Health Consultation

IRON KING MINE & HUMBOLDT SMELTER

DEWEY-HUMBOLDT, YAVAPAI COUNTY, ARIZONA

EPA FACILITY ID: AZ0000309013

MARCH 26, 2009

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

Health Consultation: A Note of Explanation

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

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

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HEALTH CONSULTATION

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Prepared By:

Arizona Department of Health Services
Office of Environmental Health
Environmental Health Consultation Services

Under a Cooperative Agreement with the
U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
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Purpose

Local residents contacted the Agency for Toxic Substances and Disease Registry (ATSDR) and US Environmental Protection Agency (EPA) to express their concerns regarding the tailings from the Iron King Mine and Humboldt Smelter at Dewey-Humboldt, AZ. The Arizona Department of Environmental Quality (ADEQ) Preliminary Assessment/Site Inspection (PA/SI) report, published in 2002, indicated some residential soil collected from the Chaparral Gulch contain arsenic and lead above EPA Residential Preliminary Remediation Goals and ADEQ Residential Soil Remediation Levels. To follow up, EPA conducted additional soil sampling in 2005. ADEQ also conducted groundwater sampling of existing wells as part of an Expanded Site Investigation (ESI) in 2006. The purpose of this health consultation is to evaluate the available water and soil sampling results to determine if the detected metal levels pose adverse health effects when residents come into contact with the water or soil.
In 2008, EPA initiated the field investigation portion of the Remedial Investigation and Feasibility Study ("RI/FS") for the Site. The primary objectives of the RI/FS are to determine the nature and extent of contamination and to gather sufficient information so that EPA can select a long-term remedy that eliminates, reduces, or controls risks to human health. The investigation included the collection of airborne particulates, groundwater, surface water, surface soil, subsurface soil, and sediment data across the entire Site. Data from the RI/FS was not available at the time the health consultation was prepared and thus it was not incorporated into this health consultation.

Background

Site Location: The Iron King Mine and the Humboldt Smelter facilities have contaminated ground water and soil 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. It covers approximately 153 acres. The mine is situated in the Agua Fria River basin. The Humboldt Smelter is located near the intersection of 3rd street and Main Street. It occupies approximately 182 acres. See Appendix A for locations of the mine and smelter.

Operation History: The Iron King Mine was an active mine from 1904 until 1969, though, some of the residents who have lived in the vicinity of Prescott the longest say that the Iron King mine was originally built in 1880. It produced fluxing ore for the copper smelter located in Humboldt during the year 1915 to 1918. Some time after the end of World War I the mine was closed. The Iron King Mine was expanded beginning in 1936 to remove 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 precious metal recovery. Waste rock and tailings were deposited in large piles adjacent to actual mine property boundaries. The mine has been inactive since 1969. Some secondary uses were occurring up until about a year ago, such as recovery of minerals from the mine tailings for use in making fertilizer. The fertilizer was bagged under the Ironite trade name. The site is mainly coved by tailings and waste rock piles. It consists of three properties: the mine property, the tailings pile, and the former fertilizer plant (Nolan property).

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. A smelter was rebuilt in 1906 that processed 1,000 tons of ore per day. This smelter operated full tilt until 1918 and then intermittently between 1922 and 1927. The smelter reopened in 1930.

Site Activity: Arsenic and lead have been detected at levels above health based standards in soil of several residential yards (EPA 2005). As a result, a removal action was initialed in 2006 to remove contaminated soil from four off-site residential properties (properties: 2, 3, 4 and 7). The removal of the contaminants was conducted by a contractor on behalf of the Ironite Products Company under EPA oversight.

Portion 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 replacement 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.

In October 2008, EPA initiated the RI/FS to further assess the nature and extent of the contaminants in soil, water and air at the site. This investigation will help EPA determine possible cleanup actions for the site. Data from the RI/FS was not available at the time the health consultation was prepared and thus it was not incorporated into this health consultation.

Statement of Issues

This health consultation will focus on the off-site migration of the mine tailings and the impacts they may have on the health of residents who live near the mine based on the available water and soil data. Several washes run near the mine and carry the tailings downstream during periods of rainfall. Drinking water wells located downstream of the facility may be impacted by this washout of materials. Local residents also have concerns about levels of heavy metals in ambient air during high wind events. This exposure pathway will not be discussed in this health consultation due to lack of airborne particulates data at the time this report was prepared. Another community concern is about the bioavailability of arsenic. A recent study (Williams et al. 2006) suggests that the form of arsenic and lead found in Ironite®, a fertilizer product, is more readily bioavailable than previously thought.

Evaluation Process

ADHS provides site-specific public health recommendations on the basis of toxicological literature, an evaluation of potential exposure pathways, levels of environmental contaminants detected at a site compared to accepted environmental guidelines (i.e. comparison values, CVs), and duration of exposure, and the characteristics of the exposed population. ADHS used this approach to determine if the detected chemical concentrations in groundwater and soil at Iron King Mine and Humboldt Smelter site pose a public health hazard.

Comparison values are screening tools used with environmental data relevant to the exposure pathways. CVs are conservatively developed based on the available scientific data and consideration for the most sensitive groups (e.g. children). If public exposure concentrations related to a site are below the corresponding CV, then the exposures are not considered of public health concern and no further analysis is conducted. However, while concentrations below the CV are not expected to lead to any observable adverse health effect, it should not be inferred that a concentration greater than the CV will necessarily lead to adverse health effects. Depending on site-specific environmental exposure factors (e.g. duration and frequency of exposure) and individual human factors (e.g. personal habits, occupation, and/or overall health), exposure to levels above the comparison value may or may not lead to a health effect. Therefore, the CVs should not be used to predict the occurrence of adverse health effects.

When determining what environmental guideline value to use, this health consultation followed Agency for Toxic Substances and Disease Registry's (ATSDR) general hierarchy and used professional judgment to select CVs that best apply to the site conditions.

Available Environmental Data for the Site

<u>Groundwater</u>

- *Groundwater Study Report* (B&C 2004): Brown and Caldwell collected groundwater samples from 10 wells (SW01 to SW10) in the vicinity of the Ironite facility. These samples were analyzed for metals by EPA approved methods.
- *Groundwater Study Report Update* (B&C 2005): Updated the lead concentration detected in SW03. It also provides the analytical results of additional groundwater sampling (SW11) in September 2005. This report indicates that the high lead concentration detected in SW03 in the previous report (B&C 2004) was due to sample contamination and was not representative of groundwater contaminant conditions. Therefore, only the updated lead concentration for SW03 in the 2005 report will be used to evaluate potential health effects.
- *Expanded Site Investigation Results* (ADEQ 2006): Groundwater samples were collected in January, February and May 2006 and analyzed by EPA approved methods. The data validation report indicates that barium and nickel concentrations in groundwater samples collected on 1/31/06 and 2/1/06 may be underestimated due to chemical and physical interferences. Therefore, they will not be evaluated in the health consultation. If the difference between sample (S) and field duplicate (D) is greater than the acceptable level, the more conservative (greater) result will be used. Otherwise, the average concentration will be used in the health effects evaluation.
- Appendix B summarizes the groundwater testing results.

Sediment and Soil

- *Preliminary Assessment/Site Inspection (PA/SI) Report, Iron King Mine and Tailings* (ADEQ 2002): Sediment and soil samples were collected from the Chaparral Gulch in the vicinity of the residential areas. Elevated arsenic and lead levels were detected in the field and background samples. The highest onsite arsenic concentration was measured at the Boneyard (sample IK-S4 taken April 11, 2002) one to two feet below ground surface at 7,600 mg/kg. The highest onsite lead concentration was measured at the former assay waste dump (sample IK-S25 taken April 10, 2002) zero to six inches below ground surface at 14,200 mg/kg.
- *Preliminary Assessment/Site Inspection* (PA/SI) *Report, Humboldt Smelter* (ADEQ 2004): Sediment and soil samples were collected from onsite sampling sites, Humboldt Elementary School, Chaparral Gulch, private residences. Two samples and one quality assurance sample was taken from the school. One sample was taken from each residence. All of the soil samples were analyzed for semi-volatile organics, total metals and cyanide by EPA methods. Background soil concentrations were determined based on samples collected from two separate locations with no known chemical usage or disposal history.
- *Removal Assessment Report*, *Iron King Mine Site*, *Humboldt, Arizona*, *Final Report*, (EPA 2005): Nine surface and one subsurface soil samples were collected from 16 residential properties and one horse pasture along the Chaparral Gulch. All of the soil samples were analyzed for arsenic and lead by EPA methods. Site-specific mean background arsenic concentration was 30.73 mg/kg and lead was 20.05 mg/kg.
- Appendix C summarizes the soil sampling results.

