Health Consultation

Exposure to Lead and Arsenic in Surface Soil, Black Eagle Community

ANACONDA COPPER MINING COMPANY SMELTER AND REFINERY SITE

GREAT FALLS, CASCADE COUNTY, MONTANA

EPA FACILITY ID: MTD093291599

SEPTEMBER 15, 2016

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Division of Community Health Investigations
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

A health consultation is a verbal or written response from ATSDR or ATSDR's Cooperative Agreement Partners 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 or ATSDR's Cooperative Agreement Partner which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

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Prepared By:

Agency for Toxic Substances and Disease Registry
Division of Community Health Investigations
Western Branch

Table of Contents

1. **Executive Summary** ... 1
2. **Statement of Issues** ... 4
3. **Background** ... 4
   - Site Description ... 4
   - Demographic Statistics ... 5
   - Site Investigation and Evaluation ... 6
4. **Environmental Data** ... 7
   - Soil Sampling Design and Analysis ... 7
   - Soil Sampling Results ... 7
5. **Public Health Evaluation** ... 8
   - Exposure potential ... 8
   - Public health implications of exposure to arsenic and lead in surface soil ... 9
   - Cascade County Blood Lead Surveillance Study ... 13
   - Home gardening and consumption of homegrown produce ... 13
   - Limitations ... 15
6. **Conclusions** ... 17
7. **Recommendations** ... 18
8. **Public Health Action Plan** ... 18
9. **Authors and Contributors** ... 19
10. **References** ... 20

Appendix A. Figures ... 30
Appendix B. Tables ... 33
Appendix C. How to reduce exposure to lead and arsenic in soil ... 43
Appendix D. Ways to prevent high levels of lead in blood ... 45
Appendix E. How to prevent lead exposure at home ... 47
Appendix F. Derivation and intended use of comparison values ... 49
Appendix G. Arsenic and Lead exposure and health effects ... 54

Figures

Figure 1A. Area Map
Figure 2A. Demographic Statistics

Tables

Table 1B. Definition of Statistical Terms

Table 2B. Descriptive Statistics for Arsenic in Surface Soil

Table 3B. Descriptive Statistics for Lead in Surface Soil

Table 4B. Estimated Arsenic Doses within Surface Soil Concentration Ranges

Table 5B. Estimated Geometric Mean BLLs and Number of Properties with Maximum Soil Lead Levels at Various Lead Concentration Ranges

Table 6B. Default Exposure Assumptions

Table 7B. Possible Sources of Lead Exposure

Table 8B. Descriptive Statistics for CCHD Blood Lead Surveillance Study

Table 9B. Survey Results, CCHD Blood Lead Surveillance Study

Abbreviations

ACM	Anaconda Copper Mining Company
ARCO	Atlantic Richfield Company
ATSDR	Agency for Toxic Substances and Disease Registry
ALM	EPA Adult Lead Methodology
BLL	blood lead level (see µg/dL)
CCA	chromated copper arsenate
CCHD	Cascade County Health Department
CDC	Centers for Disease Control and Prevention
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act (Superfund)
CI	confidence interval
COPD	chronic obstructive pulmonary disease
CREG	ATSDR cancer risk evaluation guide
CSF	cancer slope factor
CTE	central tendency exposure
CV	comparison value
DHHS	Department of Health and Human Services
EMEG	ATSDR environmental media evaluation guide
EPA	U.S. Environmental Protection Agency
gram	metric unit of mass or weight. 1 gram is about 0.0022 pound, or one tsp of garden soil.
IARC	International Agency for Research on Cancer
IEUBK	Integrated Exposure Uptake Biokinetic Model for Lead in Children
Kilogram	one thousand grams (about 2.2 pounds)
LOAEL	lowest observed adverse effect level
MDEQ	Montana Department of Environmental Quality
microgram	one one-millionth of a gram. 1,000,000 micrograms = one gram
milligram	one one-thousandth of a gram. 1000 milligrams = one gram
mg/kg	milligrams (chemical) per kilogram (soil): unit of concentration
mg/kg-day	milligrams (chemical) per kilogram (body weight) per day: unit of exposure dose
MRL	ATSDR minimal risk level
NA	not applicable
ND	non-detect
NHANES	National Health and Nutrition Examination Survey
NPL	National priorities list (Superfund)
NOAEL	no observed adverse effect level
PPM	parts per million: unit of concentration equivalent to mg/kg

QA/QC	quality assurance/quality control
RBA	relative bioavailability
RCRA	Resource Conservation and Recovery Act
RfD	EPA reference dose
RME	reasonable maximum exposure
µg/day	micrograms per day
µg/dL	micrograms (chemical) per deciliter (blood): unit of concentration for BLL.
µg/L	micrograms (chemical) per liter (liquid): unit of concentration per unit volume

1. Executive Summary

Introduction	The Environmental Protection Agency (EPA) with support from the Montana Department of Environmental Quality (MDEQ) added the Anaconda Copper Mining Company Smelter and Refinery site (ACM) to the National Priorities List. The site includes residential properties that are adjacent to the former smelter in Back Eagle and outlying areas of Great Falls, MT. EPA is conducting a remedial investigation at the ACM site, and collected soil samples from residential areas as part of that investigation. EPA provided the Agency for Toxic Substances and Disease Registry (ATSDR) with soil data from sampling events and requested that ATSDR specifically focus its evaluating whether contact with arsenic and lead in residential soil could cause harmful health effects. The purpose of this health consultation is to: 1) document ATSDR's conclusions about the public health significance of exposures to arsenic and lead in residential surface soil; and 2) present recommendations on public health actions to prevent harm from those exposures to residents in these communities.
Conclusions	Following its review of surface soil sampling data, ATSDR reaches the following conclusions:
Conclusion 1	ATSDR concludes that exposure to **arsenic and lead found in surface soil of some properties is a public health hazard.**
Basis	Children with regular exposure to arsenic in surface soil over a longer period (months to years) are at greater risk for long-term adverse health effects, including skin changes such as hyperpigmentation and keratosis. Approximately six of 422 residential properties sampled have surface soil arsenic levels of potential public health concern for children. EPA classifies inorganic arsenic as a carcinogen (cancer-causing substance). At one of the 422 residential properties sampled, estimated lifetime excess cancer risks from exposure to arsenic in surface soil were outside EPA's target risk range. Overall, ATSDR considers arsenic soil exposures at most properties to represent a low increased cancer risk for adults. There are approximately 178 residential properties with lead levels in surface soil that have potential to increase blood lead levels (BLLs) above

the reference range in children who are regularly exposed to surface soil at these properties.

Accidentially or intentionally swallowing lead-contaminated soil could increase the potential for harmful health effects in young children and in the developing fetus of pregnant women. Other indoor and outdoor sources of lead can add to the burden of exposure. Since there is currently no known safe level of lead in blood for children, it is important to reduce lead exposure wherever possible.

Conclusion 2

Contact with arsenic and lead from eating homegrown produce or gardening is not a public health hazard.

Basis

Arsenic and lead concentrations are below levels of health concern for people contacting soil during gardening.

Although contact with deeper soil where arsenic contamination may be greater is possible during gardening activities, the frequency of exposure is low, which limits exposure.

Arsenic and lead uptake in garden produce would be minimal because the garden soil concentration and bioavailability are low.

Next Steps

Following its review of available information, ATSDR recommends that:

1. Residents take simple measures to reduce potential exposure to arsenic and lead in soil and to protect themselves, their families, and visitors (see Appendix C).
2. Parents follow the American Academy of Pediatrics Guidelines and have their children tested for blood lead at 1 and 2 years of age [AAP 2012].
3. Residents follow nutrition guidelines to minimize the amount of lead that could get absorbed into the body, such as eating a balanced diet that includes foods rich in iron, calcium and vitamin C (see Appendix D for more).
4. Residents take action to prevent lead exposure from other sources at home. Lead can be found in paint in homes built before 1979, in water from leaded pipes, imported items including lead pots and home remedies, and in some consumer products such as candies, cosmetics and jewely. Appendix E has more information on making homes lead-safe.

5. Environmental regulatory agencies continue ongoing efforts to reduce arsenic and lead exposure from residential soil.
6. Local Health Department implement a community-based health education outreach program to raise awareness of lead and arsenic exposure hazards.

For More Information	Call ATSDR at 1-800-CDC-INFO and ask for information on the ACM Smelter and Refinery site in Great Falls, MT.

2. Statement of Issues

The United States Environmental Protection Agency (EPA) requested that the Agency for Toxic Substances and Disease Registry (ATSDR) evaluate the public health significance of lead and arsenic in surface soil in residential areas adjacent to the former Anaconda Copper Mining Company Smelter and Refinery NPL site (ACM). Residential properties including areas of Black Eagle and Great Falls are included as part of the ACM remedial site investigation (see Figure 1A, Appendix A).

Specifically, EPA requested that ATSDR focus on exposures to arsenic and lead in residential surface soil, and address community concerns about gardening and eating homegrown produce.

Sampling showed arsenic concentrations in surface soil at some properties that exceeded ATSDR's health guidance value. Additionally, soil lead levels in some of the yards are high enough that regular exposure could result in blood lead levels above the CDC reference level. ATSDR scientists evaluated how people contact lead and arsenic in residential soil, the magnitude of any potential public health harm, and the need for public health intervention.

The purpose of this health consultation was to: 1) document ATSDR's conclusions about the public health significance of exposures to arsenic and lead in residential surface soil, 2) address community concerns about home gardening, and 3) present recommendations and public health actions that will reduce potential harm to residents in these communities.

3. Background

Site Description

The ACM site is a former metals refinery next to the unincorporated community of Black Eagle along the Missouri River in Cascade County, Montana. The ACM Site is located in the northeast quadrant of Great Falls, Montana, on the north side of the Missouri River adjacent to the Black Eagle Dam. The city of Great Falls is located to the south across the Missouri River from the site, and the community of Black Eagle is located to the west and northwest of the former refinery site. The ACM site covers approximately 427 acres on the northern bank of the river between Black Eagle and Great Falls. The northern and southern community soils areas of interest encompass the Black Eagle community. Outlying areas of the site include a portion of Great Falls in proximity to the Missouri River and areas to the north and northeast of the former smelter site (Figure 1A).

Smelting and Refining

The Boston & Montana Consolidated Copper and Silver Mining Company began construction of the first smelter at the 427-acre metals refinery site in 1892. The company produced copper, zinc, arsenic, and cadmium. Operations began in 1893 when ore from mines in Butte, Montana was concentrated, smelted, and refined. Electrolytic and furnace refineries also operated at the site. Anaconda Copper Mining Company bought the property in 1910 and continued smelting and refining activities until it ceased operation in 1972 [EPA 2011c].

Impact on surrounding community

A 501-foot tall plant stack was part of the smelter operation at the refinery site for years before pollution control technology was common. The smoke from the stack allowed lead, arsenic and other metals to disperse in the air over a wide area around the facility. The stack went into service in 1893 and continued operation until 1972.

Chemical assays of flue dust and top soil near the stack performed in 1904 and 1905 concluded that the stack deposited over 40 pounds of arsenic trioxide (As_20_3) per acre by March 1904 at a distance 6.24 miles from the stack. Additional sampling at new locations in 1905 concluded that almost 14 pounds of arsenic trioxide contaminated soil up to 2.5 miles from the stack. An internal Anaconda Copper Mining Company Memorandum from 1951 stated that the stack emitted 15 pounds of arsenic into the air every 24 hours. For these reasons, aerial deposition from the smelter smoke between 1893 and 1972 is the most likely mechanism of contaminant transport and contamination of residential soil in the community of Black Eagle and other areas near the former smelter [EPA 2011c].

At the company, it was a common practice to dump tailings, slag, and flue dust into the adjacent Missouri River. Property owners and communities along the Missouri River filed numerous complaints involving water quality issues, and slag and smelter waste clogging the Missouri River downstream of the ACM Smelter and Refinery.

Black Eagle Community background

Workers at the nearby Great Falls Refinery founded the community of Black Eagle in 1892. The older section of Black Eagle lies between U.S. Highway 87 and the former smelter and refinery facility. The community has a rich heritage, home to immigrants from as many as twenty nationalities who came to America in the late 1800s and early 1900s. Most worked at the smelter and refinery that was part of their neighborhood. Residents are proud of their community and known for their camaraderie and loyalty to families, friends, and community [EPA 11c].

Land use

Approximately eighty percent of the homes in Black Eagle date before the 1960s, with about forty-five percent built before 1939. In addition to residential properties, churches, schools, and parks are included within the site boundaries. Gardening is a popular activity in the community. Other land use in the surrounding area varies between light industry, commercial and retail.

