toxfaqs/tf.asp?id=1186&tid=258 Last accessed: 5/30/12.

Agency for Toxic Substances and Disease Registry. 2001. Case study in environmental medicine. Nitrate/Nitrite Toxicity. Atlanta: U.S. Department of Health and Human Services. Available at: http://www.atsdr.cdc.gov/csem/csem.asp?csem=9&po=4. Last accessed: 5/30/12.

Agency for Toxic Substances and Disease Registry (ATSDR) (2005). Toxicological profile for zinc. ATSDR, Department of Health and Human Services.

Agency for Toxic Substances and Disease Registry (ATSDR) (2005). Public Health Guidance Manual (Update), Department of Health and Human Services.

Center for Disease Control and Prevention (CDC) (2012 a). Low level lead exposure harms children: a renewed call for primary prevention. Report of the Advisory Committee on Childhood Lead Poisoning Prevention. 2012 January 4

Center for Disease Control and Prevention (CDC) (2012 b). CDC Response to Advisory Committee on Childhood Lead Poisoning Prevention Recommendations in “Low Level Lead Exposure Harms Children: A Renewed Call of Primary Prevention”. 2012 May 16

[21] http://www.dhaz.gov/images/stories/pdfs/newsletters/2016/April_2016_Issue.pdf

Corbett JV. (1995) Accidental poisoning with iron supplements. MCN Am J Matern Child Nurs 20:234

Davis JE and Fields JP. 1958. Experimental production of polycythemia in humans by administration of cobalt chloride. Proc Soc Exp Biol Med 99:493-495

EA Engineering, Science, and Technology, Inc. (2010) Remediation Investigation Report (Revision 01): Iron King Mine-Humboldt Smelter Superfund Site Remedial Investigation/Feasibility Study.

European Commission. Scientific Committee on Food. (2001) Opinion on the Scientific Committee on Food on the Tolerable Upper Intake Level of Magnesium. Available at: http://ec.europa.eu/food/fs/sc/scf/out105_en.pdf. Last Access: 5/21/12

Hathcock JN. (2004). Vitamin and Mineral Safety. 2nd Edition. Council for Responsible Nutrition (CRN).

U.S. Department of Health and Human Services. Hazardous Substances Data Bank (HSDB, online database). National Toxicology Information Program, National Library of Medicine, Bethesda, MD. 1993

Institute of Medicine. Food and Nutrition Board. (1999) Dietary Reference Intakes: Calcium, Phosphorus, Magnesium, Vitamin D and Fluoride. National Academy Press. Washington, DC.

Institute of Medicine. Food and Nutrition Board. (2001) Dietary Reference Intakes for vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium and zinc. National Academy Press. Washington, DC.

Kawamura, C.L., H. Ikuta, S. Fukuzimi, R. Yamada, S. Tsubaki, T. Kodama, and S. Kurata. (1941). Intoxication by manganese in well water. Kitasato Arch. Exp. Med. 18:145-169.

Kondakis XG, Makris N, Leotsinidis M, Prinou M, and Papapetropoulos T. 1989. Possible Health Effects of High Manganese Concentration in Drinking Water. Archives of Environmental Health, 44(3): 175-178

Mizuta, N et al. (1956). An Outbreak of Acute Arsenic Poisoning Caused by ArsenicContaining Soy Sauce (Shoyu). A Clinical Report of 220 Cases. Bull Yamaguchi Med Sch 4(2-3):131-149. MRID 45496803

National Institute of Health (NIH). Office of Dietary Supplement. 2012. Dietary Supplement Fact Sheet: Magnesium. Available at: http://ods.od.nih.gov/factsheets/Magnesium-HealthProfessional/#en4 Last Access: 5/31/12

NRC (National Research Council). 1989. Recommended Dietary Allowances, 10th ed. Food and Nutrition Board, National Research Council, National Academy Press, Washington, DC. P. 230-235

Russ Radden (2005). Arsenic in Yavapai County Ground Water: Challenges and Solutions.

