Health Consultation

Exposure Investigation

Biological Testing for Exposure to Lead and Arsenic near

COLORADO SMELTER

PUEBLO, COLORADO

SEPTEMBER 10, 2015

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

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

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

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Prepared By:

U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry (ATSDR)
Division of Community Health Investigations
(DCHI), Science Support Branch (SSB)

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Abbreviations and Acronyms

As	Arsenic
ATSDR	Agency for Toxic Substances and Disease Registry
BLL	Blood Lead Level
CDC	Centers for Diseases Control and Prevention
CDPHE	Colorado Department of Public Health and the Environment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DCHI	Division of Community Health Investigations
DHHS	Department of Health and Human Services
DLS	Division of Laboratory Sciences
EI	Exposure Investigation
EPA	Environmental Protection Agency
IQ	Intelligence Quotient
LBP	Lead Based Paint
mg/dL	Milligrams per deciliter
mg/kg	Milligrams per kilogram
µg/dL	Micrograms per deciliter
µg/g	Micrograms per grams
NCDC	National Climatic Data Center
NCEH	National Center for Environmental Health
NHANES	National Health and Nutrition Examination Survey
NOAA	National Oceanic Atmospheric Administration
NPL	National Priority List
OMB	Office of Management and Budget
Pb	Lead
PCCHD	Pueblo City County Health Department
SES	Socio-economic Status
SSB	Science Support Branch
WHO	World Health Organization

Executive Summary

The Agency for Toxic Substance and Disease Registry (ATSDR) and Pueblo City County Health Department (PCCHD) conducted an Exposure Investigation (EI) in Pueblo, Colorado in September and November 2013. At the request of PCCHD, ATSDR collected blood and urine samples from participants from the area ½ mile from the Pueblo smelter and analyzed the samples for lead (in blood) and arsenic (in urine). Children under 6 years of age were tested for blood lead only and participants 6 years and older were tested for both, blood lead and urinary arsenic. Arsenic is rapidly metabolized and excreted from the body within 2 – 3 days of exposure [Orloff et al 2009]; thus, urinary arsenic testing measures only recent exposures. Therefore, a urine sample needs to be collected soon after exposure has occurred, for this reason ATSDR conducted two rounds of urine arsenic testing to increase the likelihood of finding arsenic exposures.

Deposition from the air emissions of the historic smelter, as well as an extensive slag pile left over from smelter operations are sources of lead and arsenic. The U.S. Environmental Protection Agency (EPA) and the Colorado Department of Public Health and the Environment (CDPHE) previously measured elevated lead and arsenic levels in environmental samples collected from residential soil, and a slag pile associated with the former smelter. As a result of this contamination, there is potential for exposure to lead and arsenic. The most vulnerable populations include young children with hand-to-mouth behavior, children with pica[1] behavior, pregnant women, and women who may become pregnant.

Findings – Lead

CDC adopted a reference value of 5 µg/dL to identify children who have been exposed to lead and who require case management[2]. This reference value is based on the 97.5 percentile of the 2007-2010 National Health and Nutritious Examination Survey (NHANES[3]) [CDCa 2012]. In September 2013, ATSDR tested 135 people (ages 9 months to <45 years) for blood lead. Four children ranging in age from 2 to 6 years had blood lead levels (BLLs) above 5 micrograms per deciliter (µg/dL); BLLs for all other participants were below 5µg/dL however, there were three other children with BLL approaching 5µg/dL. Studies indicate there is sufficient evidence that BLLs of 5 µg/dL and below causes neurological, cognitive and attention related behavioral effects in children [NTP 2012]. As a result blood lead levels should be kept as low as possible and below the level of 5µg/dL [CDC 2012]. In this exposure investigation, ATSDR used 5µg/dL

[1] Pica behavior is the craving to eat nonfood items, such as dirt, paint chips, and clay.
[2] Case management: "A collaborative process of assessment, planning, facilitation and advocacy for options and services to meet an individual's health needs through communication and available resources to promote quality cost-effective outcomes".
[3] National Health and Nutrition Examination Survey is a survey research program conducted by the National Center for Health Statistics (NCHS) to assess the health and nutritional status of adults and children in the United States, and to track changes over time.

as the investigation follow-up level for lead for all ages, including children older than 6 years, pregnant women, and women of child bearing age.

The head of each household completed a questionnaire to assess potential exposures to lead and arsenic resulting from daily activities. All four of the children with BLLs above 5µg/dL exhibited pica behavior for soil and paint chips (expressed through personal communication with parent and or guardian). In addition, there were three other children, also with pica behavior, with blood lead levels approaching 5µg/dL.

ATSDR notified the PCCHD of all participants with BLLs exceeding the investigation follow-up level of 5 µg/dL and the three participants with BLLs approaching 5µg/dL. PCCHD conducted a Healthy Homes Inspection of the residences. Their preliminary findings for all the homes showed that the homes had lead-based paint (LBP) that was chipping and peeling. The parent or guardians of children with elevated BLLs were instructed by ATSDR in a letter to have their children evaluated by their primary care provider for confirmatory venous BLL testing and follow-up. PCCHD Public Health Nurses followed-up with the parents or guardians of the children reported to have a BLL above or approaching 5µg/dL. Also, PCCHD nurses contacted the children's primary care providers to verify re-testing of the children.

Findings – Arsenic

Arsenic is rapidly metabolized and excreted from the body within 2 – 3 days of exposure [Orloff et al 2009]; thus, urinary arsenic testing measures only recent exposures. Therefore, a urine sample needs to be collected soon after exposure has occurred. For this reason, ATSDR conducted two rounds of urine arsenic testing to increase the likelihood of finding arsenic exposures. Ninety-nine of the 102 participants six years of age and older, had their urine collected for arsenic testing in September 2013. Sixty-five of these 99 participants provided a second urine sample for arsenic testing in November 2013.

For this EI, ATSDR selected an arsenic follow-up level based on the 95th percentile of the NHANES 2009-2010 [CDC 2013] for the specific age groups. Only one participant in the investigation, an adult from the 20 to less than 45 year age group, had total urinary arsenic concentration (179.1 µg/g of creatinine) above the 95th percentile follow-up level (87.3 µg/g of creatinine). For the participant with the elevated total urinary arsenic level, a speciation analysis indicated that most of the total arsenic was organic, which is relatively nontoxic and likely from eating seafood. Personal communication with this participant reported having had fish and rice for dinner the night before providing a urine sample in September. This person was tested a second time in November 2013 and the total urinary arsenic was below their corresponding 95th percentile reference value for arsenic (<87.3 µg/g of creatinine). This is consistent with a transient urinary arsenic elevation due to diet.

Other than the one participant, ATSDR found no evidence of elevated exposure to arsenic (above 95th percentile) in the 164 participants tested.

Limitations

- The results of this EI are applicable only to the individuals tested and cannot be generalized.
- ATSDR conducted blood lead and urinary arsenic testing for less than 10 percent of the eligible population. This sample size may not yield results representative of the area population.
- Testing occurred in the fall when outdoor activities were not as likely as during warmer months. Therefore, the EI results may not reflect worst case exposures. Studies indicate that children's exposure to lead and arsenic in soil is highest when children play outdoors and have frequent contact with soils.
- The tests results cannot be used to predict the future occurrence of disease in individuals.
- Elevated blood lead results indicates there was exposure to lead. However, results do not provide information to determine when the exposure occurred. Urinary arsenic levels indicate recent exposure. Arsenic is rapidly metabolized and excreted from the body, a urine sample needs to be collected soon after exposure has occurred, e.g. half of the amount of ingested arsenic excreted in a 4 day period, was excreted within the first 28 hours. [Orloff et al. 2009].
- Children less than 6 years of age were not evaluated for arsenic in urine because there are not NHANES values for comparison.