Exposure Pathway Analysis

In evaluating this and every site, ADHS uses established methodologies for determining how people may be exposed to contamination from a site and what effects, if any, may result from exposure to those contaminants. The ways that people may come into contact with chemical contaminants (such as breathing air and drinking water) are called exposure pathways. There are five elements to be considered when identifying exposure pathways:

- a *source* of contamination,
- a *media* such as soil or ground water through which the contaminant is transported,
- a *point of exposure* where people can contact the contaminant,
- a *route of exposure* by which the contaminant enters or contacts the body; and
- a *receptor* population

Exposure pathways are divided into three categories: completed, potential, and eliminated. A completed exposure pathway is observed when all five elements are present. 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 an eliminated exposure pathway, at least one element of the pathway is not present and either will never be present or is extremely unlikely to ever be present. Identifying an exposure pathway does not necessarily indicate the presence or concentration of potential contaminants; it is simply a way of determining the possibility of exposure as if the contaminants were present in the medium. The following talk about how people may get contact with chemicals in groundwater or soil.

Groundwater

Completed and potential exposure pathways may result from people using the water for domestic purposes. Typical potable and municipal supply well exposures to metals include dermal exposures from bathing and showering, and ingestion exposures from drinking and using water for cooking. Inhalation while showering is not a relevant pathway for metals, because they are not volatile (i.e. do not evaporate). Metals tend not to be absorbed through the skin, and are not likely to be available to people as aerosol while showering.

For irrigation wells, only limited dermal and ingestion exposures could occur to anyone who comes in contact with the contaminated water. This could include exposure to adults while they are watering the lawn or gardens, children playing at grounds that are irrigated with contaminated water, or anyone who eats vegetables or fruits that are irrigated with contaminated water and accumulate contaminants.

For industrial/non-potable/not used wells, ADHS determined that the exposure pathway is eliminated since residents are unlikely to have contact with chemicals through inhalation, ingestion, or skin contact. This water is mainly used for commercial establishments, manufacturing process, and dust control.

Soil

Residents can 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 they eat food with their hands or put their fingers in their mouths, because soil or dust particles can adhere to food, cigarettes, and hands. As a result of a normal phase of childhood in which they display hand-to-mouth behavior, children are particularly sensitive because they are likely to ingest more soil than adults. Dermal exposure to the soil can also occur through a variety of activities such as gardening, outdoor recreation, or construction. People may breathe in fugitive dust especially during high winds or activities that stir up the dust (i.e. driving down a dirt road or riding a horse).

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). Eliminated exposure pathways require no further evaluation.

Table 1. Complete and Potential Exposure Pathways

Exposure Pathway Elements					Time frame	Type of Exposure Pathway
Source	**Media**	**Point of exposure**	**Route of exposure**	**Potentially exposed population**		
Potable wells	Groundwater	Residences, tap	Ingestion Skin contact	Residents	Past	Completed
					Current	Completed
					Future	Potential
Municipal water supply wells	Groundwater	Residences, tap	Ingestion Skin contact	Residents	Past	Completed
					Current	Completed
					Future	Potential
Irrigation wells	Groundwater	Residential yards and gardens	Ingestion Skin contact	Residents	Past	Completed
					Current	Completed
					Future	Potential
Contaminated soil/Mine tailing	Soil	Residential yards and gardens	Ingestion Skin contact Inhalation*	Residents	Past	Completed
					Current	Completed
					Future	Potential

* Inhalation exposure route will not be discussed in this health consultation due to lack of airborne data.

Screening Analysis

Conducting Environmental Guidelines Comparisons: Chemicals of Interest Selection

Chemicals of interest are the site-specific chemical substances selected for further evaluation of potential health effects. Chemicals of interest are identified by (1) reviewing the concentration levels reported for each chemical, (2) evaluating sampling data and techniques used to obtain the data, and (3) making data comparisons with environmental guidelines (i.e. comparison values).

Groundwater

The CVs used in initial screening analyses for groundwater include: Environmental Media Evaluation Guides (EMEGs), Reference Dose Media Evaluation Guides (RMEGs), and Maximum Contaminant Levels (MCLs). The Agency for Toxic Substances and Disease Registry (ATSDR) develops EMEGs and RMEGs based conservative assumptions about exposure. EMEGs and RMEGs represent concentrations of substances in water, soil, or air to which daily human exposure is unlikely to result in adverse health effects. MCLs, developed by EPA, are enforceable standards for public drinking water supplies that are protective of human health, over a lifetime. MCLs are not threshold levels of toxicity effects, because they include a substantial margin of safety to account for uncertainty and variability in studies and technology. Therefore, in general, people ingesting chemicals at or slightly above MCLs will not necessary experience any illness or other adverse health effects. The identified chemicals of interest in groundwater are *arsenic, boron, and copper* (see Appendix D, Table D-1).

Soil

The CVs used in initial screening analyses for soil samples include: EMEG, RMEG, Soil Remediation Level (SRL), and Risk-based Concentration (RBC). The selected chemicals of interest are *arsenic and lead* (see Appendix D, Table D-2 and D-3). The concentration of lead in one of the residential samples from the 2004 PA/SI Report exceeded the ADEQ Residential SRL, which is set at 400 mg/kg. The averaged lead concentrations detected in the soil samples from the 2005 Removal Assessment Report are below the ADEQ Residential SRL. Arsenic soil concentrations, including background samples, from both the 2004 PA/SI and 2005 Removal Assessment Reports exceeded the ATSDR EMEG of 20 mg/kg and ADEQ SRL of 10 mg/kg.

EPA established an arsenic removal action trigger of 80 mg/kg and a soil cleanup goal of 23 mg/kg due to high background arsenic levels (30.72 mg/kg, EPA 2005). For example, if a property had 85 mg/kg arsenic, the EPA would remediate this property because it is above the Removal Action Trigger of 80 mg/kg. Remediation entails removing the soil until the arsenic concentration is below 23 mg/kg and filling in the area with clean soil. Results for the properties 2, 3, 4 and 7 were not included, because they were part of EPA's Removal Action, and there is no longer a completed pathway.

Conducting Health Guidelines Comparisons

Estimating Exposure Doses

To further evaluate the selected chemicals of interest, ADHS estimated the Daily Intakes (DIs) based on the site-specific conditions (e.g. duration and frequency) and compared them to health-based guidelines. The health-based guidelines are estimates of the daily human exposure to a chemical that is likely to be without appreciable risk of adverse, non-cancer health effects over a specified duration of exposure.

As indicated in Table 1, residents can uptake chemicals in groundwater or soil via ingestion, inhalation or skin contact. Residents have expressed concern over the inhalation pathway, especially the dust that is intermittently blown from the mine toward nearby residences. However, ADHS could not evaluate the inhalation exposure pathway because no air sampling results were available at the time the health consultation was prepared. Residents were also concerned about new development and new land uses on the properties surrounding the site. These properties were not included in previous sampling events, so potentially associated risks could not be calculated at this time.