U.S. EPA. 1999. Health Effects From Exposure to High Levels of Sulfate in Drinking Water

Study. Office of Water, Washington, DC. EPA 815-R-99-001

U.S. EPA. 2003. Drinking Water Advisory: Consumer Acceptability Advice and Health Effects Analysis on Sulfate. Office of Water, Washington, DC. EPA 822-R-03-007

US Environmental Protection Agency (EPA). Integrated Risk Information System (IRIS). Available at: http://www.epa.gov/iris/index.html. Last updated: Last accessed: June 8, 2012

WHO (World Health Organization). 1973. Trace Elements in Human Nutrition: Manganese. Report of a WHO Expert Committee. Technical Report Service, 532, WHO, Geneva, Switzerland. P. 34-36

WHO (World Health Organization). 2009. Bromide in Drinking Water: background document for development of WHO guidelines for drinking water quality. WHO/HSE/WSH/09.01/6 WHO, Geneva, Switzerland.

WHO (World Health Organization). 1996. Total Dissolved Solids in Drinking Water: background document for development of WHO guidelines for drinking water quality. WHO/SDE/WSH/03.04/16 WHO, Geneva, Switzerland.

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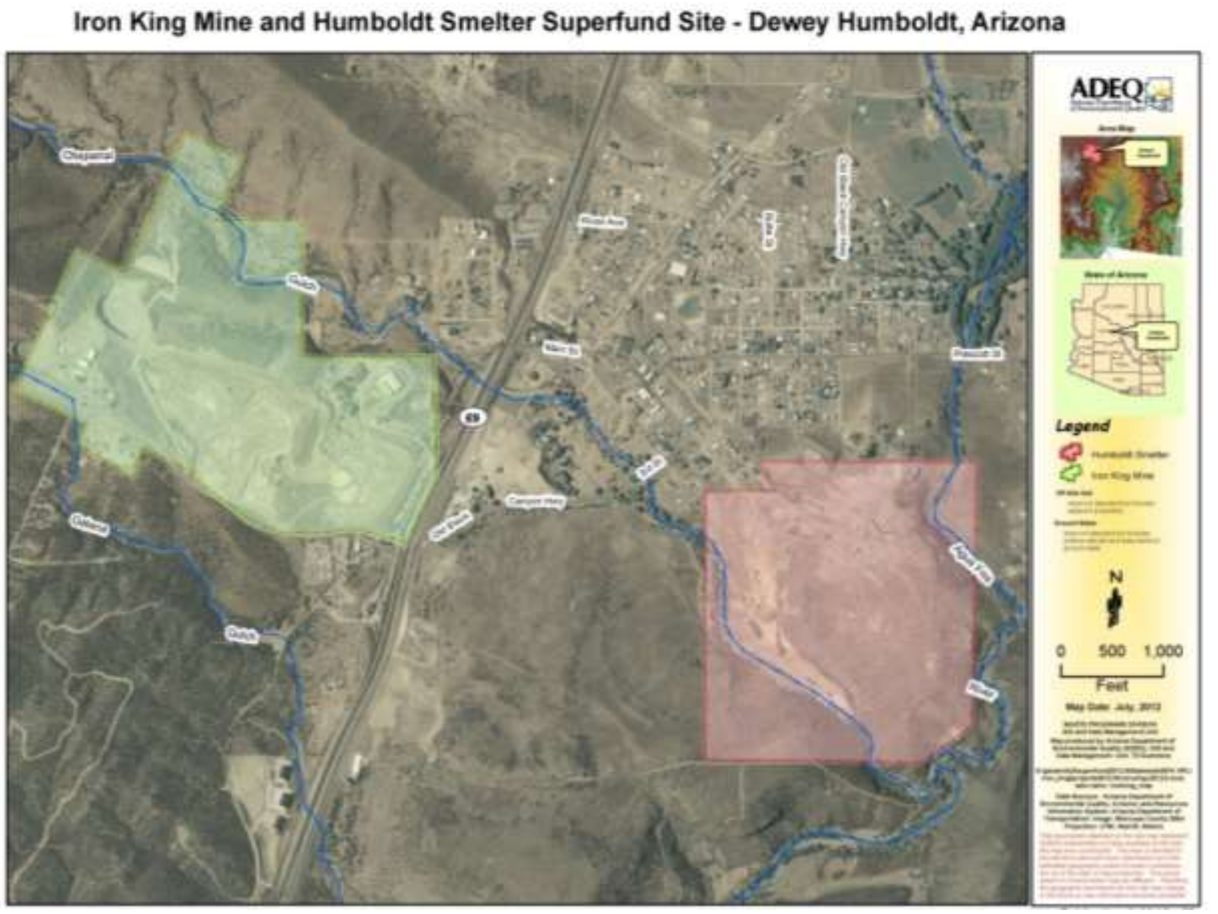