Recommendations

ATSDR recommends primary prevention efforts to avoid exposure to lead and arsenic wherever possible.
Therefore ATSDR supports the following Public Health Actions:

1. **Prevent exposure to contaminated soil outside:**

   - Cover bare soil with vegetation (grass, mulch, etc.)
   - Create safe play areas for children with appropriate and clean ground covers. Consider sand boxes for children that like to dig.
   - Supervise children closely to identify any age appropriate hand-to-mouth behavior or intentional eating of dirt– Pica, should be modified or eliminated.
   - Keep children’s hands clean, wash them frequently before coming inside, and before eating. Do not eat food, or chew gum when playing or working in the yard.

2. **Prevent exposure to contaminated soil in the home:**

   - Remove shoes before going in the house.
   - Regularly conduct damp mopping and damp dusting of surfaces. Dry sweeping and dusting could increase the amount of lead-contaminated dust in the air.
   - Change and launder any dirty clothes separately after playing outside.
   - Frequently bathe your pets as they could also track contaminated soil into your home.

3. **Take additional measures to protect children 1 to 5 years of age:**

   - Separate children from sources of exposure.
   - Supervise children closely to prevent pica behavior.
   - Practice good hygiene with frequent hand washing especially before meals.
   - Wash children’s bottles, pacifiers and toys frequently.
   - Offer frequent, small, nutritious, age appropriate meals rich in calcium, and vitamin C and E. Children who eat healthy diets absorb less lead.
   - Have children evaluated for qualification in the Women Infants and Children (WIC) program.

4. **Continue blood lead testing of children, pregnant women and women of child-bearing age**; and conduct appropriate follow-up in the area surrounding the former

smelter. Primary care providers should conduct confirmatory venous blood lead testing as mandated by the state of Colorado.

5. **Educate health professionals** about the following:
    - Locations of soil lead and arsenic contamination in Pueblo,
    - How to prevent or reduce soil lead and arsenic exposure and other sources of potential lead exposure such as lead-based paint, and
    - Conducting blood lead screening and confirmatory venous blood lead testing

6. **Characterize the nature and the extent of lead and arsenic contamination, to include bioavailability testing of soil lead and arsenic.**

7. **Stop or reduce exposure to mining wastes in residential soil and slag piles.** For example, take actions to prevent children from playing or riding bicycles on the slag pile.

8. **Develop a sustainable health education program in the area** to provide information to community members about lead and arsenic contamination and how to reduce exposures.

Background and Purpose of the Exposure Investigation

The Colorado Smelter operated from 1883 until 1908 in Pueblo, Colorado, just south of the Arkansas River at the south end of Santa Fe Avenue. The communities of Eilers and Bessemer are in close proximity to the former Colorado Smelter (Figure 1). The area of focus for the EI is within ½ mile of the site, as shown by the red boundary in Figure 1. Appendix A contains a map showing the demographics for this area.

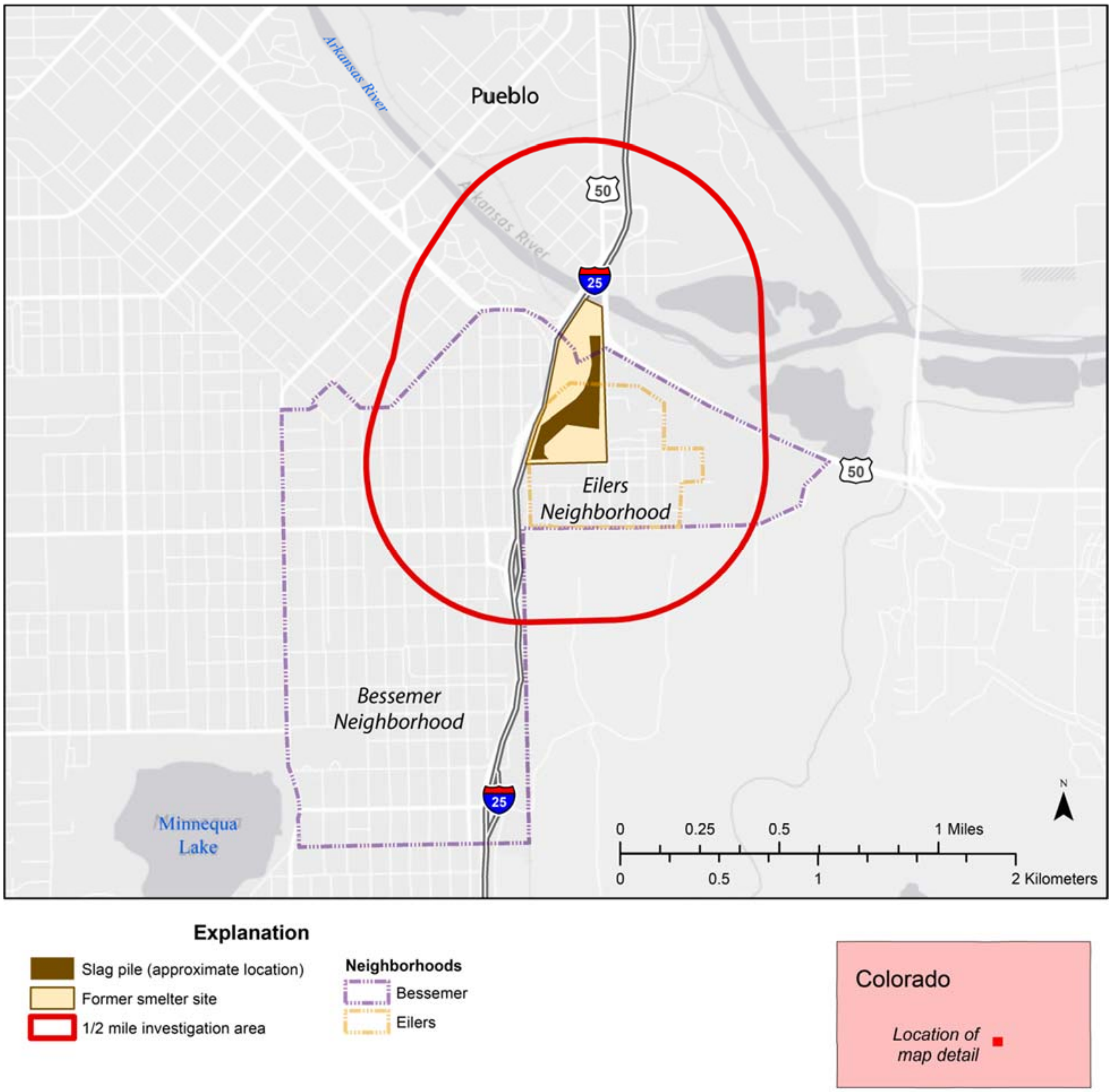


Figure 1. Area map for the Colorado Smelter site, Pueblo, Colorado

From 1992 to 2010, Colorado Department of Public Health and the Environment (CDPHE) and the Environmental Protection Agency (EPA) sampled residential soils and the slag pile to assess lead and arsenic levels as part of the CERCLA (Superfund) mandate. Over the course of five sampling events, lead was detected in the slag pile from 1,950 milligram per kilogram (mg/kg) to 26,500 mg/kg. Residential soil lead values ranged from 336 mg/kg to 962 mg/kg [CDPHE 2008]. The Superfund program measured arsenic twice in the slag pile with the following results: 79.4 mg/kg and 1,740 mg/kg [CDPHE 2008, CDPHE 2011]. Similarly, the Superfund Site Assessment program measured arsenic in residential soils twice with the following results: 44 mg/kg and 343 mg/kg [CDPHE 2008, 2011].

The prevailing wind direction in the area close to the old smelter is towards the southeast (40% frequency) (Appendix B). This suggests that lead and arsenic contamination from air emissions and subsequent deposition in the area soil may be relatively higher in the area southeast of the old smelter site. About 15% of the time, winds are toward the northwest. However the pattern of air emissions and deposition could depend on a number of factors, such as area emissions from the slag pile, fugitive emissions when the facility was operating, and the topography and vegetative cover of the land surrounding the site. The presence of buildings or other structures in the area of the site may also impact air movement and particle deposition.

Because high lead and arsenic levels are present in the soil near the former Colorado Smelter in Pueblo, the potential for human exposure to these contaminants exists. The most vulnerable populations to the health effects of lead exposure include young children with hand-to-mouth behavior, children with pica behavior, pregnant women, and women who may become pregnant. The slag pile located between the Eilers and Bessemer neighborhoods has been accessed by children riding bikes and also on foot, through a broken fence (Figure 2).