ADHS determined that uptake of most metals through skin contact can be ignored, because metals are not readily absorbed through the skin. Exposure to metals through skin contact results in a much lower dose than the ingestion pathway. For example, dermal exposure to arsenic is usually not of concern, because only a small percentage will pass through skin and into the body (ATSDR 2000a). Direct skin contact with arsenic could cause some irritation or swelling, but skin contact is not likely to result in any serious internal effects. The DIs from water and soil ingestion were estimated by following the Arizona Department of Health Services *Deterministic Risk Assessment Guidance* (ADHS 2003). See Appendix F for the DI calculations.

Additional Consideration for Arsenic Exposure Dose Estimations: Bioavailability

Bioavailability is the measurement of the degree to which contaminants can be absorbed into the body. Determining a contaminant's bioavailability is a key factor in assessing the potential risks associated with the contaminant. In general, it is believed that inorganic arsenic is highly bioavailable in solutions such as water, with most estimates in excess of 95%. For example, if we consume a glass of water containing 1 g of arsenic, more than 0.95 g of arsenic will be absorbed into the body. However, the bioavailability of mineralized arsenic in soils is considerably less than that in solution, because they are present in water-insoluble forms or because they interact with other soil constituents.

The community's concern regarding the bioavailability of arsenic at the Site was discussed at a Town Meeting in November 2006. Williams et al. (2006) indicates that the bioavailable arsenic released from Ironite® is dependent on its mineralogical form. Their study shows that 60~70% of arsenic in Ironite® purchased from three commercial retail stores (two in Ohio and one in Florida) is associated with iron oxides, which has a high bioavailability, rather than arsenopyrite, which has limited bioavailability. A previous, non-peer reviewed study performed on behalf of the manufacturer had stated that the arsenic was mainly found (95%) as arsenopyrite. The community also expressed concern regarding the stability of the arsenic in the mine waste. Williams et al (2006) concluded that the arsenic in Ironite® seemed to change over time from arsenopyrate to arsenic bound in iron oxides. The authors claim that under surficial conditions, arsenopyrate cannot be expected to remain stable, but rather transforms into a more bioavailable form of arsenic (e.g. arsenic bound in iron oxides). The community expressed concern that this could be happening in the mine tailings and dust that blows into nearby residences. While Ironite® is derived from the mine tailings themselves, there is not enough evidence to show that the mine tailings contain the same constituents as Ironite. The bioavailability of any contaminant is both soil- and contaminant-specific. At this point, no specific arsenic bioavailability study has been conducted at this Site.

A number of studies (Freeman et al., 1993; Freeman et al., 1995; Groen et al., 1994; Casteel et al., 1997b; Rodriguez et al., 1999) examine the arsenic bioavailability in soil from different mining sites. These studies indicate that arsenic in soil is typically only one-tenth to one-half as bioavailable as soluble arsenic forms. In other words, these studies support relative bioavailability adjustments ranging from 10% to 50% in exposure assessments for these sites. Since there is no site-specific arsenic bioavailability information for soil in the Dewey-Humboldt area, toxicologists at ADHS, ATSDR and EPA decided that the use of 50% bioavailability will provide reasonable estimations without overestimation of risks. If a bioavailability study is conducted at this site in the future, ADHS will revisit this issue and determine if the risk should be recalculated.

Comparing Exposure Dose Estimates with Health Guidelines

The estimated DI was compared to ATSDR Minimal Risk Level (MRL) or EPA Reference Dose (RfD). MRL/RfD is an estimate of daily exposure to the human population (including sensitive subgroups) that is not likely to cause harmful effects during a lifetime. MRL/RfD is derived based on the Non-Observed-Adverse-Effect Level[1] (NOAEL) or Lowest-Observed-Adverse-Effect Level[2] (LOAEL) and an uncertainty factor. MRL/RfD contains uncertainty that is due to the lack of knowledge about the data on which it is based. To account for this uncertainty, "safety factors" are used to set MRL/RfD below actual toxic effect levels (i.e. NOAEL or LOAEL). This approach provides an added measure of protection against the potential for adverse health effects to occur.

Appendix E shows the comparison results for chronic (long-term) exposure. Samples with estimated DIs below their respective MRL/RfD are not expected to cause any non-cancer health effects. The following section will discuss whether harmful effects might be possible for samples with estimated daily intakes greater than their respect health guidelines.

Discussion

Arsenic in Groundwater and Residential Soil

Arsenic is a naturally occurring element widely distributed in the earth's crust and may be found in air, water and soil. Arsenic exists as inorganic arsenic, organic arsenic, and arsine gas. Generally, organic arsenic is less toxic than inorganic arsenic. Humans normally take in small amounts of arsenic through inhalation of air and ingestion of food and water, with food being the largest source of arsenic. Fish and seafood contain the highest concentrations of arsenic; however, most of this is in the less toxic organic form of arsenic (ATSDR 2000). Inorganic arsenic is a known carcinogen. Ingesting or breathing small amounts of inorganic arsenic for a long time can cause a darkening of the skin and the appearance of small "corns" or "warts" on the palms, soles, and torso. Ingestion of arsenic can increase the risk for skin cancer and internal cancers: liver, lung, bladder, and kidney (ATSDR 2000).

(A) Non-cancer Health Effects

Groundwater

To reach the level of acute MRL (0.005 mg/kg/day), a 70-kg adult would have to drink 2 L of water containing more than 0.175 mg/L arsenic and a 15-kg child would have to drink 1 L of water containing more than 0.075 mg/L arsenic. Among the potable wells, the highest detected arsenic concentration was 0.05 mg/L (H65), thus ADHS does not expected to see acute adverse effects among the exposed population.

The estimated chronic child/adult DI for groundwater samples: H51, H62, H65, H68, H70, H80, H81, and SW02 were above the chronic MRL (0.0003 mg/kg/day), but they

[1] NOAEL: the highest exposure level of a chemical at which non-cancer adverse health effects were not observed.
[2] LOAEL: the lowest exposure level of a chemical at which non-cancer adverse health effects were observed.

were lower than the long-term LOAEL of 0.014 mg/kg/day, where exposure to arsenic above this level resulted in keratosis (patches of hardened skin), hyperpigmentation of the skin, and possible vascular complication. In addition, studies have shown no dermal or other effects to people exposed to arsenic in drinking water at chronic doses of 0.0004 to 0.01 mg/kg/day (ATSDR 2000a). None of the estimated chronic daily intakes exceeded 0.01 mg/kg/day (See Appendix E, Table E-1).

Soil[3]

To reach the level of acute MRL, a 70-kg adult would have to ingest 100 mg of soil containing more than 7,000 mg/kg of arsenic and a 15-kg child would have to ingest 200 mg of soil containing more than 746 mg/kg of arsenic. Children with soil-pica behavior may have increased risk associated with the exposure. In additional to accidental ingestion, some toddlers (typically 1~3 years old) intentionally eat large amounts of soil. This intentional soil ingestion is called soil-pica behavior. Soil pica behavior is rare though happens occasionally in young children, possibly due to normal exploratory behavior. Studies have shown that the amount of soil ingested during a soil-pica behavior episode varies and ranges from levels above 200 mg to a high of 5,000 mg (about ½ teaspoon) or more (extremely rare). General pica behavior is greatest in 1- to 2-year old children and decreases as children age (Calabrese 1997, Calabrese 1998, ATSDR 2005). Various studies have reported that this behavior occurs in as few as 4% of children or in as many as 21% of children (Barltrop 1966, Robischon 1971, Vermeer 1979).

For some contaminants periodic pica episodes potentially could result in acute intoxication (Calabrese 1997). To explore the potential public health significance of pica behavior, we used a soil intake of 5,000 mg/day and a bioavailability of 50% to estimate soil exposures for soil-pica children since there is no evidence for differences in absorption of arsenic in children and children (ATSDR 2007). The estimated exposure doses of arsenic from pica behavior ranged from 0.004 to 0.02 mg/kg/day. Fourteen samples (properties 8, 10, 12, 15, 16, 17, 20, S-02, S-04, S-06, S-07 and H-43SS) had concentrations above the acute MRL of 0.005 mg/kg/day, which would indicate some degree of risk. Most of the estimated exposure doses are about 7~10 times lower than the dose reported to cause gastrointestinal effects in humans (0.05 mg/kg/day), which is based on a study of 220 poisoning cases associated with an episode of arsenic contamination of soy sauce in Japan (Mizuta 1956).