Figure 1. Site Map[22]. The Iron King Mine is about 153 acres, approximately ¼ miles west of Humboldt, AZ. The Humboldt Smelter is about 182 acres and situated along the eastern site of the town.

[22] The map is adapted from ADEQ's website: http://www.azdeq.gov/environ/waste/sps/download/state/ironking_map.pdf.

TABLES

Table 1. Exposure Pathways Analysis

Exposure Pathway Elements					Time frame	Type of Exposure Pathway
Source	Media	Point of exposure	Route of exposure	Potentially exposed population		
Contaminated soil/Mine tailing	Air	Ambient Air	Inhalation	Residents/ Visitors	Past	Completed
					Current	Completed
					Future	Potential
	Groundwater	Residences, tap	Ingestion	Residents/ Visitors	Past	Completed
					Current	Completed
					Future	Potential
	Soil	Residences	Incidental ingestion, skin contact	Residents/ Visitors	Past	Completed
					Current	Completed
					Future	Potential

This health consultation evaluated the exposure to groundwater. ADHS evaluated health risk associated with the exposure to each individual groundwater sample. For cumulative health risk, all exposure pathways were considered.

Table 2-1. Summary of the measured chemical concentrations in EPA groundwater samples.

Chemical	Detected Frequency	Minimum Detected Concentration (µg/L)	Maximum Detected Concentration (µg/L)	Comparison Value (CV) for noncancer health effects (µg/L)	Source of CV	Number of Wells Exceeds CV	Is it a Chemical of Potential Concern?
aluminum	7/53	17.9	79.9	16,000 35,000	RSL[1] EMEG-c[2]	0	No
antimony	6/53	0.089	2	6	MCL[3]	0	No
arsenic	53/53	1.2	41	10 11	MCL EMEG-c	20	**Yes**
barium	41/53	10.8	200	2,000 7,000	MCL EMEG-c	0	No
bromide	6/53	120	4,100	2,000	ADI[4]	2	**Yes**
cadmium	6/53	0.02	0.61	5	MCL	0	No
calcium	53/53	4,000	404,000	1,000,000	ULDRI[5]	0	No
chloride	7/53	16,000	1,000,000	1,800,000	ULDRI	0	No
chromium	30/53	0.069	19.2	100 (total Cr) 32 ($Cr\ 6^{+}$)	MCL EMEG-c	0	No
cobalt	19/53	0.089	3.6	4.7 350	RSL EMEG-m[6]	0	No
copper	48/53	2.2	334	1,300 350	MCL EMEG-m	0	No
cyanide	7/53	1.4	9.9	200 21	MCL RMEG[7]	0	No
fluoride	7/53	150	920	4,000	MCL	0	No
iron	33/53	7.3	5,980	11,000	RSL	0	No
lead	29/53	0.18	49.8	15	MCL	1	**Yes**
magnesium	53/53	1,110	94,700	65,000	ULDRI	1	**Yes**
manganese	37/53	0.092	835	320 1,800	RSL RMEG	1	**Yes**
mercury	5/53	0.018	1.3	2 11	MCL RMEG	0	No
nickel	46/53	0.6	15.5	300 700	RSL RMEG	0	No
nitrate As N	11/53	600	59,000	10,000 16,000	MCL RMEG	2	**Yes**
perchlorate	3/53	1.9	3.3	11 25	RSL EMEG-c	0	No
potassium	50/53	666	52,400	2,350,000	RLDRI[8]	0	No
selenium	28/53	0.29	24.1	50 180	MCL EMEG-c	0	No
silver	2/53	0.11	0.29	71 180	RSL RMEG	0	No
sodium	53/53	16,400	279,000	1,150,000	DRI	0	No
sulfate	11/53	13,000	1,100,000	500,000	HA[9]	1	**Yes**