In addition to the potential exposure to contaminated soil, people living in the area have multiple factors associated with increased risk of higher blood lead levels. The census tract showed a large percentage of Mexican-Americans (65%) [American Community Survey 2006-2010 tract-level from the US Census], individuals living in poverty (46%) [American Community Survey 2006-2010 tract-level from the US Census], and homes built before 1978 (96%) that may have lead based paint [American Community Survey 2006-2010 tract-level from the US Census]. Studies have indicated that these are all risk factors for higher blood lead levels (BLLs) [Dixon et al. 2009, Jones et al 2009, Bernard 2003].

ATSDR recruited participants living within a ½ mile radius of the former Colorado Smelter site, as shown in Figure 1 and the figure in Appendix A. The total number of houses in the area is approximately 1910 (Appendix A). Most of these homes were built prior to 1978. There are 382 children 6 years of age and younger in the area. The total population within this area is 3,830 [2010 U.S. Census].

A local biologist Dr. Moussa Diawara conducted blood lead testing in 162 children living in Pueblo [Diawara et al. 2006]. Considering the potential for exposure and the fact that testing was not focused on the area close to the former smelter, in February 2013, the Pueblo City County Health Department (PCCHD) requested that the Agency for Toxic Substances and Disease Registry (ATSDR) conduct an exposure investigation (EI). The purpose of the EI was to investigate whether people with a risk of exposure had elevated levels of blood lead and /or urinary arsenic.

Figure 2. Slag pile and broken perimeter fence, Colorado Smelter site, Pueblo, Colorado

Agency Roles

ATSDR, the lead agency for the EI, collaborated with EPA, Pueblo City County Health Department (PCCHD), the Centers for Disease Control and Prevention (CDC) National Center for Environmental Health (NCEH) Division of Laboratory Sciences (DLS). The roles of each agency are described in Table 1.

Table 1. Agency roles for the Exposure Investigation (EI) in Pueblo, Colorado

Activity	Agency	Agency Roles
Developed EI protocol	ATSDR	Wrote the EI protocol which included Fact Sheets, Questionnaire, Consent and Assent Forms, Sampling and Analysis Plan
Identified the general investigation area	EPA, PCCHD	Recommended area based on past soil sampling results (EPA) Identified the Eilers and Bessemer neighborhoods for recruitment based on proximity to and prevailing winds from the former Colorado Smelter and slag pile (PCCHD)
Recruited participants	ATSDR, EPA, PCCHD	Worked as a team to conduct door-to-door recruiting, to schedule appointments, and to provide health education packages.
Collected biological samples	ATSDR, PCCHD	Worked as a team to collect blood and urine samples from participants.
Analyzed blood and urine samples	NCEH/DLS	Used approved laboratory methods to analyze biological samples and provide results to ATSDR.
Prepared the report	ATSDR	Prepared and mailed letters with results to participants Called participants to discuss blood lead and urine arsenic results

Abbreviations: ATSDR, Agency for Toxic Substances and Disease Registry; PCCHD, Pueblo City County Health Department; EPA, Environmental Protection Agency; NCEH/DLS, National Center for Environmental Health/Division of Laboratory Services]

Methods

The methods used to identify and recruit participants, collect biologic samples, perform laboratory analyses, and the interpretations of results are described below.

Criteria for Participation/Target Population

Participants were recruited for the EI based on the following criteria:

1. Lived within the approximate ½ mile perimeter of the historic Colorado Smelter site (Figure 1 –investigation area), and
2. Belonged to one of the following groups:
    a. child from 9 months to less than 6 years old (blood lead testing only),
    b. children/adults from 6 to less than 20 years old (blood lead testing and urine arsenic testing), and

   c. pregnant women and women of childbearing age from 16 to less than 45 years old (blood lead testing and urine arsenic testing).
3. Provided written consent/assent/parental permission.

Participant Recruitment

ATSDR, PCCHD, and EPA teams went door to door, within the ½ mile radius around the historic smelter, to recruit potential participants for the EI. Prior to the recruitment effort, EPA had several meetings in the area to increase the community's awareness of the soil contamination.

During the recruitment, ATSDR provided information packets to the potential participants that included the following: a factsheet about ATSDR, a factsheet about how people can be exposed to lead and arsenic in soil, a fact sheet about the Colorado Smelter EI (in English and Spanish), and instructions to collect and freeze urine samples. Two hundred and twelve people were provided an appointment date and time; 136 of the 212 (64%) participated in the EI.

Biologic Sample Collection and Analytic Procedures

ATSDR administered Consent/Assent/Parental Permission forms prior to collecting the blood and urine samples. Blood and urine samples were collected during the week of September 22, 2013. A second urine sample was collected during the week of November 6, 2013.

ATSDR team members collected pertinent information from the head of each household using an Office of Management and Budget (OMB) approved questionnaire (OMB # 0923-0048). The household questionnaire included questions on demographics, characteristics and age of residence, and activities that might result in exposure to lead and arsenic. Federal rules require that ATSDR maintain confidentiality of the information gathered through interviews as well as the results of laboratory tests unless the data is aggregate and without identifiable information.

Blood Sample Collection

Blood lead sampling is the most reliable method for measuring lead exposure from all sources [Barbosa F et al. 2005]. Whole blood samples were obtained by venous puncture. A phlebotomist (medical professional who draws blood from a vein) collected 3 milliliters (ml) of blood from each participant who provided consent. The collection tubes and supplies were provided by the National Center for Environmental Health (NCEH)/Division of Laboratory Sciences (DLS). To maintain privacy, the samples were labeled with a unique identification number.

After collection, blood samples were maintained near 4º C throughout the week and during overnight shipment. Samples were delivered for analysis to the NCEH/DLS laboratory in Atlanta, Georgia.

Urine Sample Collection

Determining urinary arsenic levels is the most reliable method to account for recent exposures (within a few days of the collection) to arsenic [Orloff et al, 2009]. A 24-hour urine collection is considered optimal due to fluctuations in excretion rates. However, most studies use a first morning void or random spot sample because it is convenient and increases compliance. Both methods correlate well with 24-hour collection results [Orloff 2009]. ATSDR collected spot (random) urine samples. Urine specimens were creatinine corrected to take into account the variation in urine output.

The collection cups were supplied by NCEH/DLS. Participants collected their urine sample at home, and brought the sample to the collection centers for the first round of sampling in September 2013. For the second round of samples in November 2013, participants collected the urine sample at home and an ATSDR and PCCHD staff went door-to-door to gather the samples. To maintain privacy, the samples were labeled with a unique identification number. Samples were maintained frozen in dry ice and shipped to the NCEH/DLS laboratory in Atlanta, Georgia.

Laboratory Analytic Procedures

The NCEH/DLS laboratory performed blood lead and urinary arsenic testing (total, speciated, and creatinine corrected) in Atlanta, Georgia, according to the following methods:

- Blood Lead Testing [NHANES Method 2009-2010].
- Urine Arsenic Testing [Jeffery, 2007].
- Urine Arsenic Speciation [Verdon CP, 2009]
- Urine Creatinine [NHANES 2007-2008a]
- Quality Assurance/Quality Control for lead and arsenic testing [NHANES 2007-2008b]

Results

Participants in the Exposure Investigation

One hundred thirty-six people participated in the EI. ATSDR collected 135 samples from 136 participants (ages 9 months to 44 years) for blood lead testing in September 2013 (Table 2). The phlebotomist could not collect a blood sample from one participant in the 9 months to less than 6 years group. Ninety-nine of the 102 participants (6 years and older) had their urine collected for arsenic testing. Sixty-five of these 99 participants provided a second urine sample in November 2013. Adults evaluated in the Pueblo, Colorado EI were either pregnant women (one female participant identified herself as pregnant) or women who may become pregnant. The Biomonitoring results by age distribution are reported in Table 2.