The acute MRL has a safety factor of 10 as an extra precaution, as the lowest level to show health effects in the Japanese study was estimated to be 0.05 mg/kg/day. An early feature of the poisoning was appearance of facial edema that was most marked on the eyelids. In majority of the patients, the symptoms appeared within two days of ingestion and then declined even with continued exposure. Children who are exposed to high levels of arsenic exhibits symptoms similar to those seen in adults. In addition, there is no evidence for differences in absorption of arsenic in children and children (ATSDR

[3] Results for the properties 2, 3, 4 and 7 were not included, because they were part of EPA's Removal Action, and there is no longer a completed pathway.

2007). The highest estimated exposure dose (sample: H43-SS) is about 3 times lower than the dose reported to cause gastrointestinal effects in humans, the likelihood that it would result in adverse health effects is low.

The estimated chronic child DI for soil sample: S-06-0 and HS-43SS were above the chronic MRL, but they were more than 18 times lower the long-term LOAEL of 0.014 mg/kg/day (see Appendix E, Table E-2).

Based on the assumed exposure scenarios, ADHS does not expected to see arsenic associated acute or chronic non-cancer health effects among the resident who may have come into contact with the arsenic-contaminated groundwater or soil.

(B) Cancer Health Effect

The Department of Health and Human Services, the International Agency for Research on Cancer and US EPA have determined that arsenic is carcinogenic to humans. This is based on evidence from many studies of people who were exposed to arsenic-contaminated drinking water, arsenical medications, or arsenic-contaminated air in the workplace for exposure durations ranging from a few years to an entire lifetime.
ADHS used mathematical model to estimate the opportunity of a person developing cancer from ingestion groundwater/soil containing a specific concentration of a chemical. In general, estimated excess theoretical lifetime cancer risks between $1x10^{-6}$ (one chance in a million) and $1x10^{-4}$ (one chance in ten thousand) are considered to be below a level of public health concern as a matter of policy by various states and federal agencies.

Groundwater

a) *H51, H68, H70, H80, H81 and SW02*: The estimated excess lifetime theoretical cancer risks are 2 in 10,000 for H51 and H68, 3 in 10,000 for H70, H80, H81 and SW02, over a lifetime. It means that there will be 2 to 3 additional occurrences of cancer in a population of 10,000 due to exposure to arsenic contaminated water[4]. The estimated excess lifetime theoretical cancer risks are slightly above the EPA's guidance range (i.e. 10^{-6} to 10^{-4}, USEPA 1991). However, the cancer slope factor of arsenic may be overestimated due to the uncertainty related to the model assumptions and differences in the health and nutrition between studied and American populations (ATSDR 2000). As a result, the ability of arsenic to cause cancer is reduced. For example, the MCL for arsenic of 10 µg/L is associated with excess lifetime cancer risk of 1.8 in 10,000 (i.e. 1.8 cases per 10,000 persons). While the estimated excess lifetime theoretical cancer risks (i.e. 2 in 10,000 or 3 in 10,000 for residents consuming water from H51, H68, H70, H80, H81 and SW02, over lifetime) due to arsenic from water ingestion are considered to be below the level of public health concern for the residents, ADHS recommends the users of the wells to install a treatment system to reduce arsenic exposures as a precaution.

[4] There is a background incidence of cancer in the general population due to everyday exposure to common materials. Nearly half of all men and one-third of all women in US population will develop cancer at some point in their life (American Cancer society 2008).

b) *H62 and H65*: The estimated excess lifetime theoretical cancer risks are 8 in 10,000 and 9 in 10,000, over a life time, which is considerably greater than the upper bound of the EPA's guidance, one-in-ten-thousand persons.

<u>Soil</u>

The same approach was used to estimate the excess lifetime theoretical cancer risks due to exposure to arsenic contaminated soil. All of the estimated excess lifetime theoretical cancer risks are below the level of public health concern (See Appendix E, Table E-3).

After a review of available exposure and health effect data, ADHS determined that detected **arsenic level in the well H62 and H65 pose a health hazard.**

Copper in Groundwater

Copper is essential for good health. In the US, the median copper intake from food ranges from 0.013 to 0.019 mg/kg/day for adults. The recommended dietary allowance is 0.013 mg/kg/day. However, exposure to higher doses can be harmful. Drinking water with high levels of copper may cause nausea, vomiting, stomach cramps, or diarrhea. Intentionally high intakes of copper can cause liver and kidney damage and even death (ATSDR 2004). ADHS determined that children exposed to copper detected in SW03 are not expected to result in harmful health effects. The estimated child chronic daily intake (0.0147 mg/kg/day) is below doses reported to show no harmful effects in human studies. The NOAEL (0.042 mg/kg/day) is established by the ATSDR based on gastrointestinal effects using the data from Araya et al. (2003).

Lead in Residential Soil

People may be exposed to lead by breathing air, drinking water, eating foods, or swallowing dust or dirt that contain lead. The main target for lead toxicity is the nervous system, both in adults and children. Children are more sensitive to the health effects of lead than adults. Lead exposure may also cause weakness in fingers, wrists, or ankles. Lead exposure also causes small increases in blood pressure, particularly in middle-aged and older people. Lead exposure may also cause anemia. At high levels of exposure, lead can severely damage the brain and kidneys in adults or children and ultimately cause death. In pregnant women, high levels of exposure to lead may cause miscarriage. High-level exposure in men can damage the organs responsible for sperm production (ATSDR 2005a).

While lead in soil also can have an impact on adults, the potential impact on adults is low compared to the potential impact on young pre-school age children. The Centers for Disease Control and Prevention (CDC) has determined that a blood lead level 10 microgram per deciliter (µg/dL) in children indicates excessive lead absorption and constitutes the grounds for intervention. For adults, a blood level of 25 µg/dL is considered to be "elevated."

In general, lead in soil has the greatest impact on preschool-age children as they are more likely to play in dirt and place their hands and other contaminated objects in their mouths. They also are better at absorbing lead through the gastrointestinal tract than adults and are more likely to exhibit the types of nutritional deficiencies that facilitate the absorption of lead. The predicted 95th percentile blood lead level for children that is associated with a soil lead concentration of between 400 to 500 mg/kg is approximately 10 μg/dL. In other words, a child regularly exposed to soil lead levels greater than 400 to 500 mg/kg should have no more than a 5% chance of having a blood lead level greater than 10 μg/dL as a result of that exposure.

The concentration of lead in one of the residential samples (HS-43SS) from the 2004 PA/SI report exceeded the EPA Regional Residential Preliminary Remediation Goal (PRG) and ADEQ's Residential Soil Remediation Level (SRL) of 400 milligrams per kilogram (mg/kg). While there is no clear relationship between soil lead and blood lead applicable to all sites, a number of models have been developed to estimate the potential impact that lead in soil could have on different populations.

To evaluate the public health significance of lead on soil, ADHS used EPA Integrated Exposure Uptake Biokinetic Model (IEUBK) to predict the blood levels in children. Site-specific soil concentration and default assumptions (i.e. air and drinking water concentrations as well as bioavailability) were used as inputs. The output from the IEUBK Model indicated that the estimate risk of exceeding 10 μg/dL for a typical child would be about 15% (See Appendix F). Based on the output, **ADHS concludes that the lead concentration detected at this residence (HS-43SS) poses a Public Health Hazard.**

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.

Pica behavior can lead to increased blood lead levels. The model used in the previous section to estimate blood lead levels is not appropriate in the case of pica behavior, because the model assumes a steady exposure to lead, and pica behavior is generally sporadic and unpredictable. If parents suspect pica behavior in their children, a physician should be consulted to discus a need for a blood lead test.