Chemical	Detected Frequency	Minimum Detected Concentration (µg/L)	Maximum Detected Concentration (µg/L)	Comparison Value (CV) for noncancer health effects (µg/L)	Source of CV	Number of Wells Exceeds CV	Is it a Chemical of Potential Concern?
thallium	02/53	0.02	0.027	2	MCL	0	No
toluene	0/53	0	0	1,000 700	MCL EMEG-m	0	No
TDS[10]	7/53	330,000	3,000,000	500,000	SMCL[11]	5	**Yes**
vanadium	52/53	1.8	17.2	78 350	RSL EMEG-m	0	No
zinc	53/53	5.7	4,310	4,700 11,000	RSL EMEG-c	0	No

1. RSL: EPA Regional Screen Level
2. EMEG-c: ATSDR Environmental Media Evaluation Guide-chronic exposure
3. MCL: EPA Maximum Contaminant Level
4. ADI: World Health Organization (WHO) Acceptable Daily Intake for bromide (WHO 2009)
5. ULDRI: Institute Of Medicine (IOM) Dietary Reference Intake: Tolerable Upper Intake Levels (IOM 2010)
6. EMEG-m: ATSDR Environmental Media Evaluation Guide-intermediate exposure
7. RMEG: ATDSR Reference Dose Media Evaluation Guide
8. RLDRI: Institute Of Medicine (IOM) Dietary Reference Intake: Recommended Intake Level (IOM 2010)
9. HA: EPA Drinking Water Health Advisory
10. TDS: Total Dissolved Solids
11. SMCL: EPA Secondary Maximum Contaminant Level

Table 2-2. Summary of the measured chemical concentrations in public drinking water samples. The samples were collected from 2007 to 2013. The water samples were not collected directly from the municipal supply wells. They were collected after processing and storage in the water plant but before the first customer at the entry point to the distribution system (EPDS).

Chemical	Detected Frequency	Minimum Detected Concentration (µg/L)	Maximum Detected Concentration (µg/L)	Average of Detected Concentration (µg/L)	CV for noncancer health effects (µg/L)	Source of CV	Number of Wells Exceeds CV	Is it a Chemical of Potential Concern?
arsenic	8/8	3.8	21.8	15.5	10 11	MCL[1] EMEG-c[2]	6	**Yes**
nitrate as N	18/18	3,970	11,400	6,310	10,000 16,000	MCL RMEG[3]	2	No

1. EMEG-c: ATSDR Environmental Media Evaluation Guide-chronic exposure
2. MCL: EPA Maximum Contaminant Level
3. RMEG: ATDSR Reference Dose Media Evaluation Guide for child

Table 3. Summary of possible health concerns for the groundwater samples containing elevated chemical concentration(s). Children may experience greater than expected neurological effects if the groundwater sample contains more than one of the following chemicals: lead, arsenic, cadmium & chromium (VI). Estimated cancer risks exceeded the upper bound of EPA's target risk (10^{-4}) are in bold fonts.