Table 2. **Summary of participant Biomonitoring results by age and sex group**

Age Group	Total number of participants with Blood Lead Testing (n=135[1])			Number of Participants with Urinary Arsenic Testing	
	Males	Females	Total	SEP 2013 (n=99)	NOV 2013 (n=65)
9 months to < 6 years	11	22	33	Not applicable[2]	Not Applicable[2]
6 to < 12 years	35	12	47	45	33
12 to < 20 years	8	15	23	19	13
20 to < 45 years	0	32	32	35	19

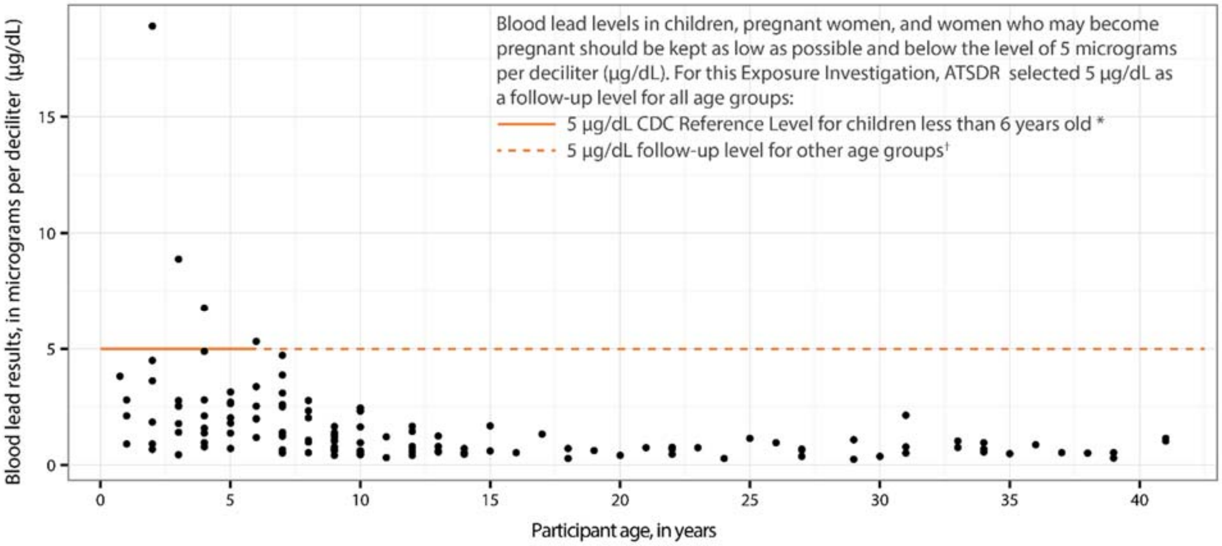
[1] 136 persons participated in the EI; one sample from a child less than 6 was not collected. Therefore a total of 135 blood samples were analyzed;
[2] Urinary arsenic values from NHANES are not available for children under 6 years of age. Therefore, urine samples were not collected.

Based on the questionnaire responses, 75% (102 of 136) of the participants are Hispanic or Latino, 25% (34 of 136) are Non-Hispanic. Of the self-reported Hispanic or Latino, 45% (46 of 102) indicated they are of Mexican ancestry, 1% (1 of 102) identified as being Puerto Rican and 54% (55 of 102) identified themselves as “other”. In addition, with regards to race, 93% (126 of 136) of the participants (including Hispanics or Latinos) self-reported their race as white.

Blood Lead Results

CDC has adopted the 97.5 percentile of the National Health and Nutrition Examination Survey (NHANES) as blood lead reference level; the level is 5 micrograms per deciliter (µg/dL). This new level is based on the U.S. population of children ages 1-5 years with BLLs in the highest 2.5% who require case management [CDCa, 2012]. For this investigation, ATSDR used 5µg/dL of blood lead as the investigation level to identify participants for follow-up, (including children older than 6 years, pregnant women, and women who may become pregnant).

The highest BLLs were observed in children less than 6 years old (Figure 3). Overall, four children had BLLs that exceeded the investigation follow-up level of 5µg/dL; of those, one child (2 years of age) exceeded a 10 µg/dL BLL. Three of 33 (9%) children in the 9 months to less than 6 years old age group had BLLs that exceeded the investigation 5µg/dL follow-up level (Table 3). One of 47 (2%) children age 6 to less than 12 years old had a blood level that exceeded 5µg/dL (a six-year old). Additionally, two children ages 2 and 4 and one child age 7 had blood levels between 4 and 5 µg/dL (Figure 3). No participants older than 12 years of age had lead levels above 5µg/dL (Table 3).



* Centers for Disease Control and Prevention (CDC 2012a).
† ATSDR selected a 5 µg/dL investigation follow-up level for all age groups based on the demographics (age and gender distribution) of the participants in this Exposure Investigation.

Figure 3. Blood lead results (n = 135) by age, Colorado Smelter, Pueblo, Colorado

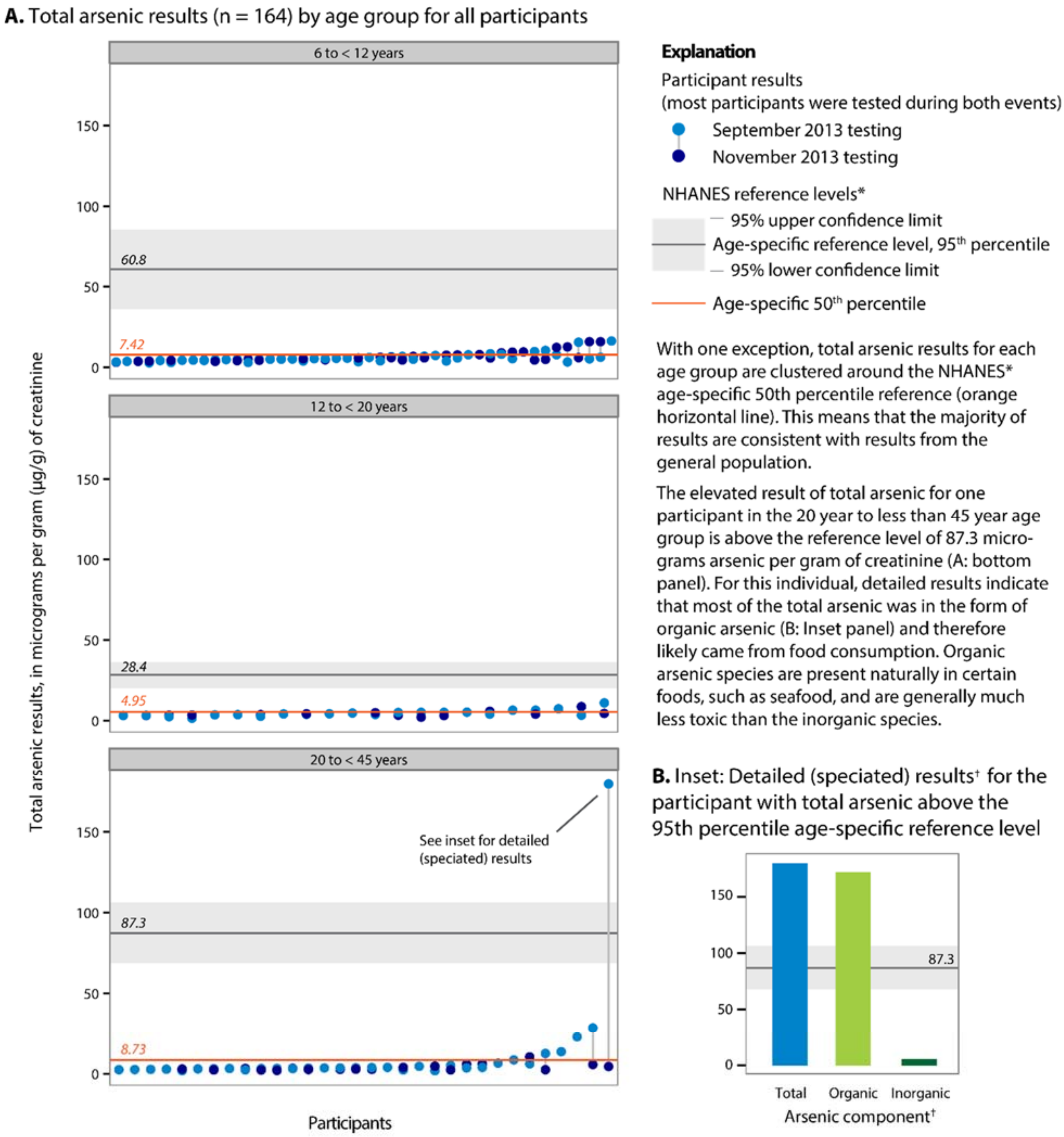
Table 3. Blood lead levels (BLLs) that exceed the investigation follow-up level of 5 micrograms per deciliter (µg/dL), by age and sex (n=135)