Demographic Statistics

Using 2010 U.S. Census data and an area-proportion spatial analysis technique, ATSDR calculated that 5155 persons live within one mile of the boundaries of the ACM Smelter site. At the time of the 2010 census, about 612 (12%) were age 65 and older, 386 (7%) children 6 years or younger, and 930 (18%) female of reproductive age. Figure 2A, Appendix A, provides a graphic representation and additional demographic statistics.

Site Investigation and Evaluation

This section provides a brief discussion of site investigation and corrective activities.

Anaconda Copper Mining Co. Smelter and Refinery

In 1973, the company initiated closure operations at the former smelter facility, including demolition and removal of buildings, backfilling of basement substructures, and salvaging and on-site burial of flue dust, granulated slag, asbestos-containing material, demolition debris, and other wastes. A soil cover ranging from six-inches to five-feet thick covered the wastes. There are no records of any regulatory oversight of the closure activities [EPA 2011c].

In the mid-1980s, a preliminary assessment report recommended the need for further investigations at the site. The Montana Department of Environmental Quality (MDEQ) requested that EPA investigate the site.

In the mid-2000s, EPA initiated a formal site investigation. Initial soil studies included residential yards in Black Eagle, and that study identified a large area in the community contaminated with arsenic and lead.

In 2011, EPA with support from MDEQ added the ACM Smelter and Refinery site to the National Priorities List of Superfund sites. Under an agreement with the EPA and MDEQ, ARCO began investigation and cleanup work at the site to address the impacts from past facility operations.

BNSF Rail corridor and Art Higgin's Memorial Park

The Burlington Northern and Santa Fe Railroad (BNSF) rail corridor runs along the southern boundary of the Black Eagle community, with the rail right-of-way adjacent to Art Higgin's Park. Past smelter and rail operations contaminated surface soil next to the rail bed.

In 2013, EPA Region 8 Montana contacted ATSDR for assistance in evaluating sampling data collected from the BNSF railroad corridor and Higgins Park. EPA asked ATSDR to provide input on three issues: 1) Identify areas of the rail corridor that may pose short-term public health exposure concerns; 2) Recommend appropriate time-critical actions that may be necessary to mitigate exposures to surface soil contaminants; and 3) Identify data gaps or areas of that may require additional investigation. ATSDR evaluated sampling data from the park and adjacent rail corridor and concluded that short-term exposure to arsenic in surface soil was not a health hazard for children who do not intentionally eat soil during play activities. However, localized areas of higher contamination warranted corrective action as recommended in a letter health consultation to the EPA Region 8 Montana office [ATSDR 2013b].

The ongoing BNSF rail corridor remedial investigation is concurrent with remedial investigations at the ACM Smelter site.

4. Environmental Data

With oversight from EPA and MDEQ, ARCO conducted additional environmental sampling and remedial investigation activities in residential parcels in the site study area [Figure 1a].

Soil Sampling Design and Analysis

During 2011-2013, Atlantic Richfield initiated soil sampling in areas of Black Eagle and Great Falls. The objective of the sampling was to characterize the distributions of metals in the upper 18 inches of soil. In Black Eagle, 391 residential properties were sampled. Including residential properties sampled in northern Great Falls and outlying unincorporated areas adjacent to Black Eagle, the total number of properties sampled increased to 422.

Each residential property was divided into individual components (i.e., front yard, back yard, flower garden, rock garden, vegetable garden, earthen drive, play area, bare area, and drip zone). Composite samples were collected from each yard component at various depth intervals (0-2, 2-6, 6-12, and 12-18 inches below ground surface). Most residential areas are covered with grass; consequently, a surface sample was collected from immediately beneath the vegetation, or in the absence of vegetation, 0 to 2 inches below ground surface [Pioneer 2014].

Pace Analytical, located in Minneapolis, Minnesota, performed the sample analyses and associated laboratory QA/QC on all soil and field QC samples. All samples were analyzed using the analytical methods identified in the *Black Eagle Residential Soils Quality Assurance Project Plan (QAPP)* and *Addendum No. 1, Black Eagle Residential Soils Quality Assurance Project Plan (QAPP) ACM Smelter and Refinery Site Great Falls, Cascade County, Montana* [Pioneer 2014].

Soil Sampling Results

In this document, ATSDR reports on the results of our evaluation of exposure to arsenic and lead in surface soil. ATSDR defines surface soil as 0–2 inches below ground surface.

Appendix B includes tables providing descriptive statistics[1] for arsenic and lead concentrations detected in surface and subsurface soil sampled in Black Eagle, Great Falls and outlying areas. ATSDR calculated maximum and average values at the property level using data from individual property components.

Table 2B provides descriptive statistics for arsenic in surface soil.

Table 3B provides descriptive statistics for lead in surface soil. ATSDR does not have a comparison value for screening lead in surface soil since currently there is no clear threshold for some of the more sensitive health effects associated with lead exposure.

[1] Table 1B, Appendix B, provides a definition of statistical terms used.

5. Public Health Evaluation

Exposure potential

To determine whether people have the potential for exposure to harmful substances, ATSDR examines the connection between a contaminant source and a person exposed to the contaminant.

Completed exposure pathways have five components:

1. A contamination source (e.g. environmental release into air or a waste pile),
2. Transport through an environmental medium (e.g. wind or surface water runoff),
3. An exposure point (e.g. residential yard),
4. A route for exposure (e.g. touching and accidentally swallowing contaminated soil), and
5. People.

These components are like links in a chain. Each link must be present for there to be an exposure. If any are missing, the pathway is broken and no exposure or possibility of health harm can occur.

At the ACM site, ATSDR considers exposure to residential surface soil to be a completed exposure pathway. Surface soil could have been impacted by aerial deposition from releases to the environment when the smelter was in operation (e.g. metals released in smoke stacks moving as wind-blown particulates and landing on the soil), as well as through surface water runoff from these facilities and flooding. Many homes in the area date prior to 1978, before there was a ban on the use of lead in house paint. Some homes may still have lead paint that could be a source of exposure to occupants. Deteriorating lead paint on window frames, the outside of homes or other surfaces could contaminate soil or indoor dust. It is possible that some residents obtained contaminated aggregate materials from the ACM facility as soil fill material.

Exposure to contaminants in surface soil occurs primarily through incidental (accidental) ingestion of soil particles adhered to skin via hand-to mouth transfer. Preschool age children tend to swallow more soil than other age groups due to more contact with soil through their play activities, mouthing of objects and hand-to-mouth behavior. Children in elementary school, teenagers, and adults swallow much smaller amounts of soil. Some children exhibit a rare and infrequent behavior (called soil pica) involving intentional consumption of non-food items like soil. Groups that are at an increased risk for this behavior are children typically 1–3 years of age. The amount of vegetative or other soil cover in an area, the amount of time spent outdoors, and weather also influence the magnitude and frequency of contact with soil contaminants.

This document focuses on a residential exposure scenario with primary exposures involving direct contact with the surface soil within the property. The primary route of exposure would be incidental (unintentional) ingestion of soil and dust during play, work and gardening activities. The evaluation focuses primarily on the most highly exposed individual, in this case a young child exposed to yard soil during play and gardening activities. Residents would also have exposure to interior dust originating from soil tracked in or blown into the home. Additional sources of exposure to lead and arsenic in soil involve inhaling soil particulates (dust) and skin contact. These minor exposure pathways do not contribute significantly to total exposure in this scenario, so they are not included in this evaluation.

Residential gardens may be a source of exposure to soil contaminants, primarily via consumption of soil on the surface of the produce, and accidental ingestion of soil during or following gardening activity. Plant uptake of lead and arsenic into the produce is possible, but very low relative to the garden soil for the types of produce grown and less bioavailable forms of arsenic and lead. This evaluation accounts for incidental ingestion of garden soil and garden soil-derived interior dust in the home. Further discussion of exposures from home gardening is included later in this section.

Public health implications of exposure to arsenic and lead

In this section of the document, ATSDR addresses the question of whether exposure to arsenic and lead at the concentrations detected would result in adverse health effects. While the relative toxicity of a chemical is important, several factors influence the human body's response to a chemical including:

- The concentration (how much) of the chemical the person was exposed to,
- The amount of time the person was exposed (how long), and
- How the person was exposed (through breathing, eating, drinking, or contact with something containing the chemical).

Lifestyle factors (for example, occupation and personal habits) have a major impact on the likelihood, magnitude, and duration of exposure. Individual characteristics such as age, sex, nutritional status, overall health, and genetic constitution affect how a human body absorbs, distributes, metabolizes, and eliminates a contaminant. A unique combination of all these factors will determine the individual's physiologic response to a chemical contaminant and any harmful health effects the individual may suffer from exposure.

As part of its evaluation, ATSDR typically estimates exposure doses for children and adults. Estimating a dose requires identifying how a chemical enters the body, how often, and how long someone has exposure to the contaminant. Exposure doses help ATSDR determine the likelihood that exposure to a chemical might be associated with harmful health effects.

Key steps in ATSDR's analysis involve: (1) screening environmental sampling data against health comparison values; 2) comparing the estimated site-specific exposure doses with observed effect levels reported in scientific studies from the biomedical literature; and 3) carefully considering study parameters in the context of site-specific exposures [ATSDR 2005]. This analysis requires the examination and interpretation of reliable substance-specific health effects data. This includes reviews of epidemiologic (human) and experimental (animal) studies. ATSDR's chemical-specific toxicological profiles summarize these studies. Each peer-reviewed profile identifies and reviews the key literature that describes a hazardous substance's toxicological properties. When evaluating a site, ATSDR scientists review information in the scientific literature to ensure that public health evaluations reflect current knowledge.

Overall, assessing the relevance of available epidemiologic and experimental studies with respect to site-specific exposures requires both technical expertise and professional judgment. Because of uncertainties regarding exposure conditions and the harmful effects associated with environmental levels of chemical exposure, definitive answers about whether health effects will or will not occur are not currently possible. However, providing a framework that puts site-specific exposures and the potential for harm in perspective is possible [ATSDR 2005].

Appendix G summarizes relevant epidemiologic and toxicological information for arsenic and lead.

For the defined exposure scenario, ATSDR estimated arsenic exposure from incidental ingestion of surface soil using the exposure models depicted in exhibit 1 and 2.

Exhibit 1: Exposure Dose Equation for Ingestion of Soil

$$D = \frac{C \times IR \times EF \times AF \times CF}{BW}$$

where,

D	=	exposure dose in milligrams per kilogram per day (mg/kg/day)
C	=	chemical concentration in milligrams per kilogram (mg/kg)
IR	=	intake rate in milligrams per day (mg/day)
EF	=	exposure factor (unitless)
AF	=	bioavailability factor
CF	=	conversion factor, 1×10^{-6} kilograms/milligram (kg/mg)
BW	=	body weight in kilograms (kg)

As part of its evaluation, ATSDR also calculated cancer risk estimates using the US EPA arsenic oral CSF of 1.5 $(mg/kg/day)^{-1}$. Cancer risk estimates represent a probability of an extra cancer in an exposed population during a lifetime of exposure. (Exhibit 2).

Exhibit 2: Cancer Risk Equation

$$\textbf{Age-Specific Cancer Risk} = D \times CSF \times (ED / 78)$$

where,

D	=	age-specific exposure dose in milligrams per kilogram per day (mg/kg/day)
CSF	=	cancer slope factor in $(mg/kg/day)^{-1}$
ED	=	age-specific exposure duration in years

ATSDR calculated reasonable maximum exposure (RME), which refers to persons who are at the upper end of the exposure distribution (approximately the 95th percentile). Using the mean (or average) value as the exposure point concentration at that property is most representative of the concentration that a resident would contact over time. Most people would not exclusively contact the maximum concentration. In the absence of complete exposure-specific information regarding soil exposures, ATSDR applied several conservative exposure assumptions to define site-specific RME (see **Table 6B**,

Appendix B). An evaluation of mineralogy and bioaccessibility of residential soil in Black Eagle determined a site-specific arsenic RBA of 29% [Environ 2014, 2015].

In **Table 4B**, ATSDR provides estimated arsenic doses grouped by surface soil concentration. This table includes the number of properties sampled with average arsenic concentrations within specific ranges. Under the defined scenario, arsenic soil concentrations greater than 685 ppm are a level of public health concern for acute (short-term) exposures in this group because the estimated doses approach the acute (short-term) arsenic LOAEL of 0.05 mg/kg-day. The maximum arsenic concentration in residential surface soil was 581 ppm. ATSDR does not anticipate short-term health hazards from contact with soil containing arsenic at this concentration.