Conclusions

Based on the available information, ADHS concluded:

- Groundwater wells H62 and H65 pose a **Public Health Hazard**, because arsenic levels in the wells are higher than the acceptable levels. Residents who use the well water for drinking or cooking for a long time may experience adverse health effects.
- Soil sample HS-43SS poses a **Public Health Hazard** due to elevated lead concentration.
- Detected soil metal concentrations at other residences pose **no apparent public health hazard**. ADHS does not expect to see acute or chronic adverse effects among the exposed population. No significant increase in cancer would be expected among the exposed population.
- The conclusions do not apply to soil samples collected from property 2, 3, 4, and 7 because they were part of EPA's Removal Action, and there is no longer a completed pathway.

Recommendations

- For groundwater wells containing arsenic above the safety level, a treatment system that effectively removes arsenic should be installed. Meanwhile, residents should have an alternative water source, such as bottled water, for drinking and cooking.
- All residents in the Dewey-Humboldt area who use private well water for drinking or cooking should have their well water tested yearly for bacteria and nitrates, and at least once for primary metals, such as arsenic, copper, and lead, etc.
- To reduce children's exposure to chemicals by ingesting soil, encourage children to wash their hands after playing outdoors, and supervise toddlers and other children who exhibit pica behavior.
- Parents who suspect pica behavior in their children are encouraged to contact ADHS (at 602-364-3128) or their physician to discuss whether there is a need for a blood lead test.

Public Health Action Plan

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

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Certification

This Health Consultation entitled *Iron King Mine, Dewey-Humboldt, Yavapai County, Arizona* was prepared by the Arizona Department of Health Services under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with approved methodology and procedures existing at the time the health consultation was initiated. Editorial review was completed by the cooperative agreement partner.

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The Division of Health Assessment and Consultation, Agency for Toxic Substance and Disease Registry, has reviewed this health consultation and concurs with its findings.

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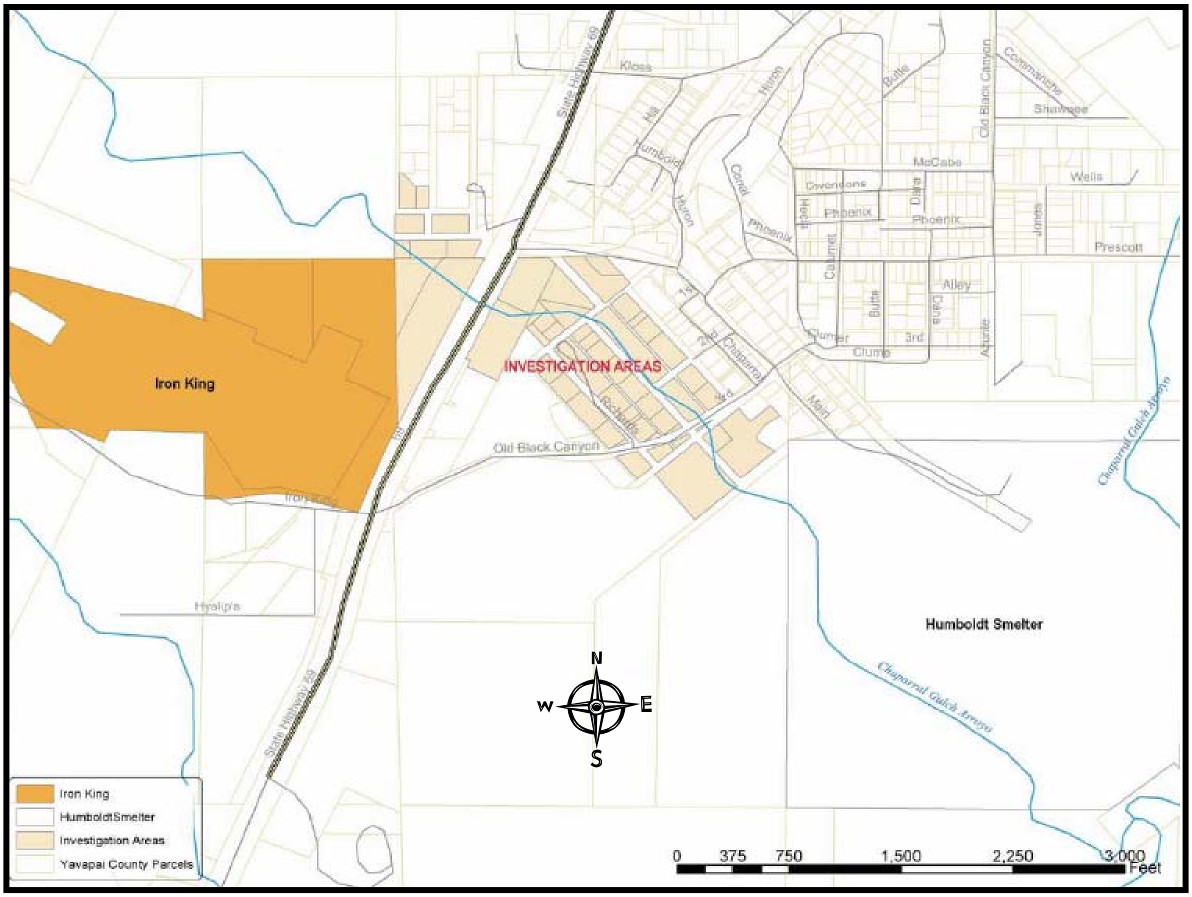
Appendix A



Site Map[5]. 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.

[5] The map is adapted from EPA report: Iron King Mine Site, Humboldt, Arizona, Final Report, 2005.

Appendix B

Analytical results of groundwater well samples (microgram per liter, µg/L) listed in the B&Cs Groundwater Study 2004 Report, 2005 Update and ADEQ Expended Site Investigation Results.