Age Group	Males	Females	Total number of participants with Blood Lead Testing (n=135[1])	Number of Participants with BLLs > 5µg/dL
9 months to < 6 years	11	22	33	3[2] 18.9, 8.87, 6.77
6 to < 12 years	35	12	47	1[2] 5.32
12 to < 20 years	8	15	23	0[3]
20 to < 45 years[4]	0	32	32	0[3]

[1] 136 persons participated in the EI; a sample from a child less than 6 was not collected. Therefore a total of 135 samples were analyzed.
[2] The participants with a BLLs of 18.9 µg/dL and 8.87 µg/dL are females, the participants with a BLLs of 6.77 µg/dL and 5.32 µg/dL are males.
[3] There were no participants aged > 12 and <45 with increased BLLs.
[4] Only one participant (between 20 to <45 years) was pregnant at the time of testing.

Urinary Arsenic Results

ATSDR compared the urinary arsenic results to the 95th percentile of the specific 2009-2010 NHANES age groups (Figure 4). Of the 99 participants who provided urine samples in September 2013, one participant in the 20 to less than 45 years old age group had a total urinary arsenic concentration above the 95th percentile (87.3 µg arsenic/g creatinine level) for that age group (Figure 4). The participant’s total urine arsenic concentration was 179.7µg/g creatinine. Subsequent sample speciation of all urinary arsenic results showed the elevated sample was predominantly organic arsenic, which indicates a recent fish meal. In the second round of testing for this participant in November 2013, the total urinary arsenic level was 4.6µg/g creatinine, which is less than the 50th percentile (8.7µg/g) for that age group.



* Reference levels are from the National Health and Nutrition Examination Survey (NHANES) conducted by the Centers for Disease Control and Prevention during 2009–2010 (CDC 2013). Each age-specific reference level (solid horizontal line) corresponds to the NHANES 50th or 95th percentile results for that age group.

† Total arsenic levels and speciated arsenic levels are obtained from two different laboratory analysis methods. Individual results for the various arsenic species are summed to yield the estimates for the organic and inorganic components shown here.

Figure 4. Laboratory results for urine samples tested for (A) total arsenic (n=164 samples) and (B) speciated arsenic (organic and inorganic fractions) for one participant. ASTDR collected urine samples from 99 participants in September 2013 (round 1) and 65 participants in November 2013 (round 2) in Pueblo County, Colorado.

For this EI, urine creatinine concentration was the method used by the NCEH/DLS laboratory for adjusting dilution and for determining whether a spot urine sample is valid for assessing arsenic exposure. Arsenic results are then reported as microgram of arsenic per gram creatinine (µg of arsenic per g creatinine). The creatinine adjustment is meant to correct for states of over or under hydration. In a state of dehydration or over hydration, the kidney's excretion rate of contaminants changes, which can yield results that are not an accurate reflection of the participant's exposure. Urinary creatinine concentrations from the World Health Organization (WHO) guidelines are often used to determine valid spot urine samples for occupational monitoring although it should be noted that these guidelines focus on the adult population and do not generally take into consideration children under 16 years of age which make up a significant number of the investigation participants. The WHO recommends that if a sample is too dilute (creatinine concentration < 30 mg/dL) or too concentrated (creatinine concentration > 300 mg/dL), another spot urine sample should be collected (WHO 1996) and analyzed for creatinine and the target chemical, in this case arsenic. A urine sample from a dehydrated participant (elevated creatinine) might underestimate the level of urinary arsenic present and cause an elevated level of urinary arsenic to go unrecognized. Conversely, adjusting an arsenic concentration from an overly hydrated participant (dilute creatinine level) may yield a falsely elevated result and cause undue concerns.

In this investigation 164 spot urine samples were collected including 27 participants who provided two urine samples approximately eight weeks apart. Five samples from four different participants had a creatinine level above 300 mg/dL (3%) ranging from 326 to 457 mg/dL. A creatinine level above 300 mg/dL could potentially result in an artificially low value for creatinine correct urinary arsenic.

All four participants provided two separate urine samples. Three of the four participants had a creatinine level below 300 mg/dL for their second urine sample with a corrected total urinary arsenic level well below the 95th percentile of their specific 2009-2010 NHANES age group. The fourth participant, a Hispanic male between the ages of 12-19, had a creatinine level above 300 mg/dL for both spot urine samples. Males generally have a higher creatinine level than females [Barr, et al. 2005]. The creatinine corrected urinary arsenic level in both of his samples was well below the 95th percentile of his 2009-2010 NHANES age-group.

A prior study found that unadjusted and creatinine-adjusted concentrations of inorganic urinary arsenic were significantly correlated in a population with low-level environmental arsenic exposure as was the case in this investigation [Hinwood et al., 2002]. The urine samples from all four participants had a creatinine corrected urinary arsenic level well below the investigation follow-up level. Evaluation of the uncorrected total urinary arsenic of the spot urine samples for the four participants in this investigation found them all to be below the 75th percentile of their specific 2009-2010 NHANES for age, gender and race/ethnicity which was consistent with their creatinine corrected urinary arsenic levels. These findings indicate that although the creatinine levels were outside of the target range, the total uncorrected urinary arsenic values suggest that they are below are 95th percentile screening level.

Discussion

Lead and Health Effects

Lead is a naturally occurring metal. Typically found at low levels in soil, lead is processed for many industrial and manufacturing applications, and it is found in many metallic alloys. Lead was previously found in many gasoline additives, but by the mid 1970's the U.S. began phasing out the use of lead as an additive to gasoline and effective January 1, 1996, the Clean Air Act banned the sale of leaded fuel for on-road vehicles [EPA 1996]. Lead was banned from paint in 1978. Today, lead can be found in all parts of our environment because of past and current human activities including burning fossil fuels, mining, and manufacturing processes [ATSDR 2007a]. Because of this, lead is often found in the body in low levels. Lead exposure occurs primarily via the oral route, with some contribution from the inhalation route. The toxic effects of lead are the same regardless of the route of entry into the body.

Depending on the level of exposure, lead can adversely affect the nervous system, kidney function, immune system, reproductive system, development, and cardiovascular system. Lead exposure also affects the oxygen carrying capacity of the blood. The lead effects most commonly encountered in current population are neurological effects in children, and cardiovascular effects (e.g., high blood pressure and heart disease) in adults. Infants and young children are especially sensitive to even low levels of lead, which may contribute to behavioral problems, learning deficits, and lowered IQ [USEPA 2012].

Lead can be passed from a mother's body to negatively affect the health of her unborn child. Lead exposure can also cause a miscarriage. It is not known for certain if lead causes cancer in humans. Rats and mice fed large amounts of lead in their food developed kidney tumors. DHHS classifies lead as “reasonably anticipated” to cause cancer and EPA considers lead a “probable” cancer causing substance [ATSDR 2007].

There may be no lower threshold for some of the adverse neurological effects of lead in children [USEPA 2013]. Because of the absence of any clear threshold for some of lead's more sensitive health effects, ATSDR has not established guidelines for a low or no risk lead intake dose.

Currently a blood lead level of 5µg/dL is used to identify children with blood lead levels greater than most children in the U.S. Five micrograms per deciliter is the 97.5 percentile for the distribution of blood lead levels of U.S. children 1 – 5 years old [CDC 2012]. These levels are known to have adverse effects. As a result, blood lead levels should be kept as low as possible since no safe blood lead level in children has been identified [ACCLPP 2012]. Young children and the developing fetus are particularly sensitive to the effects of lead.