Under the defined exposure scenario, ATSDR would not expect adults to experience *noncancer* harmful health effects from long-term exposures to arsenic in surface soil in properties sampled in Black Eagle, Great Falls or outlying areas as part of the ACM site investigation. For chronic[2] child exposures (i.e., those lasting a year or longer), arsenic levels in surface soil greater than 60 ppm exceed the MRL of 0.0003 mg/kg-day. Sample results show six properties have average arsenic concentrations in surface soil above 60 ppm (**Table 4B**). Under the same exposure scenario, arsenic concentrations greater than 400 ppm exceed the threshold level of 0.002 mg/kg-day for dermal effects (hyperpigmentation and hyperkeratosis). Sample results show one property has a maximum arsenic concentration exceeding 400 ppm in surface soil.

Note that it is more likely that children will come into frequent, repeated contact with the soil in yards that contain gardens or play areas with bare soil. At the ACM Smelter site, ATSDR considers long-term exposure to arsenic concentrations above 60 ppm in surface soil a potential public health concern for children, especially at properties with gardens and play areas with bare soil.

With regard to cancer risk, ATSDR calculated lifetime excess cancer risk estimates using the formula shown in Exhibit 2 and the EPA arsenic oral CSF of 1.5 $(mg/kg/day)^{-1}$. Arsenic surface soil levels >150 ppm indicate levels exceeding cancer risk over 1×10^{-4} (or one additional cancer over a lifetime in a population of 10,000 similarly exposed) under the defined exposure scenario. The EPA defines a risk range of 1×10^{-6} to 1×10^{-4}, used to support regulatory decisions regarding remedial activities. This risk estimate is a statistical probability and differs from actuarial (measured) risks such as injury or death from an auto accident. This cancer risk estimate applies to a population, not an individual - the actual number of people in Black Eagle who may experience adverse cancer effects from exposure to arsenic in soil is unknown, and could be as low as zero. See **Appendix G** for an example risk calculation.

These exposure estimates intentionally incorporate several health-protective assumptions that would likely overestimate true health risks. For example, ATSDR assumed daily soil contact 365 days/year, however historical climate data indicate that for six or seven months of the year the ground is covered with snow, is muddy or frozen, limiting direct contact with soil as well as soil-derived dust.

The adverse health effects observed in the studies on arsenic ingestion involve daily, long-term ingestion of elevated arsenic levels in drinking water. These exposures at the ACM site involve soil, not drinking water. This creates uncertainty about the degree of absorption of the arsenic in soil relative to the water

[2] Note that some preschool children might intentionally eat soil once during their preschool years, while others might go through a stage of eating soil several times during a week or even over several months [ATSDR 2014]. Overall, though, intentionally eating soil is not considered to occur over the long-term, i.e., every day for longer than a year.

that was the source of exposure in the health studies. ATSDR considers arsenic exposures from soil at most properties to represent a low health risk for non-cancer and cancer endpoints.

Biokinetic lead model application to exposure evaluation

EPA's Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK) estimates the probability of exceeding a defined blood lead level from exposure to multiple environmental sources including air, water, soil, dust, food, and paint.

The IEUBK model integrates exposure with pharmacokinetic modeling to predict blood lead concentrations. The IEUBK model is composed of four components. The first is an exposure model that relates environmental lead concentrations to age-dependent intake of lead into the gastrointestinal tract. Second, an absorption model that relates lead intake into the gastrointestinal tract and lead uptake into the blood. The third, a biokinetic model that relates lead uptake in the blood to the concentrations of lead in several organ and tissue compartments. The fourth is a model that accounts for uncertainty in exposure and for population variability in absorption and biokinetics [EPA 1994].

The IEUBK model is a predictive tool for estimating changes in blood concentrations as environmental lead exposures change [EPA 1994]. The IEUBK model allows the user multiple options to modify the exposure situation in estimating a child's blood lead concentration. The reliability of the results obtained using the model is dependent on the selection of the model inputs and assumptions.

ATSDR scientists used the IEUBK model (IEUBKwin Model 1.1 Build 11) using default parameters for model inputs except for a site-specific soil/interior dust ratio of 0.45, site-specific soil lead bioavailability, and a target blood lead level of 5 micrograms lead per deciliter blood (µg/dL), equivalent to the current CDC reference value. **Appendix G** includes an example of the IEUBK model output assuming a soil lead concentration of 600 ppm.

In **Table 5B**, ATSDR provides the IEUBK estimated probability of exceeding a BLL of 5 µg/dL and the geometric mean BLLs for various lead concentration ranges. ATSDR also provides in this table the number of properties with lead concentrations within the specified ranges.

Based on results of the IEUBK model, there are approximately 178 residential properties with lead in surface soil that are a potential health hazard. Children (ages 1 to 7 years old) who live or regularly visit these properties could be exposed to lead in surface soil that could result in blood lead levels above the current BLL reference concentration of 5 µg/dL. In addition, pregnant women exposed to increasing soil lead levels have the potential for increased BLLs in their developing fetuses. Other indoor and outdoor sources (see **Table 7B**) may result in additional sources of lead exposure in addition to soil.

Lead cannot be eliminated from the environment so there will always be some residual level following cleanup actions at lead-contaminated sites. Non-site-specific sources of lead (e.g., lead-based paint in homes built before 1978) can be an ongoing exposure source. Reducing exposure by controlling contamination sources and taking additional steps to make the home environment lead-safe can help prevent elevated blood lead levels (see **Appendices D and E for more information**).

Cascade County Blood Lead Surveillance Study

During the fall of 2013, the Cascade City County Health Department conducted a countywide effort to survey current blood lead levels in the local population. The study primarily focused on young children (< 5 years) enrolled in Medicaid. However, media promotion and public education brought in additional children and adults.

Outreach efforts: CCHD took several measures to inform the public. CCHD mailed 2,578 letters and educational fact sheets to families based on Medicaid enrollment files. Water bills included an informative flyer for families in Black Eagle. All families from Black Eagle on the Medicaid enrollment file and 255 individuals from Cascade County whose letters were returned were contacted and informed of this study by phone. Local TV stations aired a public service announcement advertising the study. Two community clinics in Black Eagle provided a walk-in opportunity to participate, with an option for a home appointment.

Participants: In total 71 participants were tested. Thirty-nine were children age 1-5 years, 12 participants were age 6-17 years and 20 were adults. Twenty-seven residents of Black Eagle were tested. Of these Black Eagle residents, four were 1-5 years of age, five were 6-17 years of age and 18 were years and older.

Results: As CCHD received sampling results, a nurse gave every family a courtesy phone call explaining the test results. CCHD documented information from the participant (and their parent or guardian) about their home, lifestyle choices and possible lead exposures. **Table 8B** contains descriptive statistics of the study results. **Table 9B** contains results of a survey of study participants on risk factors associated with elevated blood lead levels.

Due to insufficient specimens for four of the participants, blood lead results were available for only 67 participants. Of these 67 individuals, 7.3 µg/dL was the highest blood lead level; this result belonged to an adult resident of Black Eagle. This was the only result in the study that exceeded the current CDC blood lead reference value of 5 µg/dL. The next highest blood lead result, 3.8 µg/dL, belonged to a young child living outside of Black Eagle. The highest blood lead result for a child resident of Black Eagle was 1.5 µg/dL. Among all results, 23.9% had a detectable level of lead in the sample provided based on a detection limit of one µg/dL.

Home gardening and consumption of homegrown produce

Gardening in Black Eagle

The Black Eagle Technical Advisory Committee conducted a brief survey of residents to gather information on gardening practices. The survey results allow for the following general characterization of Black Eagle gardening practices [ENVIRON 2015]:

- Some residents grow produce in their yards and, while gardens range in size, many are 50 square feet or less in area.
- Most gardens likely are not in raised beds and many are located near a road or alleyway, drip line, or painted building.
- Amending and tilling soil are common practices.
- Gardeners harvest produce over a period of roughly four months of the year and many residents are likely to preserve a portion of their harvest for later consumption.

- A variety of above ground and below ground crops are grown, but most gardens include tomatoes.
- Many, if not most gardeners will remove outer layers of leafy crops and peel root vegetables.
- Nearly all gardening residents are likely take at least one action to reduce soil contact while gardening (e.g., produce washing, hand washing).
- The quantity of produce grown by Black Eagle residents is unknown. What proportion of total diet consists of homegrown produce is uncertain.

Impact of arsenic and lead contamination on garden produce

Garden soil and produce could be impacted by aerial deposition (particles landing on the surface of the produce) and root uptake (movement of the chemicals from the soil into the produce). Garden produce can absorb small amounts of lead and arsenic from the soil, and soil/dust particles containing arsenic and lead can stick to the surface of leaves and root vegetables. How much accumulates depends on many factors such as the kind of produce, soil concentration, bioavailability of the metals and soil chemistry.

One study showed that all garden vegetable plants grown in contaminated soil accumulate lead to some level, and that the majority of the contamination is in the plant root. Smaller levels of lead were in the plant shoot, with low to non-detectable levels in the fruit (e.g., tomatoes, peppers, beans, and zucchini) [Finster et al. 2004]. Most lead compounds are relatively insoluble; therefore, natural plant uptake is minimal [Barocsi et al. 2003]. Garden plants grown in contaminated soil can take up small amounts of arsenic in their roots [Thorton 1994; Samsøe-Petersen et al. 2002; ATSDR 2007a].

Between 2012 and 2015, ATSDR evaluated surface soil and garden produce exposures in residential neighborhoods impacted by the 35th Avenue industrial site in Birmingham, Alabama. Arsenic and lead concentrations in residential soil near the site were similar to Black Eagle residential soil. As part of the evaluation, samples of homegrown produce were collected from gardens and analyzed for arsenic and lead. In total, twenty produce samples were tested including tomatoes, cucumbers, collard greens, zucchinis, green onion, okra, and peppers. Arsenic was detected in only one sample (unwashed collard green) at a concentration of 0.069 ppm. Lead was detected in four garden produce samples: 0.063 ppm (unwashed cucumber), 0.16 ppm (unwashed collard green), 0.43 ppm (unwashed tomato), and 0.57 ppm (washed green onion) [ATSDR 2015].

ATSDR evaluated arsenic and lead concentrations in garden produce and determined they were not a health hazard to people who ate them [ATSDR 2015]. Unwashed vegetables had the highest arsenic and lead levels. Thoroughly cleaning the produce and peeling root vegetables would significantly reduce or even eliminate this exposure source.

Black Eagle garden soil sampling

During the investigation, 83 gardens were sampled with results corresponding to four depth intervals (0-2, 2-6, 6-12, and 12-18 inches). Soil sampling showed that arsenic concentrations increased with depth. Developing garden areas would result in soil mixing over time, so sampling results were reported as a depth-weighted average concentration over the 0-18 inch depth interval. Lead averaged of 185 ppm, while arsenic averaged 29 ppm.

The EPA Technical Review Workgroup (TRW) provides recommendations regarding gardening and reducing exposure to lead-contaminated soil [EPA 2013c]. The TRW defines a “potential risk” category for lead concentrations in gardens ranging from 100 ppm (low risk) to 1,200 ppm (high risk). Thirty-seven percent of Black Eagle gardens were below the "low risk" category of 100 ppm, and none of the sampled gardens exceeded the "high risk" category of 1,200 ppm. Lead in gardens averaged 185 ppm, while corresponding yards averaged 195 ppm ($p=0.003$) [ENVIRON 2015]. For arsenic, 49% of gardens were equal to or below the State of Montana background concentration limit of 22.5 ppm [MDEQ 2014], and 87% averaged below 40 ppm.

Exposure to arsenic and lead from gardening and eating homegrown produce in Black Eagle is not a public health hazard.

The main source of exposure to lead and arsenic from home gardening is ingesting contaminated soil on the exterior of the produce and incidental ingestion of garden soil during gardening activities. Soil sampling showed that arsenic concentrations increased with depth. Gardening increases the potential for contact with shallow soil below 2 inches.

Depth-weighted average concentrations of arsenic and lead were below levels of health concern for exposure during gardening. Although contact with deeper soil is possible during gardening and landscaping, frequency of exposure is low further limiting exposure. Although sample data are not available for homegrown produce in Black Eagle, arsenic and lead uptake in garden produce should be minimal given the concentrations in garden soil and the low bioavailability of lead and arsenic. The results of produce sampling at the 35th Avenue site supports this conclusion.

People who are concerned may reduce exposure to arsenic and lead from home gardening by peeling root crop vegetables, such as carrots and potatoes. Other ways to minimize exposures include removing dirt from garden produce before bringing it into the home and planting in raised-bed gardens with clean soil. Washing homegrown produce thoroughly will also remove soil particles that may contain contaminants. See **Appendix C** for steps people can take to reduce exposure to arsenic and lead in soil.