Sampling Date	Welll Name	Well Depth (ft)	Well Type	Chemical Concentrations (µg/L)																				
				Al	Sb	As	Ba	Be	B	Cd	Cr	Co	Cu	Pb	Mn	Hg	Mo	Ni	Se	Ag	Ti	V	Zn	CN^-
01/31/06	H51	305	Municipal (S)	–	2	11.6	45.8	1	–	1	0.92	0.17	12.9	3.8	1.6	0.2	–	1.1	3.4	1	1	10.9	197	10
01/31/06	H52	170	Municipal	–	2	5.9	39.5	1	–	1	0.76	0.06	3.8	0.84	0.41	0.2	–	1.2	5	1	1	8.2	44.1	11
01/31/06	H53	305	Municipal (D)	–	2	11.9	45.3	1	–	1	0.98	0.19	13.1	1.3	1.2	0.2	–	0.96	2.5	1	1	11	85.2	10
01/31/06	H55	340	Potable	–	2	4.9	40.3	1	–	1	0.2	1.9	10.5	0.83	0.33	0.2	–	0.86	1.9	1	1	602	26.8	10
01/31/06	H58	100	Not Used	–	2	1.2	37.9	1	–	1	0.09	3.6	3	0.2	50.9	0.2	–	4.3	2.4	1	1	2.3	14.6	10
01/31/06	H59	225	Potable	–	2	3.7	44.1	1	–	1	0.11	3.3	1.3	0.21	0.49	0.2	–	1.2	2.7	1	1	4.3	45	10
01/31/06	H61	261	Potable	–	2	4.5	40.3	1	–	1	0.18	2.9	1.3	0.27	0.16	0.2	–	0.83	5	1	1	5.8	31.9	10.2
01/31/06	H63	220	Potable	–	2	5.7	37.3	1	–	1	0.19	0.3	1.9	0.14	0.75	0.2	–	1.5	5	1	1	5.5	30.9	10.8
02/01/06	H54	325	Not Used	–	2	306	26	1	–	1	5.2	1.7	327	18.6	55.2	0.2	–	5.6	5	1	1	26.4	109	11.7
02/01/06	H56	90	Potable (S)	–	2	3.5	67.7	1	–	1	0.73	3.5	1.1	0.11	2.5	0.2	–	1.2	14.5	1	1	6.8	17.8	13.3
02/01/06	H57	90	Potable (D)	–	2	3.3	67.3	1	–	1	0.73	3.5	0.94	0.11	2.6	0.2	–	1.2	13.4	1	1	6.9	23.1	11.3
02/01/06	H62	77	Potable	–	2	47.5	53.1	1	–	1	1.6	0.04	3.6	0.32	1.1	0.2	–	0.77	1.9	1	1	6.1	13.1	10
02/01/06	H66	220	Potable	–	2	3.3	52.9	1	–	1	1.6	0.31	16.6	2	0.33	0.2	–	2.3	14.1	1	1	5.4	34.9	11
02/01/06	H80	104	Potable (BG)	–	2	17.2	66.8	1	–	1	4.7	1	0.58	0.18	0.14	0.2	–	0.68	2.1	1	1	5.5	85.3	10
05/24/06	H65	90	Potable	20	1	50	27	0.5	330	1	1	0.5	4.5	2	2	0.03	1.7	1	2.4	0.5	2	7.4	150	10
05/24/06	H67	800	Irrigation	20	1	150	20	0.5	5,800	1	1	0.5	1.4	2	1.5	0.03	22	3.4	1.3	0.5	2	4	79	10
05/24/06	H68	100	Potable (S)	20	1	11	3.6	0.5	200	1	1	0.86	9.4	2	2	0.034	1.2	1.2	6.4	0.5	2	3.9	81	10
05/24/06	H69	100	Potable (D)	20	1	10	3.5	0.5	190	1	1	0.87	11	2	2	0.032	1.1	1.1	6.3	0.5	2	3.9	56	10
05/24/06	H70	710	Potable	20	1	15	31	0.5	56	1	5.5	0.5	44	9.3	2	0.03	2.4	1	2.1	0.5	2	13	44	10
05/24/06	H81	125	Potable (BG)	20	1	20	93	0.5	100	1	3.7	0.5	7.7	2	2	0.03	1.2	1	3.1	0.5	2	6.7	17	10
05/24/06	H82	125	Potable (BG)	20	1	17	87	0.5	100	1	8.5	0.5	3.5	2	2	0.03	1.3	0.64	2.2	0.5	2	8.4	54	10
08/10/04	SW01	340	Potable	< 100	< 3	4.4	45	< 1	–	< 3	< 10	–	27	< 3	–	< 0.2	–	–	< 3	< 5	< 1	–	67	< 10
08/10/04	SW02	40	Potable	< 100	< 3	17	38	< 1	–	< 3	< 10	–	< 10	< 3	–	< 0.2	–	–	< 3	< 5	< 1	–	< 50	< 10
08/10/04	SW03	150	Potable	< 100	< 3	< 4	52	< 1	–	< 3	< 10	–	230	140	–	< 0.2	–	–	< 3	< 5	< 1	–	310	< 10
08/10/04	SW04	220	Non-Potable	< 100	< 3	5.3	51	1.7	–	< 3	< 10	–	< 10	< 3	–	< 0.2	–	–	7.6	< 5	< 1	–	< 50	< 10
08/10/04	SW05	NA	Industrial	< 100	< 3	870	25	< 1	–	< 3	< 10	–	< 10	25	–	< 0.2	–	–	< 3	< 5	< 2	–	8300	< 10
08/10/04	SW06	200	Non-Potable	< 100	< 3	6.1	56	< 1	–	< 3	< 10	–	14	< 3	–	< 0.2	–	–	11	< 5	< 1	–	58	< 10
08/10/04	SW07	238	Non-Potable	< 100	< 3	20	< 10	< 1	–	< 3	< 10	–	< 10	< 3	–	< 0.2	–	–	< 3	< 5	< 1	–	< 50	< 10
08/10/04	SW08	140	Non-Potable	< 100	< 3	< 4	24	1.1	–	< 3	< 10	–	11	< 3	–	< 0.2	–	–	6.8	< 5	< 1	–	180	< 10
08/10/04	SW09	300	Industrial (S)	< 100	< 3	7.2	40	1.2	–	< 3	< 10	–	< 10	4.8	–	< 0.2	–	–	19	< 5	< 1	–	2300	< 10
08/10/04	SW09	300	Industrial (D)	< 100	< 3	7	40	1.7	–	< 3	< 10	–	< 10	5.1	–	< 0.2	–	–	21	< 5	< 1	–	2600	< 10
08/10/04	SW10	980	Industrial	< 100	< 3	5.7	51	1.5	–	< 3	< 10	–	< 10	5.7	–	< 0.2	–	–	16	< 5	< 1	–	3100	< 10
09/29/04	SW03	150	Potable	< 100	< 3	< 4	51	< 1	–	< 3	< 10	–	230	< 3	–	< 0.2	–	–	< 3	< 5	< 1	–	320	< 10
09/29/04	SW11	200	Potable	170	< 3	4	62	<1	–	< 3	<10	–	< 10	4	–	< 0.2	–	–	< 3	< 5	< 1	–	520	< 10
04/00/02	IK-G1	600	Non-Potable	–	–	4.7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
04/00/02	IK-G5	400	Non-Potable (S)	–	–	20.9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
04/00/02	IK-G6	400	Non-Potable (D)	–	–	22.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
04/00/02	IK-G9	260	Non-Potable	–	–	5.6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Al: aluminum; Sb: antimony; As: arsenic; Ba: barium; Be: beryllium; B: boron; Cd: cadmium; Cr: chromium; Co: cobalt; Cu: copper; Pb: lead; Mn: manganese; Hg: mercury; Mo: molybdenumNi: nickel; Se: selenium; Ag: silver; Ti: thallium; V: vanadium; Zn: zinc; CN^-: cyanide; S: sample; D: Field duplicate; BG: background Sample

Appendix C

C-1. 2002 ADEQ PA/SI, Iron King Mine & Tailings sediment sample results (milligrams per kilogram, mg/kg)

Sample ID	Sample Location	Lead (mg/kg)	Arsenic (mg/kg)
IK-D1	Background sediment collected from an unnamed ephemeral stream, upstream of the mine property, from 0 to 6 inches	11[a]	25.5
IK-D2	Background sediment collected from Chaparral Gulch, upstream of the waste rock pile on mine property, from 0 to 6 inches	8.9	22.8
IK-D3	Background sediment sample collected from the Agua Fria River, upstream of its confluence with Chaparral Gulch, from 0 to 3 inches	36.3[a]	13.7
IK-D10	Sediment sample collected from Chaparral Gulch downstream of mine tailings near the former Humboldt smelter, from 0 to 3 inches	84.7[a]	149
IK-D12	Sediment sample collected from Chaparral Gulch in the vicinity of houses on the west side of Highway69, from 0 to 6 inches	339[a]	509
IK-D13	Sediment sample collected from Chaparral Gulch in the vicinity of houses on the east side of Highway 69, from 0 to 6 inches	298	285
IK-D14	Sediment sample collected from Chaparral Gulch in the vicinity of houses near 3[rd] street and Richards Lane, from 0 to 6 inches	303	371[a]
IK-D15	Duplicate of IK-D14	513	475[a]

[a] Compound was positively identified but associated concentration is approximate

C-2. 2004 ADEQ PA/SI, Humboldt Smelter soil sample results from onsite locations

Sample ID	Sample Location	Lead (mg/kg)	Arsenic (mg/kg)
HS-01SS	Ore Pile #1 near former office building	666[a]	1,100[a]
HS-04SS	Evaporation Pond	406[a]	78.9[a]
HS-05SS	Ash Pile between the metal building and the smelter stack	2,880[a]	30.7[a]
HS-06SS	Large ash pile between the metal building and the smelter stack	1,410[a]	30.7[a]
HS-07SS	Between the former assay laboratory and the former office building	756[a]	63.2[a]
HS-08SS	Near former assay laboratory building, where gray ash was visible	543[a]	270[a]
HS-09SS	Near former assay laboratory building, where gray ash was visible	315[a]	45.1[a]
HS-12SS	Large tailings pile	265[a]	134[a]
HS-13SS	Large tailings pile	215[a]	179[a]
HS-14SS	Large tailings pile	290[a]	204[a]
HS-15SS	Duplicate of HS-14SS	300[a]	263[a]
HS-16SS	Large tailings pile in Chaparral Gulch	408[a]	516[a]
HS-23SS	Retention basin	789[a]	75.8[a]
HS-38SS	Chaparral Gulch (downstream side)	89.1[a]	2,320[a]
HS-39SS	In the Agua Fria River beneath the large slag pile	4.8[a]	12
HS-40SS	Duplicate of HS-39SS	4.3[a]	7.3
HS-41SS	Upstream of slag pile	9.5[a]	12.8
Background		14.15	58.35