Studies conducted in pregnant women and fetus, children and adults substantiate there is sufficient evidence of health effects at blood lead level <5μg/dL [Lanphear et al, 2005].

Lead has no physiological value, and if it gets into the blood, lead can affect various organ systems and be stored in the bones. Lead that is not stored in bones and teeth is excreted from the body in urine and feces. About 99% of the amount of lead taken into the body of an adult will leave the body in urine or feces within a couple of weeks, while about 30% of the lead taken into the body of a child will leave the body in urine or feces [ATSDR 2007c]. Lead can stay in bones for decades [CDC 2007]. Lead can leave bones and re-enter the blood and deposit in organs under certain circumstances; for example, during pregnancy and lactation, after a bone is broken, and during menopause in women due to osteoporosis.

An elevated level of lead in a person's blood is an indication that an exposure has occurred. In general, BLL correlates well with adverse health effects [ATSDR 2007d].

The population in the census track where the EI took place (Figure 1) contains a large percentage of Mexican-Americans (65%) [American Community Survey 2006-2010 tract-level from the US Census]. In addition, 46% of this population lives in poverty [American Community Survey 2006-2010 tract-level from the US Census] and 93% of the homes in this area were built before 1978 [American Community Survey 2006-2010 tract-level from the US Census]. These risk factors increase this population's likelihood for higher BLLs; the lead-contaminated soil could add to their risk [CDC 2013, Bernard 2003, Dixon et al 2009, Jones 2009], because certain characteristics combined put people at higher risks for lead exposure and higher blood lead levels.

Some characteristics contribute to susceptibility (e.g., age, race, sex) and others to vulnerability (e.g., socio-economic status (SES)). Living in older housing [CDC 2013a, Bernard et al. 2003], and poverty [CDC 2013a, Jones et al. 2009], combined with being Mexican-American [Dixon et al. 2009, USEPA 2013] and being non-Hispanic black [Bernard et al. 2003, CDC 2013a, Jones et al. 2009] are risk factors for higher blood lead levels.

In this exposure investigation, the BLLs in 4 children between the ages of 1 to 6 years were greater than 5μg/dL. Levels such as these can adversely affect the child's health [NTP 2012]. Furthermore, 3 other children (ages 2, 4, and 7) had BLLs very close to 5 μg/dL (4.5, 4.72, and 4.89). All 7 children were included in the PCCHD Healthy Homes inspection of residences. Their preliminary findings showed that the homes had lead-based paint that was chipping and peeling. In addition, all four of the children with BLLs above 5μg/dL exhibited pica behavior (expressed through personal communication between the authors and the parent or guardian).

Three of 33 children ages 9 months to less than 6 years and one six-year old child had BLLs greater than 5μg/dL (Figure 3). They resided in housing built before 1978 when paint still contained lead. Figure 5 show that 2 of the 4 children were siblings. One of the other two children was not a resident living within the ½ mile radius of the smelter but was included in the

EI because the family stayed in the area and the child's mother asked that the child be included. The fourth child with a BLL greater than 5µg/dL had a sibling with a BLL approaching 5µg/dL (4.7µg/dL). Parents/guardians of the four children with elevated BLLs reported to ATSDR that their children frequently eat dirt and lead-based paint chips (pica behavior).

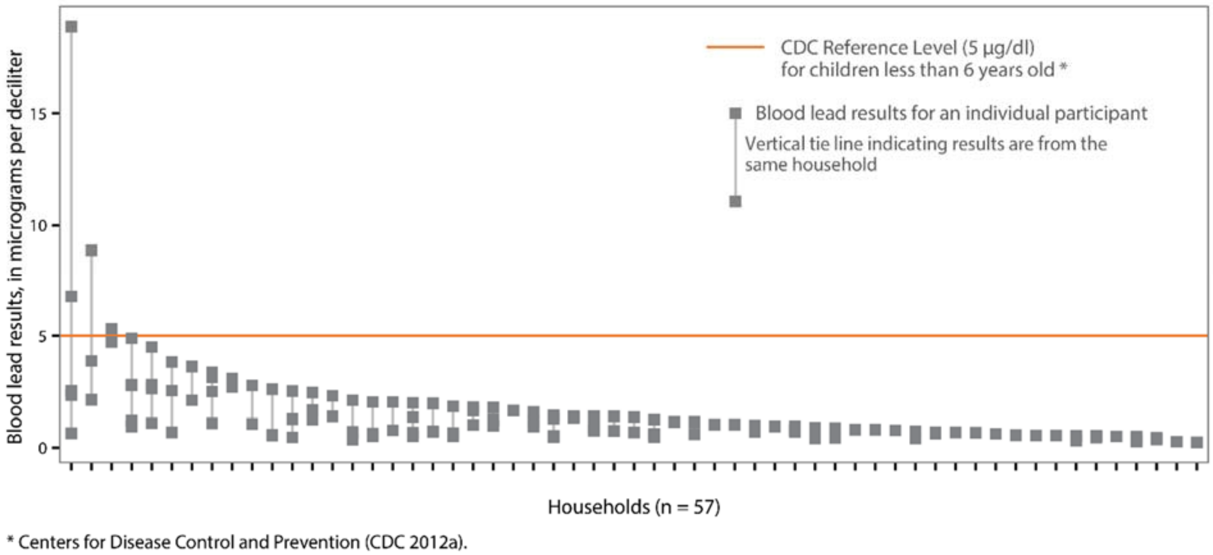


Figure 5. Blood lead results (n = 135) by household, Colorado Smelter, Pueblo, Colorado

Only 1 participant was pregnant; her blood lead level was below 5µg/dL.

The EI blood lead results are compared to the NHANES results by age groups, using a boxplot format that highlights the 25^{th}, 50^{th} and 75^{th} percentiles (Figure 6; also see Appendix C for additional information about interpreting boxplots). Figure 6A indicates that, in general, median (i.e., 50^{th} percentile) blood lead levels for the youngest age groups, (9 months to less than 6 years old, and 6 to less than 12 years old), are higher than corresponding NHANES levels (Table 4). If the EI participants are representative of the population living within ½ mile of the site, this suggests that they have higher exposure to lead compared to the U.S. population.

Table 4. Calculated median values and confidence intervals for blood lead results, by age

Age Group	Median blood lead level (BLL) and 95% confidence interval for ATSDR EI results, in micrograms per deciliter (µg/dL)	Median BLL and 95% confidence interval for corresponding NHANES results, in µg/dL
9 m to < 6years	2.11 (1.8–2.4)	1.15 (1.12–1.18)
6 to < 12 years	1.23 (1.01–1.45)	0.81 (0.79–0.83)
12 to <20 years	0.62 (0.57–0.67)	0.66 (0.65–0.67)
20 to <45 years	0.68 (0.61–0.75)	1.2 (1.19–1.21)

Abbreviations: BLL, blood lead level; ATSDR, Agency for Toxic Substances and Disease Registry; EI, Exposure Investigation; NHANES, National Health and Nutrition Survey (2009–2010 data).