Limitations

There are recognized uncertainties in ATSDR's evaluation, though providing a framework that puts site-specific exposures and the potential for harm into perspective is one of the primary goals of this health evaluation process [ATSDR 2005]. This public health evaluation has several limitations:

- Estimating a dose requires assumptions about how exposure occurs. These assumptions are intentionally conservative and likely overestimate the magnitude. Individual exposures will vary depending on lifestyle and individual characteristics that influence contact with contaminated soil.
- Although sample location, collection, and quality assurance procedures were established and resulted in a consistent, well-documented data set, ATSDR notes that not all property owners allowed access for sampling activities. The untested properties may have elevated levels of soil contamination.
- ATSDR's evaluation required the examination and interpretation of reliable, substance-specific, health effects data. The evaluation included a review of epidemiologic (human) and experimental (animal) studies. A study based on human data would hold the greatest weight in describing relationships between a particular exposure and a human health effect. However, in

some cases, only animal studies were available, increasing uncertainties about whether effects seen in animal studies are applicable to human populations.

- Substance-specific health effects data are in terms of "ingested dose" rather than "absorbed dose." With regard to exposure to arsenic and lead in soil, the distinction between ingested dose and absorbed dose is important. Generally, lead and arsenic in soil are absorbed into the body to a much lesser extent than when it is in drinking water or food.
- The IEUBK model depends on reliable estimates of site-specific information for several key parameters that include the following:
    - Lead concentration in outdoor soil (fine fraction) and indoor dust,
    - Soil/dust ingestion rate,
    - Lead concentration in deteriorating paint and indoor paint dust,
    - Individual variability in child blood lead concentrations affecting the Geometric Standard Deviation (GSD) and,
    - Rate and extent of lead absorption from soil (i.e., bioavailability).
- There are several limitations to the IEUBK model. The model was designed to evaluate relatively stable exposure situations (i.e., every day), rather than rapidly varying exposures or exposures occurring for less than a year. The model applies only to age groups seven years and younger. Additionally, it does not take into account the soil cover (e.g., vegetation), and whether there is limited contact with the bare soil. Furthermore, the model assumes that children do not have any nutritional challenges or intentionally eat soil (i.e. pica behavior).
- In the CCHD BLL surveillance, over 2,578 letters went out to eligible individuals. Seventy-one individuals participated. This reflects about a three percent response rate. As a result, there are not enough data to support the conclusion that there is no lead exposure outside normal ranges in the community. The small sample size of individuals tested does not represent the BLL in the broader community with much certainty.

  Fortunately, no children tested showed BLL outside the current reference range. Given multiple sources of lead exposure in the community, it is possible that there are children with elevated BLL not included in the study. The surveillance program provides BLL data that represent a snapshot in time and not indicative of longer-term trends. ATSDR supports future BLL sampling that would identify unusual lead exposures in Black Eagle and the greater community.

6. Conclusions

1. **Exposure to arsenic and lead found in surface soil of some properties is a public health hazard.**

   - Children with regular exposure to arsenic in surface soil over a longer period (months to years) are at greater risk for long-term adverse health effects, including skin changes such as hyperpigmentation and keratosis. Approximately six of 422 residential properties sampled have surface soil arsenic levels of potential public health concern for children.

   - EPA classifies inorganic arsenic as a carcinogen (cancer-causing substance). At one of the 422 residential properties sampled, estimated lifetime excess cancer risks from exposure to arsenic in surface soil exceeded EPA's target risk range. Overall, ATSDR considers arsenic soil exposures at most properties to represent a low increased cancer risk in adults.

   - There are approximately 178 residential properties with lead levels in surface soil that might increase blood lead levels (BLLs) above the reference range in children who are regularly exposed to surface soil at these properties.

   - Accidentially or intentionally swallowing lead-contaminated soil could increase the potential for harmful health effects in young children and in the developing fetus of pregnant women. Other indoor and outdoor sources of lead can add to the burden of exposure. Since there is currently no known safe level of lead in blood for children, it is important to reduce lead exposure wherever possible.

2. **Contact with arsenic and lead from eating homegrown produce or gardening is not a public health hazard.**

   - Arsenic and lead concentrations are below levels of health concern for people contacting soil during gardening.
   - Although contact with deeper soil where arsenic contamination may be greater is possible during gardening activities, the frequency of exposure is low which limits exposure.
   - Arsenic and lead uptake in garden produce would be minimal because the garden soil concentration and bioavailability are low.

7. Recommendations

Following its review of available information, ATSDR recommends that:

1. Residents take simple measures to reduce potential exposure to arsenic and lead in soil and to protect themselves, their families, and visitors (see Appendix C).
2. Parents follow the American Academy of Pediatrics Guidelines and have their children tested for blood lead at 1 and 2 years of age [AAP 2012].
3. Residents follow nutrition guidelines to reduce the amount of lead that could get absorbed into the body, such as eating a balanced diet that includes foods rich in iron, calcium and vitamin C (see Appendix D for more).
4. Residents take action to prevent lead exposure from other sources at home. Lead can be found in paint in homes built before 1979, in water from leaded pipes, imported items including lead pots and home remedies, and in some consumer products such as candies, cosmetics and jewely. Appendix E has more information on making homes lead-safe.
5. Environmental regulatory agencies continue ongoing efforts to reduce arsenic and lead exposure from residential soil.
6. Local Health Department implement a community-based health education outreach program to raise awareness of lead and arsenic exposure hazards.

8. Public Health Action Plan

The purpose of the public health action plan is to ensure that this evaluation not only identifies potential and ongoing public health hazards, but also provides a plan of action designed to mitigate and prevent adverse human health effects resulting from exposure to hazardous substances in the environment.

- ATSDR is providing its recommendations to community members, local, state and federal agencies involved with the ACM site.

- ATSDR will collaborate with partners to develop and implement a community-based health education program to raise awareness of health hazards of exposure to arsenic and lead.

  Design and implementation of this program will complement the efforts by local, state and federal agencies to address the health concerns of the community and actions to identify and reduce exposure to harmful substances at the ACM site.

9. Authors and Contributors

Scott Sudweeks
ATSDR Region 8
Denver, CO

Danielle M. Langmann
ATSDR Division of Community Health Investigations
Atlanta, GA

Barbara Anderson
ATSDR Division of Community Health Investigations
Atlanta, GA

Chris Poulet
ATSDR Region 8
Denver, CO

Dan Strausbaugh
ATSDR Region 8
Helena, MT

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Charlie Partridge
USEPA Region 8
Denver, CO

Charles Coleman
USEPA Region 8
Helena MT

Richard Sloan
Montana Department of Environmental Quality
Helena, MT

Tanya Houston
Cascade City/County Health Department
Great Falls, MT

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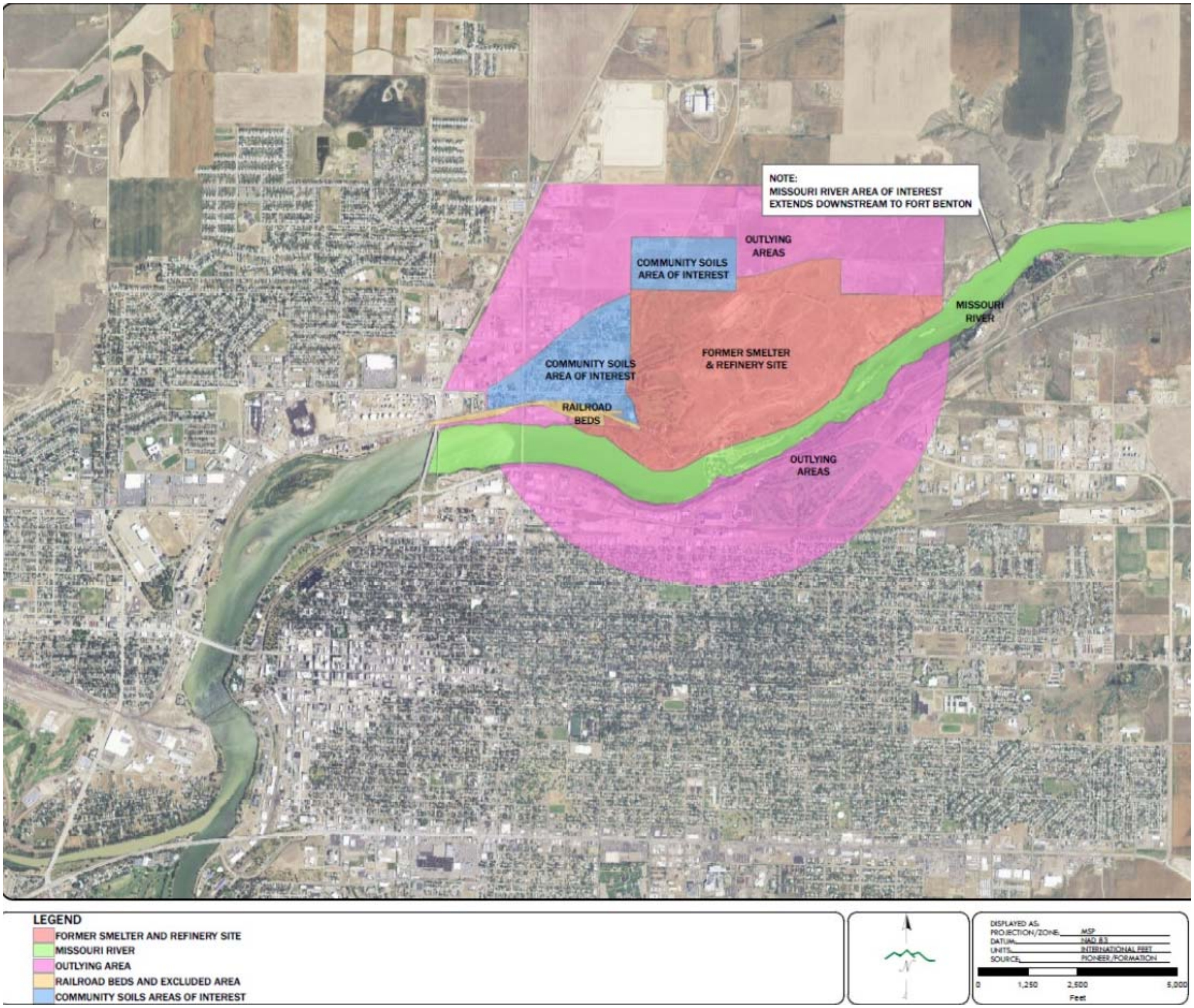
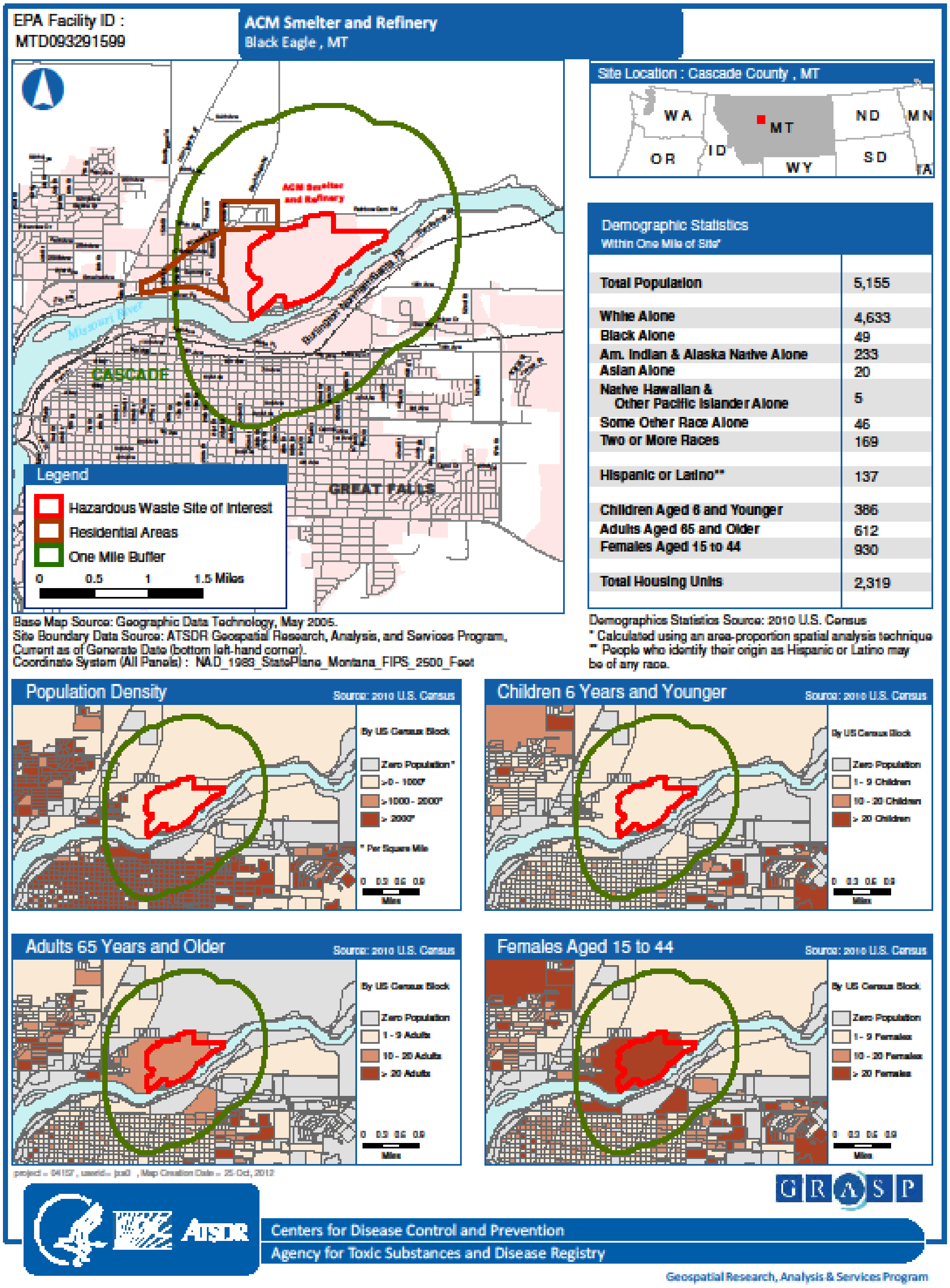
Appendix A. Figures

Figure 1A. Area Map, ACM Smelter and Refinery, Great Falls, Montana.