	Potential non-cancerous health concerns		Contaminants of concern for non-cancerous health effects	Estimated Cancer Risk due to exposure to arsenic in groundwater samples[1]
GW-999953	Adults	—	—	**1.1×10^{-4}**
	Children (1 - 6 yrs)	blood lead level > 5 μg/dL, methemoglobinemia	lead, nitrates	
	Infants (up to 1 yr)	blood lead level > 5 μg/dL, methemoglobinemia	lead, nitrates	
GW-999952	Adults	—	—	**3.0×10^{-4}**
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	skin	arsenic	
GW-999951	Adults	—	—	6.7×10^{-5}
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	—	—	
GW-999950	Adults	—	—	8.1×10^{-5}
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	—	—	
GW-999949	Adults	unpleasant taste	TDS[2]	**2.9×10^{-4}**
	Children (1 - 6 yrs)	unpleasant taste	TDS	
	Infants (up to 1 yr)	skin, unpleasant taste	arsenic, TDS	
GW-999947	Adults	laxative effects, unpleasant taste,	sulfates, TDS	**1.1×10^{-4}**
	Children (1 - 6 yrs)	laxative effects, unpleasant taste,	sulfates, TDS	
	Infants (up to 1 yr)	GI discomfort, methemoglobinemia, laxative effects, unpleasant taste	magnesium, nitrates, sulfates, TDS	
GW-999946	Adults	—	—	3.9×10^{-5}
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	—	—	
GW-999945	Adults	unpleasant taste	TDS	7.7×10^{-5}
	Children (1 - 6 yrs)	unpleasant taste	TDS	
	Infants (up to 1 yr)	unpleasant taste	TDS	
GW-999944	Adults	—	—	**2.8×10^{-4}**
	Children (1 - 6 yrs)	—	—	

	Potential non-cancerous health concerns		Contaminants of concern for non-cancerous health effects	Estimated Cancer Risk due to exposure to arsenic in groundwater samples[1]
	Infants (up to 1 yr)	skin	arsenic	
GW-999943	Adults	—	—	**3.7×10^{-4}**
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	skin	arsenic	
GW-999941	Adults	—	—	**2.1×10^{-4}**
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	—	—	
GW-999940	Adults	—	—	8.5×10^{-5}
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	—	—	
GW-999939	Adults	—	—	**4.1×10^{-4}**
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	skin	arsenic	
GW-999938	Adults	—	—	8.8×10^{-5}
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	—	—	
GW-999937	Adults	—	—	**2.9×10^{-4}**
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	skin	arsenic	
GW-999936	Adults	—	—	**3.7×10^{-4}**
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	skin	arsenic	
GW-999935	Adults	—	—	**3.4×10^{-4}**
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	skin	arsenic	
GW-999934	Adults	—	—	**3.5×10^{-4}**
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	skin	arsenic	
GW-999933	Adults	—	—	7.2×10^{-5}
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	—	—	
GW-999932	Adults	—	—	**1.5×10^{-4}**
	Children (1 - 6 yrs)	—	—	

	Potential non-cancerous health concerns		Contaminants of concern for non-cancerous health effects	Estimated Cancer Risk due to exposure to arsenic in groundwater samples[1]
	Infants (up to 1 yr)	—	—	
GW-999931	Adults	—	—	4.9×10^{-5}
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	—	—	
GW-999930	Adults	—	—	**3.7×10^{-4}**
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	skin	arsenic	
GW-999929	Adults	—	—	3.9×10^{-5}
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	—	—	
GW-999928	Adults	—	—	**1.5×10^{-4}**
	Children (1 - 6 yrs)	blood lead level > 5 μg/dL	lead	
	Infants (up to 1 yr)	blood lead level > 5 μg/dL	lead	
GW-999927	Adults	—	—	**7.2×10^{-4}**
	Children (1 - 6 yrs)	skin	arsenic	
	Infants (up to 1 yr)	skin	arsenic	
GW-999926	Adults	—	—	4.2×10^{-5}
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	—	—	
GW-999925	Adults	—	—	9.7×10^{-5}
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	—	—	
GW-999924	Adults	—	—	3.9×10^{-5}
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	—	—	
GW-999923	Adults	—	—	**1.6×10^{-4}**
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	—	—	
GW-999922	Adults	—	—	**3.8×10^{-4}**
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	skin	arsenic	
GW-999921	Adults	—	—	3.9×10^{-5}
	Children (1 - 6 yrs)	—	—	