[a] Compound was positively identified but associated concentration is approximate

C-3. 2004 ADEQ PA/SI, Humboldt Smelter soil sample results from school and residences

Property		Lead (mg/kg)	Arsenic (mg/kg)
School	HS-34SS	67.9	34.5[a]
	HS-35SS	53.6[a]	25.4
	HS-36SS[b]	15.8	20.7
Residences	HS-42SS	35.3[a]	25.5[a]
	HS-43SS	543[a]	119[a]
Background		14.15	58.35

[a] Compound was positively identified but associated concentration is approximate
[b] Sample is a QA/QC sample taken from the same location as HS-35SS

C-4. 2005 EPA Removal Assessment Report, soil sample results from residences near the Iron King Mine and Smelter

Property		Lead (mg/kg)	Arsenic (mg/kg)
Background		20.05	30.72
Mine	2	63.5	107.1
	3	37.4	80.3
	4	78.1	114.5
	6	43.77	32.7
	7	53.79	91.2
	8	42.5	46.9
	9	24.2	30.47
	10	43.7	40.3
	11	170	31.97
	12	61.3	49.3
	13	65.2	32.3
	14	39.8	29.4
	15	113.8	40.7
	16	111.2	47
	17	58.2	49
	19	43.5	28.1
	20	33.9	51.6
Smelter		Lead (grab samples) (mg/kg)	Arsenic (grab samples) (mg/kg)
	S-01-0	13	24
	S-02-0	120	36
	S-02-1	130	45
	S-03-0	67	29
	S-04-0	62	35
	S-05-0	77	44
	S-06-0	180	66
	S-07-0	36	33
	S-08-0	37	31

Appendix D

D-1. Chemicals of interest in groundwater were identified by comparing them to their respective comparison values (CVs)

Chemical	Number of Samples	Ranges of detected concentration (µg/L)	Health-based CVs (µg/L)	Type of CV	Number of detections greater than CV	Is it a chemical of interest?
Aluminum	9	20 − 170	10,000	*C*-EMEG-ci[a]	0	No
Antimony	19	1 − < 3	6	MCL[b]	0	No
Arsenic	19	3.3 − 150	10	MCL	**9**	**Yes**
Barium	9	3.55 − 90	2,000	MCL	0	No
Beryllium	19	0.5 − 1	4	MCL	0	No
Boron	5	56 − 5,800	2,000	RMEG-ci[c]	**1**	**Yes**
Cadmium	19	1 − < 3	5	MCL	0	No
Chromium	19	0.11 − < 10	100	MCL	0	No
Cobalt	15	0.04 − 3.5	100	*I*-EMEG-ci[d]	0	No
Copper	19	0.58 − 230	100	*I*-EMEG-ci	**1**	**Yes**
Lead	19	0.11 − 9.3	15	MCL	0	No
Manganese	15	0.14 − 2.55	500	RMEG-ci	0	No
Mercury	19	0.03 − 0.2	2	MCL	0	No
Molybdenum	5	1.15 − 22	50	RMEG-ci	0	No
Nickel	5	0.82 − 3.4	200	RMEG-ci	0	No
Selenium	19	1.3 − 14.1	50	MCL	0	No
Silver	19	0.5 − < 5	50	RMEG-ci	0	No
Thallium	19	<1 − 2	2	MCL	0	No
Vanadium	15	3.9 − 13	30	*I*-EMEG-ci	0	No
Zinc	19	13.1 − 520	3,000	*C*-EMEG-ci	0	No
Cyanide	19	< 10 − 12.3	200	MCL	0	No

[a] *C*-EMEG-ci: Environmental Media Evaluation Guide for children's chronic exposure (≥ 365 days, ATSDR)
[b] MCL: Maximum Contaminant Level (EPA)
[c] RMEG-ci: Reference Dose Media Evaluation Guides for children's exposure (ATSDR)
[d] *I*-EMEG-ci: Environmental Media Evaluation Guide for children's intermediate exposure (15-365 days, ATSDR)

D-2. Chemicals of interest in soil samples taken from residences near the smelter were identified by comparing them to their respective comparison values (CVs). Data source: 2005 Removal Assessment Report

Chemical	Number of Samples	Ranges of detected concentration (mg/kg)	Health-based CVs (mg/kg)	Type of CV	Number of detections greater than health-based CV	Is it a chemical of interest?
Aluminum	5	13,000 – 48,000	50,000	*C*-EMEG-ci [a]	0	NO
Antimony	5	ND	20	RMEG-ci [b]	0	NO
Arsenic	5	24 – 66	20	*C*-EMEG-ci [a]	**5**	**YES**
Barium	5	110 – 1000	10,000	*C*-EMEG-ci [a]	0	NO
Beryllium	5	0.56 – 1.7	100	*C*-EMEG-ci [a]	0	NO
Cadmium	5	ND – 1.5	10	*C*-EMEG-ci [a]	0	NO
Chromium	5	16 – 150	2,100	1997 R-SRL [c]	0	NO
Cobalt	5	8.3 – 28	500	*I*-EMEG-ci [d]	0	NO
Copper	5	43 – 170	500	*I*-EMEG-ci [d]	0	NO
Lead	5	13 – 180	400	2007 R-SRL [e]	0	NO
Manganese	5	420 – 1,100	3,000	RMEG-ci [b]	0	NO
Molybdenum	5	ND	300	RMEG-ci [b]	0	NO
Nickel	5	13 – 150	1,000	RMEG-ci [b]	0	NO
Selenium	5	ND – 2.5	300	*C*-EMEG-ci [a]	0	NO
Silver	5	ND	300	RMEG-ci [b]	0	NO
Thallium	5	ND	5.2	2007 R-SRL [e]	0	NO
Vanadium	5	49 – 110	200	*I*-EMEG-ci [d]	0	NO
Zinc	5	100 – 530	20,000	*C*-EMEG-ci [a]	0	NO

[a] *C*-EMEG-ci: Environmental Media Evaluation Guide for children's chronic exposure (≥ 365 days, ATSDR)
[b] RMEG-ci: Reference Dose Media Evaluation Guides for children's exposure (ATSDR)
[c] 1997 R-SRL: 1997 Arizona Department of Environmental Quality Residential Soil Remediation Level
[d] *I*-EMEG-ci: Environmental Media Evaluation Guide for children's intermediate exposure (15-365 days, ATSDR)
[e] 2007 R-SRL: 2007 Arizona Department of Environmental Quality Residential Soil Remediation Level

D-3. Chemicals of interest in soil samples taken from residences and the school were identified by comparing them to their respective comparison values (CVs). Data source: 2004 PA/SI Report