Source: Pioneer Technical Services

Figure 2A. Demographic statistics within one mile of ACM Smelter site, Great Falls, Montana.



Appendix B. Tables

Table 1B. Definition of Statistical Terms*

Term	Definition
Minimum	The minimum is the lowest value in the data set.
Maximum	The maximum is the highest value in the data set.
Mean	Also called the average, the mean is a measure of the center of the data distribution (range from maximum to minimum).
Median	The median, also known as the 50^{th} percentile, is another measure of the center of the data. If the data are ordered from highest to lowest, the median is the value that is in the middle of the data. For any given data set, 50% of the data will be above the median and 50% of the data will be below the median. Because the median is less affected by extreme values in the data, it can be a better–or more robust–central measure than the average.
25^{th} percentile	The 25^{th} percentile is the value that delineates the lowest 25% of the data values from the upper 75% of the data values.
75^{th} percentile	The 75^{th} percentile is the value that delineates the highest 25% of the data values from the lowest 75% of the data values.
Interquartile range	The interquartile range (IQR) is the range between the first and third quartiles (Q3-Q1), which corresponds to the data within the 25^{th} and 75^{th} percentiles. The range represents 50% of the data.
Confidence interval	A confidence interval is a range of values that will likely contain the value of the parameter of interest–the mean for example. A confidence interval typically has a percentage level associated with it that indicates how often the interval will contain the true value of the parameter of interest. Common levels for the confidence interval are 90%, 95%, and 99%.

* Reference Tables 2B–5B for application of these terms to the site-related soil data.

Table 2B. Descriptive Statistics for Arsenic in Residential Soil

Descriptive Statistics		Black Eagle only		All Areas†	
		Surface (0-2 in.)	Subsurface (> 2in.)	Surface (0-2 in.)	Subsurface (> 2in.)
Number of samples		1947	5850	2115	6355
Number of properties sampled		391	391	422	422
Concentration (ppm)	Maximum	581	1560	581	1560
	75th percentile	28.5	45.1	27.6	44.4
	Median	19.8	29.5	19.2	28.9
	25th percentile	13.9	18.1	13.4	17.7
	Minimum	0.3	0.1	0.3	0.1
	Interquartile range	14.5	27	14.2	26.7
	Mean	24.1	37.3	23.6	36.8
	95% confidence interval on the mean	23.1 - 25.3	36.3 – 38.4	22.7 – 24.8	35.9 – 37.8
Number of sampled properties > 15 ppm (ATSDR chronic child EMEG)		364	390	390	421
Percent of sampled properties > 15 ppm (ATSDR chronic child EMEG)		93	100	92	100

Data Source: Atlantic Richfield

ppm parts per million (milligrams arsenic per kilogram soil)
EMEG environmental media evaluation guide
† All areas include residential properties sampled in Black Eagle, northern Great Falls (south of the Missouri River) and unincorporated areas

Table 3B. Descriptive Statistics for Lead in Residential Soil

Descriptive Statistics		**Black Eagle only**		**All Areas†**	
		Surface (0-2 in.)	Subsurface (> 2in.)	Surface (0-2 in.)	Subsurface (> 2in.)
Number of samples		1947	5850	2115	6355
Number of properties sampled		391	391	422	422
Concentration (ppm)	Maximum	6270	3610	6270	3610
	75th percentile	257.5	203.5	245.5	190
	Median	131	85.5	126	80.4
	25th percentile	59.2	35.7	59.3	34.7
	Minimum	0.1	0.2	0.1	0.2
	Interquartile range	198.3	167.8	186.2	155.3
	Mean	202.6	153.5	195.9	147.4
	95% confidence interval on the mean	191.6 – 214.9	148.6 – 158.7	185.7 – 207.6	142.5 – 152.2

Data Source: Atlantic Richfield

ppm parts per million (milligrams lead per kilogram soil)
EMEG environmental media evaluation guide
† All areas include residential properties sampled in Black Eagle, northern Great Falls (south of the Missouri River) and unincorporated areas

Table 4B. Estimated Arsenic Doses within Surface Soil Concentration Ranges

Average Arsenic Concentration in Surface soil 0-2 inches (ppm)	Child Dose[§] (mg/kg-dy)	Pica Child Dose[¶] (mg/kg-dy)	Adult Dose† (mg/kg-dy)	Dose > MRL?	Number of Properties[‡]
ND – 30	0.00 - 0.00015	0.00 - 0.0016	0.00 - 0.00001	No	343
>30 – 60	0.00015- 0.0003	0.0016 - 0.003	0.00001 - 0.00002	No	73
>60 – 90	0.0003 - 0.0005	0.003 – 0.005	0.00002 – 0.00003	Yes	4
>90 – 150	0.0005 - 0.0008	0.005 – 0.008	0.00003 – 0.00005	Yes	1
>150 – 300	0.0008 - 0.0015	0.008 – 0.02	0.00005 – 0.0001	Yes	1
>300 – 600	0.0015 – 0.0022	0.02 – 0.03	0.0001 – 0.0002	Yes	0

§ Child doses represents the RME for a child age 1-2 years without intentional soil intake. This group typically has the highest chronic (long-term) soil intake per body weight resulting in the highest dose estimate.

¶ Child age 1-2 years with intentional ingestion of soil (pica) and the highest soil intake rate per body weight. Represents acute (short-term) exposures over intermittent, infrequent events.

† Adult doses represent the most highly exposed adult group (i.e. RME for women ≥ 21 years of age) that have the highest chronic soil intake rate per body weight.

‡ All residential properties sampled including Black Eagle, Great Falls and unincorporated areas. Not all property owners allowed access for sampling activities, and these untested properties may have elevated levels of arsenic.

ppm parts per million (milligrams arsenic per kilogram soil)

ND non-detect

RME reasonable maximum exposure

MRL Minimal Risk Level (See Appendix F for definition). Acute arsenic MRL is 0.005 mg/kg-day. Chronic arsenic MRL is 0.0003 mg/kg-day. MRL is not a threshold for health effects. As exposure above MRL increases, so does potential for adverse health effects.

Table 5B. Estimated Geometric Mean BLLs and Number of Residential Properties with Surface Soil Lead Levels at Various Lead Concentration Ranges.

Average Lead Concentration Range (ppm)	Estimated Probability (%) of exceeding a BLL of 5 µg/dL	Estimated Geometric Mean BLL (µg/dL)	Black Eagle only*	All Areas *†
			Surface soil (0-2 in)	Surface soil (0-2 in)
ND – 100	NA – 1‡	NA – 1.7	128	143
>100 – 200	1 – 7	1.7 – 2.5	111	124
>200 – 300	7 – 18	2.5 – 3.3	67	70
>300 – 400	18 – 32	3.3 – 4.0	43	43
>400 – 600	32 – 45	4.0 – 5.4	28	28
>600 – 800	45 – 74	5.4 – 6.7	9	9
>800 – 1,000	74 – 84	6.7 – 7.9	3	3
>1,000 – 2,000	84 – 98	7.9 – 13.0	1	1
>2,000 – 6,270	98 – 100	13.0 – 27.4	1	1

* Not all property owners allowed access for sampling activities, and these untested properties may have elevated levels of lead.

BLL blood lead level

µg/dL micrograms per deciliter. 5 µg/dL is the current CDC reference value for pediatric BLL.

ND non-detect

NA not applicable

† All areas include residential properties sampled in Black Eagle, northern Great Falls (south of the Missouri River) and unincorporated areas

‡ As an example, the value of 1 means 1% of the BLLs in a population of children 0-84 months of age under the exposure scenario are estimated to be ≥ 5 µg/dL.

Table 6B. Default Exposure Assumptions

Group	Soil Intake (mg/day)		Exposure Frequency	Body Weight (kg)	Exposure Duration for Cancer Risk (years)
	RME	CTE			
Child 6 weeks to < 1 year of age	100	60	1	9.2	0.88
Child 1 to < 2 years	200	100	1	11.4	1
Child 2 to < 6 years	200	100	1	17.4	4
Child 6 to < 11 years	200	100	1	31.8	5
Child 11 to <16 years	200	100	1	56.8	5
Child 16 to <21 years	200	100	1	71.6	5
Child (who intentionally eats soil) 1 < 2 years	NA	5,000	0.429*	11.4	NA
Adults ≥ 21 years	100	50	1	80	33
Men ≥ 21 years	100	50	1	85	54
Women ≥ 21 years	100	50	1	75	59
Gardener ≥ 21 years	NA	100	1	80	33

Source: ATSDR 2014.

* Assumes a frequency of 3 days a week.

Table 7B. Possible Sources of Lead Exposure

Place	Source
Indoors	**Paint –** Ingesting paint chips primarily found in homes built prior to 1978 and on older toys and furniture.
	Dust – Ingesting dust (from hand-to-mouth activity) found in older homes (built prior to 1978) or tracked in from contaminated soil.
	Water – Drinking water containing lead that comes from corrosion of older fixtures, from the solder that connects pipes, or from wells where lead contamination has affected the groundwater.
	Tableware – Eating foods from imported, old, handmade, or poorly glazed ceramic dishes and pottery that contains lead. Lead may also be found in leaded crystal, pewter, and brass dishware.
	Candy – Eating consumer candies imported from Mexico. Certain candy ingredients such as chili powder and tamarind may be a source of lead exposure. Candy wrappers have also been shown to contain some lead.
	Toy Jewelry – Swallowing or putting in the mouth toy jewelry that contains lead. This inexpensive children's jewelry is generally sold in vending machines and large volume discount stores across the country.
	Traditional (folk) Medicines –Ingesting some traditional (folk) medicines used by India, Middle Eastern, West Asian, and Hispanic cultures. Lead and other heavy metals are put into certain folk medicines on purpose because these metals are thought to be useful in treating some ailments. Sometimes lead accidentally gets into the folk medicine during grinding, coloring, or other methods of preparation.
Outdoors	**Outdoor Air –** Breathing lead particles in outdoor air that comes from the residues of leaded gasoline or industrial operations.
	Soil – Ingesting dirt contaminated with lead that comes from the residues of leaded gasoline, industrial operations, or lead-based paint.
Other	**Hobbies –** Ingesting lead from hobbies using lead such as welding, auto or boat repair, the making of ceramics, stained glass, bullets, and fishing weights. Other hobbies that might involve lead include furniture refinishing, home remodeling, painting and target shooting at firing ranges.
	Workplace – Ingesting lead found at the workplace. Jobs with the potential for lead exposure include building demolition, painting, remodeling/renovation, construction, battery recycling, radiator repair, and bridge construction. People who work in a lead environment may bring lead dust into their car or home on their clothes and bodies exposing family members.

Sources: CDC 2009; NYDOH 2010.