	Potential non-cancerous health concerns		Contaminants of concern for non-cancerous health effects	Estimated Cancer Risk due to exposure to arsenic in groundwater samples[1]
	Infants (up to 1 yr)	—	—	
GW-999920	Adults	unpleasant taste	TDS	2.1×10^{-5}
	Children (1 - 6 yrs)	unpleasant taste	TDS	
	Infants (up to 1 yr)	unpleasant taste	TDS	
GW-999919	Adults	—	—	8.6×10^{-5}
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	—	—	
GW-999918	Adults	—	—	7.9×10^{-5}
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	—	—	
GW-999917	Adults	—	—	**1.7×10^{-4}**
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	central nervous system	manganese	
GW-999916	Adults	—	—	**4.1×10^{-4}**
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	skin	arsenic	
GW-999915	Adults	—	—	**3.1×10^{-4}**
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	skin	arsenic	
GW-999914	Adults	laxative effects	sulfates	6.3×10^{-5}
	Children (1 - 6 yrs)	laxative effects	sulfates	
	Infants (up to 1 yr)	laxative effects	sulfates	
GW-999913	Adults	—	—	5.8×10^{-5}
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	—	—	
GW-999912	Adults	—	—	**1.4×10^{-4}**
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	—	—	
GW-999911	Adults	—	—	4.6×10^{-5}
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	—	—	
GW-999910	Adults	—	—	**2.9×10^{-4}**
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	skin	arsenic	

	Potential non-cancerous health concerns		Contaminants of concern for non-cancerous health effects	Estimated Cancer Risk due to exposure to arsenic in groundwater samples[1]
GW-999909	Adults	—	—	6.9×10^{-5}
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	—	—	
GW-999908	Adults	—	—	**3.0×10^{-4}**
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	skin	arsenic	
GW-999907	Adults	—	—	**4.7×10^{-4}**
	Children (1 - 6 yrs)	skin	arsenic	
	Infants (up to 1 yr)	skin	arsenic	
GW-999906	Adults	—	—	5.5×10^{-5}
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	—	—	
GW-999905	Adults	—	—	**2.4×10^{-4}**
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	—	—	
GW-999904	Adults	—	—	4.8×10^{-5}
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	—	—	
GW-999903	Adults	—	—	4.9×10^{-5}
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	—	—	
GW-999902	Adults	—	—	8.1×10^{-5}
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	—	—	
GW-999901	Adults	—	—	**2.6×10^{-4}**
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	—	—	
GW-586144	Adults	—	—	**1.8×10^{-4}**
	Children (1 - 6 yrs)	—	—	
	Infants (up to 1 yr)	—	—	
GW-573389	Adults	—	—	**1.4×10^{-4}**
	Children (1 - 6 yrs)	—	—	

	Potential non-cancerous health concerns		Contaminants of concern for non-cancerous health effects	Estimated Cancer Risk due to exposure to arsenic in groundwater samples[1]
	Infants (up to 1 yr)	—	—	

[1] EPA's target cancer risk range: 10^{-6} to 10^{-4}
[2] TDS = Total Dissolved Solids

Table 4-1. Groundwater samples containing elevated levels of arsenic that may increase the chance of non-cancerous health effects among the exposed population.