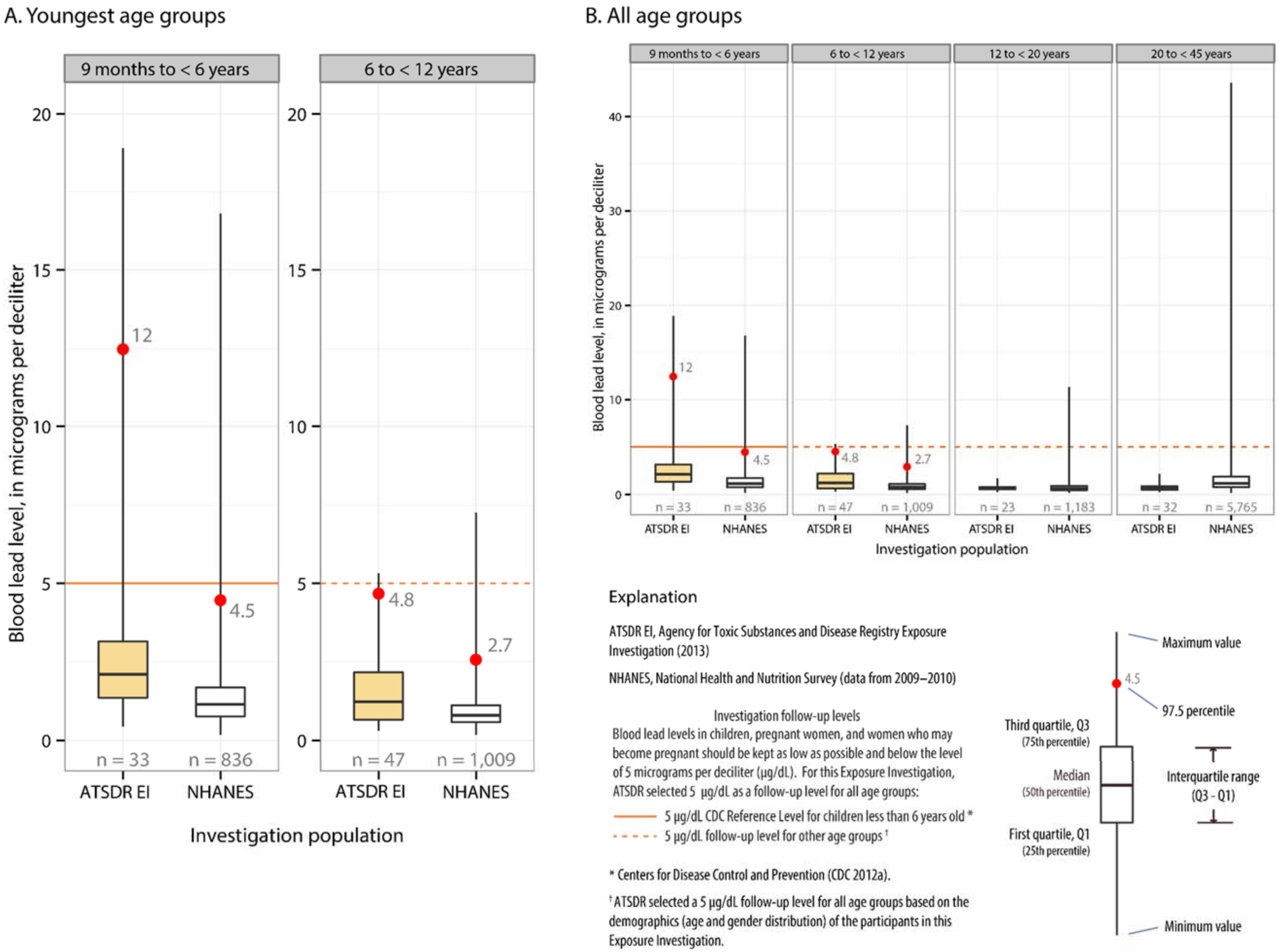


Figure 6. Blood lead results (n = 135) by age groups for the ATSDR Exposure Investigation in Pueblo, Colorado, compared to National Health and Nutrition Survey (2009–2010) data (see Appendix C for additional information about interpreting boxplots)

Arsenic and Health Effects

Arsenic is a naturally occurring element that is found in combination with either inorganic or organic substances to form many different compounds. Arsenic often occurs naturally with lead. Arsenic is also released into the environment from mining, ore smelting, and industrial use. Fish and shellfish commonly contain organic arsenic compounds this can lead to organic arsenic exposure in people consuming sea food. Inorganic arsenic compounds are of greater concern for toxicity than organic arsenic compounds and are found in soils, sediments, groundwater, and some foods. People are most likely exposed to excessive amounts of inorganic arsenic through drinking water and to a lesser extent through various foods, such as rice, and some juices. Water sources in the north-central western regions of the United States have higher naturally occurring levels of inorganic arsenic than other areas of the U.S. Other potential sources of inorganic arsenic exposure can include contact with contaminated soil or with wood preserved with arsenic. [ATSDR 2007e, NRC 1999].

Inorganic arsenic has been linked to skin, liver, bladder, and lung cancer, and the Department of Health and Human Services (DHHS) has designated it as known to be a human carcinogen [NTP 2005].

Arsenic also induces a wide variety of non-cancer effects in humans. Unusually large doses of inorganic arsenic can cause symptoms ranging from nausea, vomiting, and diarrhea to dehydration and shock. Long-term exposure to high levels of inorganic arsenic in drinking water has been associated with skin disorders (e.g., hyperkeratosis and hyperpigmentation) and increased risks for diabetes and high blood pressure.

Arsenic is rapidly metabolized and excreted from the body within 2 – 3 days of exposure [Orloff et al 2009]; thus, urinary arsenic testing measures only recent exposures. Therefore, a urine sample needs to be collected soon after exposure has occurred, for this reason ATSDR conducted two rounds of urine arsenic testing to increase the likelihood of finding arsenic exposures.

The concentration of total urinary arsenic in all but one participant was below the 95th percentile of the national reference level of NHANES 2009-2010 (Figure 4). For the one sample that exceeded the reference level, additional laboratory analysis separated the total urinary arsenic levels into organic and inorganic arsenic species. Speciated urinary arsenic analysis can distinguish between exposures to inorganic arsenic, including its organic metabolites and the relatively non-toxic forms of organic arsenic found in seafood (e.g., arsenobetaine). The laboratory identified arsenobetaine, a benign dietary form of organic arsenic mostly found in seafood, as the principal component of the one elevated total urine arsenic sample. The participant with elevated total urinary arsenic was tested a second time in November 2013; the total arsenic level was below the 95th percentile in the second testing.

The inorganic arsenic levels in all of the urine samples (both rounds of sampling) were below the 95th percentile for the NHANES 2009-2010 survey data.

Limitations of this Exposure Investigation

All investigations have some inherent limitations. This EI has the following limitations:

- The results of this EI are applicable only to the individuals tested and cannot be generalized to other individuals in the area.
- ATSDR conducted blood lead and urinary arsenic testing for less than 10 percent of the eligible population in the investigation area. This sample size may not yield results representative of the population within the ½ mile radius of the former smelter.
- Testing occurred in the fall when outdoor activities were not as likely as during warmer months. Therefore, the EI results may not reflect worst case exposures. Studies indicate that children's exposure to lead in soil is highest when children play outdoors and have frequent contact with soils.
- The tests results cannot be used to predict the future occurrence of disease in individuals. Blood lead indicates there was exposure to lead, urinary arsenic levels indicate recent exposure. Arsenic is rapidly metabolized and excreted from the body, a urine sample needs to be collected soon after exposure has occurred, e.g. half of the amount of ingested arsenic excreted in a 4 day period, was excreted within the first 28 hours. [Orloff et al, 2009].
- Children less than 6 years of age were not evaluated for arsenic in urine because there are no NHANES values for comparison.

Conclusions

Conclusion 1-Blood Lead Level

ATSDR found that young children living in the vicinity of the former smelter are at increased risk of lead exposure and higher blood lead levels compared to the background NHANES data; this exposure can harm children's health.

Basis for Decision

Three of 33 children ages 9 months to less than 6 years had BLLs greater than 5µg/dL. One six year old also had a blood lead level greater than 5µg/dL (Figure 3). Additionally three children ages 2, 4 and 7 had blood levels between 4 and 5µg/dL. The lead levels in these children are known to have adverse health effects. In general, median (i.e., 50^{th} percentile) blood lead levels for the youngest age groups, (9 months to less than 6 years old, and 6 to less than 12 years old), are higher than corresponding national levels (Table 4, Figure 6).

In addition to the potential exposure to contaminated soil, people living in the area have multiple factors associated with increased risk of higher blood lead levels. The census tract showed a large percentage of Mexican-Americans (65%) [American Community Survey 2006-2010 tract-level from the US Census], poverty (46%) [American Community Survey 2006-2010 tract-level from the US Census], and homes built before 1978 (96%) [American Community Survey 2006-2010 tract-level from the US Census]. Older housing may have lead-based paint. Studies have indicated that these are all risk factors for higher Blood Lead Levels (BLLs) [Dixon et al. 2009, Jones et al 2009, Bernard 2003].