Table 8B. Descriptive Statistics for 2013 CCHD Blood Lead Surveillance Study

Descriptive Statistics		Participants	BLL ≥ reference (5 µg/dL)	BLL detected (1-4 µg/dL)
Cascade County				
Number of people		67	1 (2%)	17 (25%)
	Child (1-5 yr)	35	0	9 (26%)
	Child (6-17 yr)	12	0	1 (8%)
	Adult (18+ yr)	20	1 (5%)	7 (35%)
	Male	37	1 (3%)	14 (38%)
	Female	30	0	3 (10%)
Black Eagle residents				
Number of people		27	1 (4%)	7 (26%)
	Child (1-5 yr)	4	0	0
	Child (6-17 yr)	5	0	1 (20%)
	Adult (18+ yr)	18	1 (6%)	6 (33%)
	Male	NR	NR	NR
	Female	NR	NR	NR

Source: CCHD 2013
BLL blood lead level
µg/dL micrograms lead per deciliter blood
NR Not reported

Table 9B. Survey Results, CCHD Blood Lead Surveillance Study

Topic	Response Category	Total # Participant Responses*	% Response		
			Non-detected results (<1 µg/dL)	Detected results below reference (< 5 µg/dL)	Detected results above ref reference (≥ 5 µg/dL)
Year house built	Before 1978	43	72.1%	27.9%	0%
	After 1978	9	77.8%	22.2%	0%
	Unknown	15	73.3%	20%	6.7%
Peeling house paint	Yes	35	74.3%	25.7%	0%
	No	31	77.5%	22.5%	0%
	Unknown	1	0%	0%	100%
House repairs/renovation	Exposure	32	71.9%	28.1%	0%
	No exposure	32	81.3%	15.6%	3.1%
	Unknown	3	0%	100%	0%
Tobacco use in home	In Home	0	--	--	--
	Not in Home	66	72.7%	25.8%	1.5%
	Unknown	1	100%	0%	0%
Tobacco use in car	Used in Car	3	66.7%	0%	33.3%
	Not in Car	61	75.4%	24.6%	0%
	Unknown	3	66.7%	33.3%	0%

Source: CCHD 2013

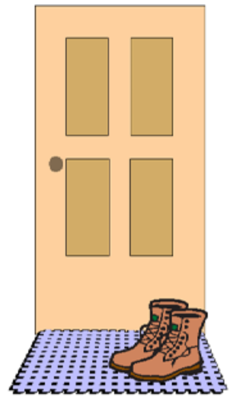
*Excludes participants whose blood lead sample could not be analyzed.

Appendix C. How to reduce exposure to lead and arsenic in soil

Ways to protect your health

By keeping dirt from getting into your house and into your body

Wash and peel all fruits, vegetables, and root crops



Wipe shoes on doormat or remove shoes

Don't eat food, chew gum, or smoke when working in the yard

Damp mop floors and damp dust counters and furniture regularly

Wash dogs regularly

Wash children's toys regularly

Wash children's hands and feet after they have been playing outside

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Appendix D. Ways to prevent high levels of lead in blood

Children and the developing fetus of pregnant women are at higher risk of developing health effects caused by exposure to high levels of lead than adults. When too much lead builds up in a child's body, it can cause learning, hearing, and behavioral problems and can harm your child's brain, kidneys, and other organs. Some of these health effects can last a lifetime. Tests are available to let people know how much lead is in their blood.

Ways to prevent high levels of lead in blood include

✔ **Eating 3 healthy meals a day and at least 2 healthy snacks.**

Eating healthy meals can help lower, but not eliminate, the risk of getting high levels of lead in blood. People with empty stomachs get more lead into their bodies than people with full stomachs.

✔ **Eating a balanced diet.**

People's bodies are less likely to absorb lead when their diet is rich in nutrients and vitamins.

- Eat iron-rich foods like
  - Lean red meats, fish or chicken
  - Cereals high in iron
  - Dried fruits such as raisins or prunes
- Eat calcium-rich foods like
  - Milk, yogurt, cheese
  - Green leafy vegetables (spinach, kale, collard greens)
- Eat foods high in Vitamin C like
  - Oranges or orange juice and grapefruits or grapefruit juice
  - Tomatoes, tomato juice
  - Green peppers

✔ **Eating less high fat and fried foods.**

People's bodies are more likely to absorb lead when they eat high fat and fried foods.

- Avoid foods like hot dogs, French fries, and potato chips

✔ **Washing your hands before fixing food and washing and peeling produce before eating it.**

Lead particles that stick to people's hands after gardening and to the surface of garden produce can be washed away before the lead enters a person's body.

✔ **Using only cold water from the tap for drinking, cooking, and for making baby formula.**

Hot water is more likely to contain lead. Run cold water 30 to 60 seconds before using it.

Appendix E. How to prevent lead exposure at home

How to Prevent Lead Exposure at Home

Parents can take simple steps to make their homes more lead-safe.

> **Lead can be found in a variety of sources.**
>
> These include:
>
> - paint in homes built before 1978
> - water pumped through leaded pipes
> - imported items including clay pots.
> - certain consumer products such as candies, make -up and jewelry
> - certain imported home remedies

- Talk to your local health department about testing paint and dust in your home for lead if you live in a home built before 1978.
- Common home renovation activities like sanding, cutting, and demolition can create hazardous lead dust and chips by disturbing lead-based paint. These can be harmful to adults and children.
- Renovation activities should be performed by certified renovators who are trained by EPA-approved training providers to follow lead-safe work practices.
- Learn more at EPA's Renovation, Repair, and Painting rule Web page: http://www.epa.gov/lead/pubs/renovation.htm.
- If you see paint chips or dust in windowsills or on floors because of peeling paint, clean these areas regularly with a wet mop.
- Wipe your feet on mats before entering the home, especially if you work in occupations where lead is used. Removing your shoes when you are entering the home is a good practice to control lead.
- Use only cold water from the tap for drinking, cooking, and for making baby formula. Hot water is more likely to contain lead. Run cold water 30 to 60 seconds before using it.
- Remove recalled toys and toy jewelry from children. Stay up-to-date on current recalls by visiting the Consumer Product Safety Commission's Web site: http://www.cpsc.gov/.

Appendix F. Derivation and intended use of comparison values

The Agency for Toxic Substances and Disease Registry (ATSDR) has developed health and environmental guidelines to use when conducting the screening analysis and evaluating exposures to substances found at sites under investigation. The information provided in this appendix comes from ATSDR's Public Health Assessment Guidance Manual [ATSDR 2005]. For further information on ATSDR's public health assessment process and comparison values, please refer to the ATSDR guidance manual available at http://www.atsdr.cdc.gov/hac/PHAManual/toc.html.

ATSDR, in cooperation with the U.S. Environmental Protection Agency (US EPA), has developed a priority list of hazardous substances found at hazardous waste sites, as directed under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendment and Reauthorization Act of 1986 (SARA). For those substances most commonly found, ATSDR has prepared Toxicological Profiles that include an examination, summary, and interpretation of available toxicologic and epidemiologic data. Using those data, ATSDR has derived health and environmental guidelines.

- ATSDR ***health guidelines*** are substance-specific doses or concentrations derived using toxicologic information. Where adequate dose-response data exist, health guidelines are derived for both the ingestion or inhalation routes of exposure. Health guidelines include ATSDR's minimal risk levels (MRLs). No health guidelines have been developed by ATSDR for dermal exposures.
- ATSDR ***environmental guidelines*** are media-specific substance concentrations derived from health guidelines using default exposure assumptions. ATSDR environmental guidelines include environmental media evaluation guides (EMEGs) and cancer risk evaluation guides (CREGs) that are available for contact with substances in water, soil, and air. No environmental guidelines have been developed by ATSDR for contact with contaminants in food or biota.

ATSDR health and environmental guidelines discussed in this appendix are MRLs, EMEGs, and CREGs. For each guideline discussed, a definition and description of the derivation and applicability or intended use are provided.

Minimal Risk Levels (MRLs)

ATSDR's minimal risk levels (MRLs) are an estimate of the daily human exposure to a substance that is likely to be without appreciable risk of adverse health effects during a specified duration of exposure. MRLs are based only on noncarcinogenic effects. MRLs are screening values only and are not indicators of health effects. Exposures to substances at doses above MRLs will not necessarily cause adverse health effects and should be further evaluated.

ATSDR derives MRLs when reliable and sufficient data can identify the target organ(s) of effect or the most sensitive health effects(s) for a specific duration for a given route of exposure. MRLs are set below levels that might cause adverse health effects in most people, including sensitive populations. MRLs are derived for acute (1–14 days), intermediate (15–364 days), and chronic (365 days and longer) durations. MRLs are generally based on the most sensitive chemical-induced endpoint considered relevant to humans. ATSDR does not use serious health endpoints (e.g., irreparable damage to the liver or kidneys, birth defects) as bases for establishing MRLs.

ATSDR derives MRLs for substances by factoring the most relevant documented no-observed-adverse-effects level (NOAEL) or lowest-observed-adverse-effects level (LOAEL) and an uncertainty factor. The specific approach used to derive MRLs for individual substances are detailed in ATSDR's Toxicological Profile for each substance available at http://www.atsdr.cdc.gov/toxprofiles/index.asp.

MRL Derivation

MRL = NOAEL (or LOAEL) / UF

where,

MRL	=	minimal risk level (mg/kg/day)
NOAEL	=	no-observed-adverse-effect level (mg/kg/day)
LOAEL	=	lowest-observed-adverse-effect level (mg/kg/day)
UF	=	uncertainty factor (unitless)

Most MRLs contain a degree of uncertainty because of the lack of precise toxicologic information about the people who might be most sensitive to the effects of environmental contamination (e.g., children, elderly, those with pre-existing illnesses). ATSDR uses a conservative (i.e., protective) approach to address this uncertainty. This approach is consistent with the public health principle of prevention.

Although human data are preferred, when relevant human studies are unavailable, ATSDR bases MRLs on animal studies. In the absence of evidence to the contrary, ATSDR assumes that humans are more sensitive to the effects of hazardous substances than are animals and that certain persons might be particularly sensitive. Uncertainties are taken into account by applying "uncertainty factors" to the NOAEL. For example, an uncertainty factor of between 1 and 10 might apply for extrapolation from animal doses to human doses or to account for sensitive persons. When more than one uncertainty factor is applied, the uncertainty factors are multiplied. For example, the combined uncertainty factor of 100 could be accounted for by an uncertainty factor of 10 for the extrapolation of animals to humans and another factor of 10 to account for sensitive persons.

ATSDR derives MRLs on the assumption that exposures occur to a single substance and that only noncarcinogenic health effects might result. But hazardous waste sites might expose people to a mixture of substances. MRLs are intended to serve only as a screening tool to help ATSDR staff decide whether to evaluate more closely exposures to a substance found at a site. MRLs are not intended to define cleanup or action levels. In addition, exposure doses above the MRL do not necessarily mean that adverse health effects will occur.

Environmental Media Evaluation Guides (EMEGs)

ATSDR's environmental media evaluation guides (EMEGs) represent concentrations of substances in water, soil, and air to which humans might be exposed during a specified period of time (acute, intermediate, or chronic) without experiencing adverse health effects. EMEGs have been calculated for substances for which ATSDR has developed Toxicological Profiles. ATSDR uses information about the substance toxicity (MRLs) and default exposure assumptions.

ATSDR uses EMEGs during a screening analysis, particularly when conducting an environmental guideline comparison. Substances found at concentrations below EMEGs are not expected to pose public health hazards. Substances found at concentrations above EMEGs require further evaluation before arriving at a public health conclusion. EMEGs are screening values only—they are not indicators of adverse public health effects. Substances found at concentrations above EMEGs will not necessarily cause adverse health effects, but will require further evaluation.

ATSDR makes three assumptions when deriving EMEGs: 1) exposures occur through contact with a single medium (e.g., water or soil) via a single route (e.g., ingestion or inhalation), 2) exposures involve a single substance, and 3) from the exposure, only noncarcinogenic health effects might result.

EMEGs are based on toxicity information (MRLs), which consider noncarcinogenic toxic effects of chemicals, including their developmental and reproductive toxicity. MRLs do not consider potential genotoxic or carcinogenic effects of a substance. Because some substances have both noncarcinogenic and carcinogenic effects, ATSDR has derived cancer risk evaluation guides (CREGs) to consider potential carcinogenic effects of a substance.

To derive the soil EMEGs, ATSDR uses the chronic oral MRLs from its Toxicological Profiles. Many chemicals bind tightly to organic matter or silicates in the soil. Therefore, the bioavailability of a chemical is dependent on the media in which it is administered. Ideally, an MRL for deriving a soil EMEG should be based on an experiment in which the chemical was administered in soil. However, data from this type of study is seldom available. Therefore, often ATSDR derives soil EMEGs from MRLs based on studies in which the chemical was administered in drinking water, food, or by gavage using oil or water as the vehicle. The Toxicological Profiles for individual substances provide detailed information about the MRL and the experiment on which it was based.