Well Name	Affected Population (Water Exposure Only)		
	10-kg Child	16-kg Child	Adults
GW-999907	×	×	
GW-999908	×		
GW-999910	×		
GW-999915	×		
GW-999916	×		
GW-999922	×		
GW-999927	×	×	
GW-999930	×		
GW-999934	×		
GW-999935	×		
GW-999936	×		
GW-999937	×		
GW-999939	×		
GW-999943	×		
GW-999944	×		
GW-999949	×		
GW-999952	×		

Table 4-2. Estimated cancer risks due to exposure to arsenic-contaminated groundwater samples.

Well Name	Estimated cancer risk from groundwater consumption	Current Well Usage
GW-573389	1.4×10^{-4}	Potable
GW-586144	1.8×10^{-4}	Potentially Potable
GW-999901	2.6×10^{-4}	Potentially Potable
GW-999902	8.1×10^{-5}	Potable
GW-999903	4.9×10^{-5}	Potable
GW-999904	4.8×10^{-5}	Potable
GW-999905	2.4×10^{-4}	Potentially Potable
GW-999906	5.5×10^{-5}	Potable
GW-999907	4.7×10^{-4}	Potentially Potable
GW-999908	3.0×10^{-4}	Potentially Potable
GW-999909	6.9×10^{-5}	Potable
GW-999910	2.9×10^{-4}	Potentially Potable
GW-999911	4.6×10^{-5}	Potable
GW-999912	1.4×10^{-4}	Potentially Potable
GW-999913	5.8×10^{-5}	Potentially Potable
GW-999914	6.3×10^{-5}	Potable
GW-999915	3.1×10^{-4}	Potentially Potable
GW-999916	4.1×10^{-4}	Potentially Potable
GW-999917	1.7×10^{-4}	Potable
GW-999918	7.9×10^{-5}	Potable
GW-999919	8.6×10^{-5}	Potable
GW-999920	2.1×10^{-5}	Potable
GW-999921	3.9×10^{-5}	Potable
GW-999922	3.8×10^{-4}	Potentially Potable
GW-999923	1.6×10^{-4}	Potable
GW-999924	3.9×10^{-5}	Potable
GW-999925	9.7×10^{-5}	Potable
GW-999926	4.2×10^{-5}	Potable
GW-999927	7.2×10^{-4}	Potentially Potable
GW-999928	1.5×10^{-4}	Potable
GW-999929	3.9×10^{-5}	Potable
GW-999930	3.7×10^{-4}	Potable
GW-999931	4.9×10^{-5}	Potable
GW-999932	1.5×10^{-4}	Potable
GW-999933	7.2×10^{-5}	Potable
GW-999934	3.5×10^{-4}	Potable
GW-999935	3.4×10^{-4}	Potentially Potable
GW-999936	3.7×10^{-4}	Potentially Potable

Well Name	Estimated cancer risk from groundwater consumption	Current Well Usage
GW-999937	2.9×10^{-4}	Potable
GW-999938	8.8×10^{-5}	Potentially Potable
GW-999939	4.1×10^{-4}	Potentially Potable
GW-999940	8.5×10^{-5}	Potable
GW-999941	2.1×10^{-4}	Potentially Potable
GW-999943	3.7×10^{-4}	Potable
GW-999944	2.8×10^{-4}	Potentially Potable
GW-999945	7.7×10^{-5}	Potable
GW-999946	3.9×10^{-5}	Potable
GW-999947	1.1×10^{-4}	Potable
GW-999949	2.9×10^{-4}	Potable
GW-999950	8.1×10^{-5}	Potable
GW-999951	6.7×10^{-5}	Potentially Potable
GW-999952	3.0×10^{-4}	Potentially Potable
GW-999953	1.1×10^{-4}	Potable

Table 5.Predicted blood lead level (microgram per deciliter liter, µg/dL) by using Integrated Exposure Uptake Biokinetic (IEUBK) model.