Chemical	Number of Samples (Location)	Ranges of detected concentration (mg/kg)	Health-based CVs (mg/kg)	Type of CV	Number of detections greater than health-based CV	Is it a chemical of interest?
Arsenic	3 (School)	20.7 – 34.5	20	*C*-EMEG-ci [a]	**3**	**YES**
	2 (residences)	25.5 – 119			**2**	**YES**
Barium	3 (School)	121 – 205	10,000	*C*-EMEG-ci [a]	0	NO
	2 (residences)	155 – 292			0	NO
Cadmium	3 (School)	0.12 – 1.1	10	*C*-EMEG-ci [a]	0	NO
	2 (residences)	1.1 – 2.1			0	NO
Chromium	3 (School)	18.2 – 26.2	2,100	1997 R-SRL [b]	0	NO
	2 (residences)	25.5 – 65.6			0	NO
Copper	3 (School)	33.5 – 65.4	500	*I*-EMEG-ci [c]	0	NO
	2 (residences)	80.3 – 115			0	NO
Lead	3 (School)	15.8 – 67.9	400	2007 R-SRL [d]	0	NO
	2 (residences)	35.3 – 543			**1**	**YES**
Mercury	3 (School)	0.06 – 0.15	6.7	RBC [e]	0	NO
	2 (residences)	0.12 – 0.03			0	NO
Zinc	3 (School)	74.6 – 234	20,000	*C*-EMEG-ci [a]	0	NO
	2 (residences)	88.5 – 1110			0	NO

[a] *C*-EMEG-ci: Environmental Media Evaluation Guide for children's chronic exposure (≥ 365 days, ATSDR)
[b] 1997 R-SRL: 1997 Arizona Department of Environmental Quality Residential Soil Remediation Level
[c] *I*-EMEG-ci: Environmental Media Evaluation Guide for children's intermediate exposure (15-365 days, ATSDR)
[d] 2007 R-SRL: 2007 Arizona Department of Environmental Quality Residential Soil Remediation Level
[e] RBC: Risk-based Concentration (EPA Region 3)

Appendix E

E-1. Estimated chronic Daily Intake (DI) through water ingestion in milligrams per kilogram per day (mg/kg/day) compared to the health based guidelines

Chemical	Chemical concentration (Sample ID) (mg/L)	Chronic daily intake (mg/kg/day)		Health guideline (mg/kg/day)	Source	Does the child CDI exceed the health guideline?	Does the adult CDI exceed the health guideline?
		Child	Adult				
Arsenic	0.012 (H51)	0.0008	0.0003	0.0003	MRL[b]	**Yes**	No
	0.048 (H62)	0.003	0.0013			**Yes**	**Yes**
	0.017 (H80)	0.0011	0.0005			**Yes**	**Yes**
	0.05 (H65)	0.0032	0.0014			**Yes**	**Yes**
	0.15[a] (H67)	0.0002	0.00001			No	No
	0.011 (H68)	0.0007	0.0003			**Yes**	No
	0.015 (H70)	0.001	0.0004			**Yes**	**Yes**
	0.019 (H81)	0.0012	0.0005			**Yes**	**Yes**
	0.017 (SW02)	0.0011	0.0005			**Yes**	**Yes**
Boron	5.8[a] (H67)	0.05	0.0004	0.2	RfD[c]	No	No
Copper	0.23 (SW03)	0.0147	0.0063	0.01	MRL	**Yes**	No

[a] Irrigation well water: An adult is assumed to have incidental contact with the water while operating. It is assumed that the amount of time for these activities combined would account for 1 hour per day, 33 days per year for 30 years. A child is assumed to play in the water for 4 hours per day, 33 days per year for 6 years. The accidental ingestion rate is assumed to be 0.05 L per hour.
[b] MRL: Minimal Risk Level (ATSDR)
[c] RfD: Reference Dose (EPA)

E-2. Estimated chronic daily intake (DI) through incidental soil ingestion in milligrams per kilogram per day (mg/kg/day) compared to the health based guidelines for residences located near the Iron King Mine

Chemical	Chemical concentration (Property ID) (mg/kg)	Chronic daily intake (mg/kg/day)		Health guideline (mg/kg/day)	Source	Does the child CDI exceed the health guideline?	Does the adult CDI exceed the health guideline?
		Child	Adult				
Arsenic	32.7 (6)	0.0002	0.00002	0.0003	MRL[a]	No	No
	46.9 (8)	0.0003	0.00003			No	No
	30.47 (9)	0.0002	0.00002			No	No
	40.3 (10)	0.0003	0.00003			No	No
	31.97 (11)	0.0002	0.00002			No	No
	49.3 (12)	0.0003	0.00003			No	No
	32.3 (13)	0.0002	0.00002			No	No
	29.4 (14)	0.0002	0.00002			No	No
	40.7 (15)	0.0003	0.00003			No	No
	47 (16)	0.0003	0.00003			No	No
	49 (17)	0.0003	0.00003			No	No
	28.1 (19)	0.0002	0.00002			No	No
	51.6 (20)	0.0003	0.00004			No	No
	24 (S-01-0)	0.0002	0.00002			No	No
	36 (S-02-0)	0.0002	0.00002			No	No
	45 (S-02-1)	0.0003	0.00003			No	No
	29 (S-03-0)	0.0002	0.00002			No	No
	35 (S-04-0)	0.0002	0.00002			No	No
	44 (S-05-0)	0.0003	0.00003			No	No
	66 (S-06-0)	0.0004	0.00005			**Yes**	No
	33 (S-07-0)	0.0002	0.00002			No	No
	31 (S-08-0)	0.0002	0.00002			No	No
	34.5 (HS34SS)	0.0002	0.00002			No	No
	25.4 (HS35SS)	0.0001	0.00002			No	No
	20.7 (QA/QC HS36SS)	0.0001	0.00001			No	No
	25.5 (HS42SS)	0.0002	0.00002			No	No
	119 (HS43SS)	0.0008	0.00008			**Yes**	No

[a] MRL: Minimal Risk Level (ATSDR)

E-3. Estimated excess lifetime theoretical cancer risks for soil samples containing > 20 mg/kg arsenic

Samples above the Comparison Value (20 mg/kg)	Concentration (mg/kg)	Excess Lifetime Cancer Risk
HS-34SS	34.5	1.52×10^{-5}
HS-35SS	25.4	1.03×10^{-5}
HS-36SS[2]	20.7	9.11×10^{-6}
HS-42SS	25.5	1.12×10^{-5}
HS-43SS	119	5.24×10^{-5}
6	32.7	1.44×10^{-5}
8	46.9	2.07×10^{-5}
9	30.47	1.34×10^{-5}
10	40.3	1.77×10^{-5}
11	31.97	1.41×10^{-5}
12	49.3	2.17×10^{-5}
13	32.3	1.42×10^{-5}
14	29.4	1.29×10^{-5}
15	40.7	1.79×10^{-5}
16	47	2.07×10^{-5}
17	49	2.16×10^{-5}
19	28.1	1.24×10^{-5}
20	51.6	2.27×10^{-5}
S-01-0	24	1.06×10^{-5}
S-02-0	36	1.59×10^{-5}
S-02-1	31	1.36×10^{-5}
S-03-0	45	1.98×10^{-5}
S-04-0	29	1.28×10^{-5}
S-05-0	35	1.54×10^{-5}
S-06-0	44	1.94×10^{-5}
S-07-0	66	2.91×10^{-5}
S-08-0	33	1.45×10^{-5}

Appendix F

Calculations for the Exposure Dose

Non-cancer Health Effects

(a) Estimated Exposure Dose via Water Ingestion

$$CDI = \frac{Conc \times IR \times EF \times ED}{BW \times AT}$$

Parameter		Unit	Adult	Child
CDI	Chronic daily intake	mg/kg/day		
Conc	Water concentration	mg/L		
IR	Ingestion rate	L/day	2	1
EF	Exposure frequency	day/year	350	350
ED	Exposure duration	year	30	6
BW	Body weight	kg	70	15
AT	Averaging time	days	10,950	2,190

(b) Estimated Exposure Dose via Accidental Soil Ingestion

$$CDI = \frac{Conc \times B \times IR \times EF \times ED}{BW \times AT}$$

Parameter		Unit	Adult	Child
CDI	Chronic daily intake	mg/kg/day		
Conc	Soil concentration	mg/kg		
B	Bioavailability	—	50%	50%
IR	Ingestion rate	mg/day	100	200
EF	Exposure frequency	day/year	350	350
ED	Exposure duration	year	30	6
BW	Body weight	kg	70	15
AT	Averaging time	days	10,950	2,190

Cancer Health Effects

$$R = CDI_C \times SF$$

IEUBK Output