Children are usually assumed to be the most highly exposed segment of the population because their soil ingestion rate is greater than adults' rate. Experimental studies have reported soil ingestion rates for children ranging from approximately 40 to 270 milligrams per day (mg/day), with 100 mg/day representing the best estimate of the average intake rate. ATSDR calculates an EMEG for a child using a daily soil ingestion rate of 200 mg/day for a 10-kg child.

For sites where the only receptors for soil ingestion are adults, an EMEG is calculated using an adult body weight of 70 kilograms and an assumed daily soil ingestion rate of 100 mg/day. There are very few data on soil ingestion by adults, but limited experimental studies suggest a soil ingestion rate in adults of up to 100 mg/day, with an average intake of 50 mg/kg. Concentrations of substances in soil are expressed as milligrams per kilogram (mg/kg) or ppm.

Cancer Risk Evaluation Guides (CREGs)

ATSDR's cancer risk evaluation guides (CREGs) are media-specific comparison values that are used to identify concentrations of cancer-causing substances that are unlikely to result in an increase of cancer rates in an exposed population. ATSDR develops CREGs using EPA's cancer slope factor (CSF) or inhalation unit risk (IUR), a target risk level (10^{-6}), and default exposure assumptions. The target risk level of 10^{-6} represents a possible risk of one excess cancer case in a population of one million people exposed. CREGs are only available for adult exposures—no CREGs specific to childhood exposures are available.

To derive soil CREGs, ATSDR uses CSFs developed by US EPA and reported in the Integrated Risk Information System (IRIS). The IRIS summaries, available at http://www.epa.gov/iris/ , provide detailed information about the derivation and basis of the CSFs for individual substances. ATSDR derives CREGs for lifetime exposures, and therefore uses exposure parameters that represent exposures as an adult. An adult is assumed to ingest 100 mg/day of soil and weigh 70 kg.

In developing the CREGs, ATSDR assumes that 1) exposures occur through contact to a single medium, (2) exposures occur to a single substance, and 3) from the exposure only cancer health effects will result. CREGs serve as a screening tool for evaluating concentrations of carcinogens during an environmental guideline comparison. CREGs are based on possible estimates of cancer risk. Therefore, CREGs should serve only as a screening tool and not that cancer is indicated, expected, or predicted.

Reference

[ATSDR] Agency for Toxic Substances and Disease Registry. 2005. Public Health Assessment Guidance Manual (update). Atlanta: US Department of Health and Human Services.

Appendix G. Arsenic and Lead : Exposure and health effects.

Arsenic

Arsenic, a naturally occurring element, is widely distributed in the Earth's crust, which contains about 3.4 ppm arsenic [Wedepohl 1991]. Most arsenic compounds have no smell or distinctive taste. Although elemental arsenic sometimes occurs naturally, arsenic is usually found in the environment in two forms—inorganic (arsenic combined with oxygen, chlorine, and sulfur) and organic (arsenic combined with carbon and hydrogen).

Most simple organic forms of arsenic are less harmful than the inorganic forms [ATSDR 2007a]. Once in the environment, arsenic cannot be destroyed. It can only change forms or become attached to or separate from soil particles (e.g., by reacting with oxygen or by the action of bacteria in soil). Some forms of arsenic may be so tightly bound to soil particles or encapsulated in other minerals that they are not readily absorbed by plants and animals.

Arsenic is released to the environment through natural sources such as wind-blown soil and volcanic eruptions. However, anthropogenic (human-made) sources of arsenic release much higher amounts of arsenic than natural sources. These anthropogenic sources include nonferrous metal mining and smelting, pesticide application, coal combustion, wood combustion, and waste incineration. About 90% of all commercially produced arsenic is used to pressure-treat wood [ATSDR 2007a]. In the past and currently, arsenic is used as a pesticide. US EPA states that pesticide manufacturers have voluntarily phased out certain chromated copper arsenate (CCA) use for wood products around the home and in children's play areas; effective December 31, 2003, no wood treater or manufacturer may treat wood with CCA for residential uses, with certain exceptions [EPA 2011a].

People may be exposed through incidentally ingesting soil containing arsenic. Arsenic concentrations for uncontaminated soils generally range from 1–40 ppm, with a mean of 5 ppm [ATSDR 2007a]. Arsenic concentrations in soils from various countries range from 0.1 to 50 ppm and can vary widely among geographic regions. The US Geological Survey reports a mean of 7.2 ppm and a range of less than 0.1–97 ppm in the United States [Shacklette and Boerngen 1984]. Higher arsenic levels may be found near arsenic-rich geological deposits, some mining and smelting sites, or agricultural areas where arsenic pesticides had been applied in the past. The Montana DEQ defines background arsenic at 22.5 mg/kg.

People may be exposed through ingestion of garden produce containing arsenic. Garden plants grown in arsenic-contaminated soils take up small amounts of arsenic in their roots [Thorton 1994; Samsøe-Petersen et al. 2002; ATSDR 2007a]. In these studies, the arsenic concentrations in the plant roots were a small fraction of arsenic concentrations in the soils and the arsenic concentrations in the plants did not exceed regulatory standards for food items [Thorton 1994; Stillwell 2002]. Several studies also indicated that the plants took in more arsenic from air (and atmospheric deposition) than from uptake through their roots from soil [Larsen et al. 1992; Thorton 1994; Stillwell 2002]. Arsenic in leafy vegetables (kale) was by direct atmospheric deposition, while arsenic in the root crops (potatoes and carrots) was a result of both soil uptake and atmospheric deposition [Larsen et al. 1992]. US dietary intake of inorganic arsenic has been estimated to range from 1 to 20 micrograms per day (µg/day), with a mean of 3.2 µg/day; these estimates of inorganic arsenic intakes are based on measured inorganic arsenic concentrations from a market basket survey [Schoof et al. 1999a, 1999b].

Ingestion of arsenic-contaminated soil and garden produce is one way that arsenic can enter the body. Dermal exposure to arsenic is usually not of concern because only a small amount will pass through skin and into the body (4.5% of inorganic arsenic in soil) [Wester et al. 1993]. The metabolism of inorganic arsenic in humans and animals is well known. Several studies in humans indicate that arsenic is well absorbed across the gastrointestinal tract (approximately 95% absorption for inorganic arsenic compounds and 75–85% for organic arsenic compounds) [Bettley and O'Shea 1975; Buchet et al. 1981; Marafante et al. 1987; Zheng et al. 2002]. Once in the body, the liver changes (i.e., through methylation) some of the inorganic arsenic to less harmful organic forms that are more readily excreted in urine. Inorganic arsenic is also excreted in urine. Most forms of organic arsenic appear to undergo little metabolism. Approximately 75% of the absorbed arsenic dose is excreted in urine [Marcus and Rispin 1988]. Several studies show that 45–85% of arsenic is eliminated within one to three days [Apostoli et al. 1999; Buchet et al. 1981; Crecelius 1977; Tam et al. 1979]. However, there appears to be an upper limit to this mechanism for reducing arsenic toxicity [ATSDR 2007a].

As noted above, water-soluble forms of inorganic arsenic are well absorbed. Ingesting less soluble forms of arsenic results in reduced absorption. Studies in laboratory animals show that arsenic in soil is only one-half to one-tenth as bioavailable as soluble arsenic forms [Casteel et al. 1997; Freeman et al. 1993; Freeman et al. 1995; Groen et al. 1994; Rodriguez et al. 1999]. In one study, approximately 80% of the arsenic from ingested soil was eliminated in the feces compared with 50% of the soluble oral dose [Freeman et al. 1993]. The bioavailability of arsenic in soil may be reduced due to low solubility and inaccessibility [Davis et al. 1992]. Most of the bioavailable arsenic in water and soil is expected to be present as inorganic arsenic (trivalent arsenic and pentavalent arsenic, specifically) [Health Canada 1993]. US EPA conducted an analysis and external independent peer review of arsenic's relative bioavailability (RBA) in soil, and concluded that:

1. available research information suggests that an RBA of arsenic in soils can be expected to be less than 100%,
2. the upper percentile of US data results in a default RBA arsenic in soil value of 60%, and
3. the default RBA for arsenic in soils should be used if site-specific assessments for arsenic RBA are not feasible.

As part of the remedial investigation, the relative oral bioavailability (RBA) of arsenic was evaluated in 35 soil samples collected from residential yards in Black Eagle between June and August 2012. Analysis of soil at the ACM site determined a relative arsenic bioavailability of 29% [ENVIRON 2014, 2015].

ATSDR's acute oral minimal risk level[3] (MRL) of 0.005 milligrams per kilogram per day (mg/kg-day) is based on a study in which 220 people in Japan were exposed to arsenic contaminated soy sauce for a 2–3 week period. The dose was estimated to be 0.05 mg/kg/day*,* which is considered the LOAEL. Facial edema and gastrointestinal symptoms (nausea, vomiting, and diarrhea) were considered to be the critical effects seen at this dose [Mizuta et al. 1956]. The MRL is further supported by the case of a man and woman in upstate New York who experienced gastrointestinal symptoms after drinking arsenic-tainted water at an estimated dose of 0.05 mg/kg-day [Franzblau and Lilis 1989].

The chronic oral MRL (0.0003 mg/kg-day) is based on a study in which a large number of farmers (both male and female) were exposed to high levels of arsenic in well water in Taiwan. US EPA's oral reference dose (RfD) is also 0.0003 mg/kg-day [EPA 2008]. A clear dose-response relationship was observed for characteristic skin lesions. A control group consisting of 17,000 people was exposed to 0.0008 mg/kg/day and did not experience adverse health effects, establishing the NOAEL. Hyperpigmentation

[3] The acute oral MRL is considered provisional because it is based on a serious LOAEL.

and keratosis of the skin were reported in farmers exposed to 0.014 mg/kg/day, establishing a LOAEL. Those exposed to 0.038–0.065 mg/kg/day experienced an increased incidence of dermal lesions [Tseng et al. 1968; Tseng 1977]. The MRL is supported by a number of well-conducted epidemiological studies that identify reliable NOAELs and LOAELs for dermal effects [Borgoño and Greiber 1972; Cebrían et al. 1983; Guha Mazumder et al. 1988; Haque et al. 2003; Harrington et al. 1978; EPA 1981; Valentine et al. 1985; Zaldívar 1974]. Collectively, these studies indicate that the threshold dose for dermal effects (ex., hyperpigmentation and hyperkeratosis) is approximately 0.002 mg/kg/day.

The Department of Health and Human Services (DHHS), the International Agency for Research on Cancer (IARC), and US EPA have all determined that inorganic arsenic is carcinogenic to humans. There is evidence from a large number of epidemiological studies and case reports that ingestion of inorganic arsenic increases the risk of cancer [Alain et al. 1993; Beane Freeman et al. 2004; Bickley and Papa 1989; Cebrián et al. 1983; Chen et al. 2003; Haupert et al. 1996; Hsueh et al. 1995; Lewis et al. 1999; Lüchtrath 1983; Mitra et al. 2004; Morris et al. 1974; Sommers and McManus 1953; Tay and Seah 1975; Tsai et al. 1998; Tsai et al. 1999; Tseng 1977; Tseng et al. 1968; Zaldívar 1974; Zaldívar et al. 1981]. A report by the National Research Council suggests that the risks calculated based on increases in incidence of lung and bladder cancers may be greater than those calculated based on incidences of skin cancer [NRC 2001]. In 2010, US EPA proposed a revised cancer slope factor (CSF) for inorganic arsenic based on a review of the scientific basis supporting the human health cancer hazard and dose-response assessment of inorganic arsenic [EPA 2010].

Example lifetime cancer risk calculation:

Risk = D × CSF × (ED / 78)

where,

D	=	age-specific exposure dose in milligrams per kilogram per day (mg/kg/day)
CSF	=	cancer slope factor in $(mg/kg/day)^{-1}$
ED	=	age-specific exposure duration in years

Risk = 0.0008 x 1.5 x 33/78 = 0.0005 = 5E-04 or 5 extra cancer cases over background rates in a population of 10,000 similarly exposed over a lifetime.

More information and resources about arsenic are available at the toxic substances portal on ATSDR's website: http://www.atsdr.cdc.gov/substances/index.asp

Lead

Lead is a naturally occurring bluish-gray metal found in the earth's crust and it has many different uses. It is used in the production of batteries, ammunition, metal products (solder and pipes), and devices to shield X-rays. Human activities including burning fossil fuels, mining, and manufacturing increase environmental lead concentrations [ATSDR 2007b, 2007c]. Many products contain lead, however because of health concerns, lead from paint, ceramic products, caulking, and pipe solder has been reduced or eliminated. Prior to 1955, there were no limits on lead in paint, but it is estimated that it was between 2.5% and 5%. After 1978, paint contained less than 0.06%. In 1996, the U.S. removed lead from gasoline. In the past three decades, blood lead levels (BLLs) in the U.S. population have decreased by 78% because of the regulation of lead in gasoline, paint, and plumbing materials [ACCLPP 2007].