Well Name	Predicted geometric mean for blood lead level (µg/dL)	Greater or equal to 5% chance to exceed blood lead level of 5 µg/dL	Greater or equal to 5% chance to exceed blood lead level of 10 µg/dL
GW-SW-08	1.28		
GW-999953	4.95	×	×
GW-999952	1.25		
GW-999951	1.84		
GW-999950	1.30		
GW-999949	1.27		
GW-999948	1.41		
GW-999947	1.96		
GW-999946	1.89		
GW-999945	1.30		
GW-999941	1.82		
GW-999940	1.50		
GW-999939	1.63		
GW-999938	1.41		
GW-999937	1.81		
GW-999936	1.62		
GW-999935	1.88		
GW-999934	1.33		
GW-999933	2.29		
GW-999932	1.33		
GW-999931	1.28		
GW-999930	1.69		
GW-999929	1.26		
GW-999928	2.39	×	
GW-999926	1.47		
GW-999923	1.63		
GW-999921	1.33		
GW-999916	1.89		
GW-999907	1.33		
GW-999904	1.38		
GW-573389	1.53		
GW-551459	1.36		

Appendix A

The following ground water samples comprise the dataset:

(1) Ground water samples were collected from two Humboldt Water Company supply wells (i.e., GW-999951 and GW-999952). These wells supply water to some residents in the vicinity of the Site. The Humboldt Water Company supply well samples were collected from a tap nearest the pump.

(2) Dozens of private wells that supply water to residents in the vicinity of the Site. The residential tap samples were collected from a tap nearest the pump.

(3) Sample location GW-999954
refers to Old Mine Shaft No. 7, which is a PVC casing that was placed in an old mine shaft with a depth of over 3,000 ft bgs. The Old Mine Shaft No. 7 was sampled from a tap nearest the pump. The Cistern contains water that was pumped from Old Mine Shaft No. 7 and was sampled while the Old Mine Shaft No. 7 pump was inoperable. The water is not used for drinking purposes at present time.

(4) MW-03-S, MW-04-S, and MW-05-S are all completed to depths of less than 60 ft bgs and were constructed to intercept the shallow ground water within the tailings. These wells were sampled using low-flow sampling techniques via a Grundfos pump. The water is not used for drinking purposes at present time.

(5) At the Humboldt Smelter, monitoring well MW-01-S was completed in basalts within the Hickey Formation and represents the shallowest ground water entering the Aqua Fria. Monitoring well MW-02-S is completed in the shallow aquifer immediately west of the Humboldt Smelter Tailings Pile. A historic ground water well in the Humboldt Smelter area of interest (i.e., GW-999948) reportedly extends over 200 ft bgs. These wells were sampled using low-flow sampling techniques via a Grundfos pump. The water is not used for drinking purposes at present time.

(6) Monitoring well MW-06-D at the Iron King Mine is a bedrock well that was completed to a depth of approximately 350 ft bgs. This sample was collected using low-flow sampling techniques via a bladder pump with a nitrogen purge. The water is not used for drinking purposes at present time.

Above information was adapted from the Iron King Mine-Humboldt Smelter Superfund Site Remedial Investigation (RI) Report (EA Engineering, Science, and Technology, Inc 2010).

Appendix B

Chronic Daily Intake from Water

$$ED_{water} = \frac{Conc. \times IR \times EF \times ED}{BW \times AT}$$

ED_{water}: chronic daily exposure via water ingestion (mg/kg/day)
Conc.: chemical concentration in water (mg/L)
IR: water ingestion rate (L/day)
EF: exposure frequency (day/year)
ED: exposure duration (year)
BW: body weight (kg)
AT: averaging time (day)

Excess Lifetime Cancer Risk Calculation

$$CR = (ED_{water}) \times SF$$

CR: cancer risk
ED_{water}: chronic daily exposure from water ingestion (mg/kg/day)
SF: slop factor $(mg/kg/day)^{-1}$