However, lead exposure can still occur from many indoor, outdoor, and other sources [CDC 2009; NYDOH 2010]. Deteriorating lead-based paint and contaminated dust are the most widespread and dangerous high-dose source of lead exposure for young children [CDC 2009]. House age is a significant predictor of soil lead and interior dust lead. Of the residential yards sampled in Black Eagle that have soil lead data, approximately 76% were built before 1950, before lead was phased out of paint. Table 7B, Appendices D and E provide additional information.

The human body has no physiological need for lead. Lead that gets into the body binds to red blood cells and travels throughout the body until it either leaves as waste or accumulates in bone. About 99% of the amount of lead taken into the body of an adult will be excreted within a couple of weeks, while about 30% of the lead taken into the body of a child will leave in the waste [ATSDR 2007b]. Most of the remaining lead moves into bones and teeth. Lead can stay in bones for decades; however, some lead can leave bones and reenter the blood and organs under certain circumstances; for example, during pregnancy, after a bone is broken, and during advancing age.

Lead uptake in gastrointestinal tract is influenced by presence of calcium and iron. Lead uptake increases as dietary levels of these nutrients decrease. The degree of uptake is a function of age, dose, chemical form, and the particle size of the lead-containing media [EPA 1994]. Appendix D provides ways people can reduce lead absorption in the human body.

Once airborne lead deposits onto soil, it does not dissipate easily, biodegrade, or decay. Lead usually binds to soil and indoor dust and can become a long-term source of lead exposure. Lead-contaminated dust can be inhaled or ingested. Exposure to lead-contaminated soil is affected by numerous factors including particle size, ground cover, soil conditions, behavior patterns, age, and outdoor activity.

In addition to contact with lead-contaminated environmental media, multiple factors have been associated with increased risk of higher BLLs [Bernard and MecGeehin 2003; CDC 2005, 2013a, 2013b; Dixon et al. 2009; Holstege et al. 2013; Jones et al. 2009; Lee et al. 2005; Mielke et al. 2010; Shannon et al. 2005; US Census Bureau 2010b; EPA 2013b]. These factors include:

- Children[4] less than 6 years of age
- Ethnicity
- People who live in homes built before 1978
- People who live in rental property
- Those in poverty
- New immigrant and refugee populations
- Living in an urban area

[4] Lead can also harm a developing fetus, so pregnant women or women likely to become pregnant should be especially careful to avoid exposure to lead [Mayo Clinic 2015].

- Living in specific regions of the U.S. (i.e., Northeast > Midwest > South> West)

Blood Lead Levels (BLLs) and Health Effects

Although lead can affect almost every organ and system in the body, the main target for lead toxicity is the nervous system. In general, the level of lead in a person's blood gives a good indication of recent exposure to lead and correlates well with harmful health effects [ATSDR 2007b, 2007c].

In May 2012, the Centers for Disease Control and Prevention (CDC) updated its recommendations on children's blood lead levels. By shifting the focus to primary prevention of lead exposure, CDC wants to reduce or eliminate dangerous lead sources in children's environments before they are exposed.

- *Blood Lead Reference Level is now 5 µg/dL* – Until recently, children were identified as having a BLL of concern if the test result was 10 or more micrograms per deciliter (µg/dL) of lead in blood. In 2010 the CDC recommended a reference level of 5 µg/dL. This reference level is based on the highest 2.5% of the U.S. population of children 1 to 5 years of age from the 2009-2010 National Health and Nutrition Examination Survey (NHANES) [ACCLPP 2012; CDC 2012a, 2012b]. The current (2011–2012) geometric mean BLL for that age group is 0.97 µg/dL [CDC 2015].
- *No Change in Blood Lead Levels Requiring Medical Treatment* – What has not changed is the recommendation for when to use medical treatment for children. Experts recommend chelation therapy when a child is found to have a test result equal to or greater than 45 µg/dL [CDC 2014], however chelation is not without risks.
- *Health Effects in Children with Measurable BLLs less than 5 µg/dL and 10 µg/dL* – There is no clear threshold for some of the more sensitive health effects associated with lead exposures. In children, the National Toxicology Program reports conclusions on health effect studies of low-level lead exposure for both <5 µg/dL and <10 µg/dL where there is sufficient evidence of [NTP 2012]
    - Decreased academic achievement (at BLL less than (<) 5 µg/dL),
    - Decreased intelligence quotient (IQ) (<5 µg/dL and <10 µg/dL),
    - Decreased specific cognitive measures (<5 µg/dL),
    - Increased incidence of attention-related and problem behavior (<5 µg/dL),
    - Decreased hearing (<10 µg/dL),
    - Reduced postnatal growth (<10 µg/dL), and
    - Delays in puberty (<10 µg/dL).
- *Health Effects of Lead on Developing Fetuses* – Lead crosses the placenta; consequently, it can pass from a pregnant woman to her developing fetus. Follow-up testing, increased patient education, and environmental, nutritional and behavioral interventions are indicated for all pregnant women with BLLs greater than or equal to 5 µg/dL to prevent undue exposure to the developing fetus and newborn [CDC 2013c]. Too much lead in a pregnant women's body can [CDC 2013C]
    - increase risk for miscarriage,

- o cause the baby to be born too early or too small,
  - o hurt the baby's brain, kidneys, and nervous system, and
  - o cause the child to have learning or behavior problems.
- *Health Effects for Adults* – Adults who are exposed to lead over many years could develop kidney problems, high blood pressure, cardiovascular disease, and cognitive dysfunction [Kosnett et al. 2007]. Also http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1849937/

ATSDR has not developed health guidance values for exposure to lead. Therefore, ATSDR cannot use the approach of estimating human exposure to an environmental contaminant and then comparing that dose to a health based comparison value (such as an MRL or RfD). Instead, ATSDR evaluated exposure to lead by using EPA's Integrated Exposure Uptake Biokinetic (IEUBK) model for lead in children. IEUBK is a mathematical model that estimates blood lead concentrations resulting from exposure to multiple sources of environmental lead.

More information is available at http://www.atsdr.cdc.gov/substances/toxsubstance.asp?toxid=22, https://www.epa.gov/lead and http://www.epa.gov/superfund/lead-superfund-sites

Example IEUBK Model Output

LEAD MODEL FOR WINDOWS Version 1.1

==
Model Version: 1.1 Build11
User Name:
Date:
Site Name:
Operable Unit:
Run Mode: Research
==

******** Air ********

Indoor Air Pb Concentration: 30.000 percent of outdoor.
Other Air Parameters:

Age	Time Outdoors (hours)	Ventilation Rate (m^3/day)	Lung Absorption (%)	Outdoor Air Pb Conc (µg Pb/m^3)
.5-1	1.000	2.000	32.000	0.100
1-2	2.000	3.000	32.000	0.100
2-3	3.000	5.000	32.000	0.100
3-4	4.000	5.000	32.000	0.100

4-5	4.000	5.000	32.000	0.100
5-6	4.000	7.000	32.000	0.100
6-7	4.000	7.000	32.000	0.100

******** Diet ********

Age	Diet Intake (µg/day)
.5-1	2.260
1-2	1.960
2-3	2.130
3-4	2.040
4-5	1.950
5-6	2.050
6-7	2.220

******** Drinking Water ********

Water Consumption:

Age	Water (L/day)
.5-1	0.200
1-2	0.500
2-3	0.520
3-4	0.530
4-5	0.550
5-6	0.580
6-7	0.590

Drinking Water Concentration: 4.000 µg Pb/L

******** Soil & Dust ********

Multiple Source Analysis Used
Average multiple source concentration: 280.000 µg/g

Mass fraction of outdoor soil to indoor dust conversion factor: 0.450
Outdoor airborne lead to indoor household dust lead concentration: 100.000
Use alternate indoor dust Pb sources? No

Age	Soil (µg Pb/g)	House Dust (µg Pb/g)
.5-1	600.000	280.000
1-2	600.000	280.000
2-3	600.000	280.000
3-4	600.000	280.000
4-5	600.000	280.000
5-6	600.000	280.000

6-7	600.000	280.000

****** Alternate Intake ******

Age	Alternate (µg Pb/day)
.5-1	0.000
1-2	0.000
2-3	0.000
3-4	0.000
4-5	0.000
5-6	0.000
6-7	0.000

****** Maternal Contribution: Infant Model ******

Maternal Blood Concentration: 1.000 µg Pb/dL

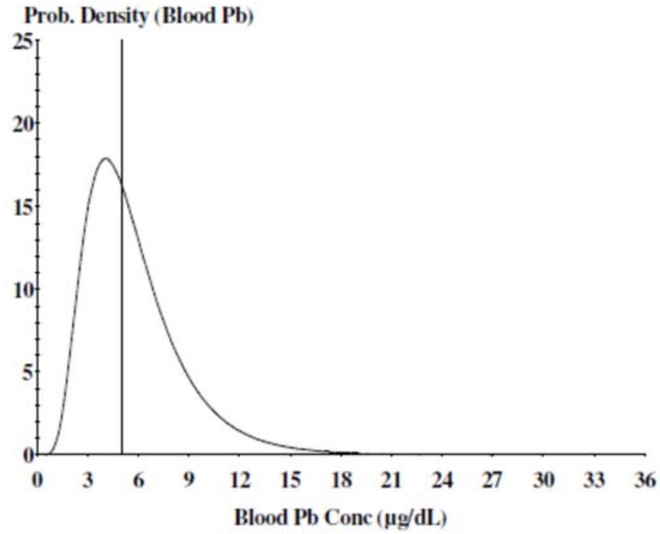
****

CALCULATED BLOOD LEAD AND LEAD UPTAKES:

****

Year	Air (µg/day)	Diet (µg/day)	Alternate (µg/day)	Water (µg/day)
.5-1	0.021	0.997	0.000	0.353
1-2	0.034	0.846	0.000	0.863
2-3	0.062	0.937	0.000	0.915
3-4	0.067	0.913	0.000	0.949
4-5	0.067	0.904	0.000	1.020
5-6	0.093	0.963	0.000	1.090
6-7	0.093	1.050	0.000	1.116

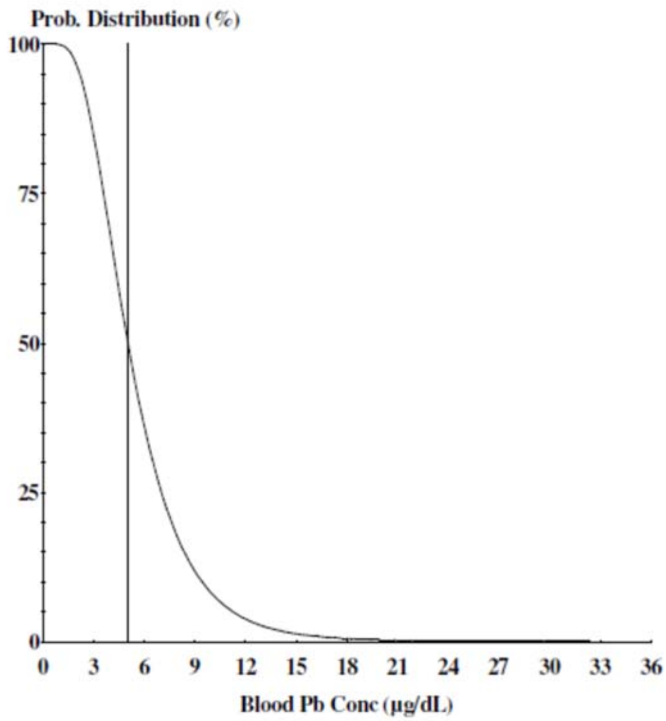
Year	Soil+Dust (µg/day)	Total (µg/day)	Blood (µg/dL)
.5-1	9.536	10.907	5.8
1-2	14.819	16.563	6.8
2-3	15.108	17.022	6.3
3-4	15.370	17.299	6.0
4-5	11.793	13.784	4.9
5-6	10.754	12.900	4.1
6-7	10.229	12.489	3.6



Cutoff = 5.000 µg/dl
Geo Mean = 5.291
GSD = 1.600
% Above = 54.787
% Below = 45.213

Age Range = 0 to 84 months

Run Mode = Research



Cutoff = 5.000 µg/dl
Geo Mean = 5.291
GSD = 1.600
% Above = 54.787

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