Conclusion 2 -Urinary Arsenic

ATSDR did not find evidence of elevated arsenic exposure in the population tested, that live near (within ½ mile) the former Colorado Smelter.

Basis for Decision

The concentration of total urine arsenic in all but one participant was below the 95th percentile of the NHANES 2009-2010 data. For the participant with the elevated total urine arsenic level, the speciation analysis identified arsenobetaine, a dietary form of organic arsenic mostly found in seafood, which are relatively nontoxic. This person was tested a second time and the total urine arsenic was below the 95th percentile reference level for arsenic.

Recommendations

ATSDR recommends primary prevention efforts to avoid exposure to lead wherever possible. Therefore, ATSDR supports the following public health actions:

1. **Prevent exposure to contaminated soil outside:**
    - Cover bare soil with vegetation (grass, mulch, etc.)
    - Create safe play areas for children with appropriate and clean ground covers. Consider sand boxes for children that like to dig.
    - Supervise children closely to identify any age appropriate hand-to-mouth behavior or intentional eating of dirt– Pica, should be modified or eliminated.
    - Keep children’s hands clean, wash them periodically before coming inside, and before eating. Do not eat food, or chew gum when playing or working in the yard.
2. **Prevent exposure to contaminated soil in the home:**
    - Remove shoes before going in the house.

- Regularly conduct damp mopping and damp dusting of surfaces. Dry sweeping and dusting could increase the amount of lead-contaminated dust in the air.
- Change and launder any dirty clothes separately after playing outside.
- Frequently bathe your pets as they could also track contaminated soil into your home.

3. **Take additional measures to protect children 1 to 5 years of age:**

    - Separate children from sources of exposure.
    - Supervise children closely to prevent pica behavior.
    - Practice good hygiene with frequent hand washing especially before meals.
    - Wash children's bottles, pacifiers and toys frequently.
    - Offer frequent, small nutritious, age appropriate meals rich in calcium, and vitamin C and E. Children who eat healthy diets absorb less lead.
    - Have children evaluated for qualification in the Women Infants and Children (WIC) program.

4. **Continue blood lead testing of children, pregnant women and women of child-bearing age**; and conduct appropriate follow-up in the area surrounding the former smelter. Primary care providers should conduct confirmatory venous blood lead testing as mandated by the state of Colorado.

5. **Educate health professionals** about the following:

    - Locations of soil lead and arsenic contamination in Pueblo,
    - How to prevent or reduce soil lead and arsenic exposure and other sources of potential lead exposure such as lead-based paint, and
    - Conducting blood lead screening and confirmatory venous blood lead testing

6. **Characterize the nature and the extent of lead and arsenic contamination, to include bioavailability testing of soil lead**

7. **Stop or reduce exposure to mining wastes in residential soil and slag piles.** For example, take actions to prevent children from playing or riding bicycles on the slag piles.

8. **Develop a sustainable health education program in the area** to provide information to community members about lead contamination and how to reduce exposures.

Public Health Action Plan

The Public Health Action Plan for the Colorado Smelter Site contains a description of actions completed and proposed actions by ATSDR, PCCHD, and EPA. The purpose of the EI is to ensure that we identify exposures that may be of public health concern and also provide a plan of action designed to prevent or mitigate adverse human health effects from contaminant exposure. ATSDR and PCCHD will follow-up on this plan to ensure these actions are carried out.

Actions Completed

1. In October 2013, ATSDR sent each participant a letter informing them of their BLL results and called every participating household to discuss their own or their child's results.

2. On October 23, 2013 ATSDR provided the results of the BLL testing to PCCHD by letter, as mandated by the State of Colorado's Regulation Pertaining to the Detection, Monitoring, and Investigation of Environmental and Chronic Diseases (6CCR1009-7). We also discussed the BLL results with the PCCHD Director of Health.

3. In October 2013, PCCHD conducted Healthy Home Inspections in the houses with children who had elevated BLLs.

4. In May 2014, ATSDR sent each participant a letter informing them of the urine arsenic results from urine samples collected in September and November 2013, and spoke with most of the participating households to discuss the arsenic test results.

5. On June 10, 2014, PCCHD obtained a six year grant from the EPA- Region 8 to conduct health education, BLL screening, assist in the coordination of developmental and cognitive evaluations in affected children from a designated area of Pueblo, and conduct other public health actions/investigations as stipulated in the grant.

6. On December 11, 2014 EPA listed the Colorado Smelter site on the National Priority List (NPL).

Actions Proposed

1. To reduce exposure

2. To ensure BLL screening of young children in the neighborhoods near the former smelter is accomplished, PCCHD will do care coordination (integration of health and social care services for a particular person) with parents (i.e. through Colorado Blue Sky, Child Find, or by their primary physician).

3. As part of the EPA grant, PCCHD public health nurses will

   a. follow-up with children with a high BLL screening,
   b. provide parents nutritional education, and
   c. ensure children with elevated BLLs are seen by their primary care physician or assist them in getting referrals for service.

4. PCCHD, ATSDR, and EPA will develop and implement a Sustainable Outreach and Health Educational Program for the area of Pueblo to prevent exposure to contaminated soil and other sources (e.g., lead-based paint).

5. ATSDR will conduct a grand rounds presentation for area primary care providers to increase awareness of the exposures to lead.

6. ATSDR will conduct a public availability session for participants after this report is released.

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References

[ATSDRa] Agency for Toxic Substances and Disease Registry. 2007. Toxicological profile for lead (update). Atlanta: US Department of Health and Human Services; 2007.

[ATSDRb] Agency for Toxic Substances and Disease Registry. 2007. Toxicological profile for lead (update). Atlanta: US Department of Health and Human Services; 2007.

[ATSDRc] Agency for Toxic Substances and Disease Registry. 2007. Toxicological profile for lead (update). Atlanta: US Department of Health and Human Services; 2007.

[ATSDRd] Agency for Toxic Substances and Disease Registry. 2007. Toxicological profile for lead (update). Atlanta: US Department of Health and Human Services; 2007.

[ATSDRe] Agency for Toxic Substances and Disease Registry. 2007. Toxicological profile for lead (update). Atlanta: US Department of Health and Human Services; 2007.

Barbosa F et al. 2005. A critical review of biomarkers used for monitoring human exposure to lead: Advantages, limitations and future needs. Environmental Health Perspective, 2005, 113:1669-1674.

Barr DB, Wilder LC 2005. Urinary Creatinine Concentrations in the U.S. Population: Implications for Urinary Biologic Monitoring Measurements. Environmental Health Perspective, Volume 113/Number 2/ February 2005.

Bearer CF. How are Children Different from Adults? 1995. Environmental Health Perspective 103(Supplement 6):7-12 (1995).

Bernard SM, McGeeing MA, Michael A.2003. Prevalence of Blood Lead Levels greater than 5µg/dL Among U.S. Children 1 to 5 Years of Age and Socioeconomic and Demographic Factors associated with Blood Lead Levels 5 to 10µg/dL, Third National Health and Nutrition Examination Survey, 1988 – 1994. Pediatrics 2003;112;1308.

[CDC] Centers for Diseases Control and Prevention, Adult Blood Lead Epidemiology and Surveillance (ABLES). http://www.cdc.gov/niosh/topics/ABLES/ables.html

[CDCa] Centers for Diseases Control and Prevention, Advisory Committee on Childhood Lead Poisoning Prevention (ACCLPP) 2012. Low level lead exposure harms children: a renewed call for primary prevention.

[CDCb] Centers for Diseases Control and Prevention, Advisory Committee on Childhood Lead Poisoning Prevention (ACCLPP) 2012. Low level lead exposure harms children: a renewed call for primary prevention.

[CDCa] Centers for Diseases Control and Prevention. 2010a. Guidelines for the Identification and Management of Lead Exposure in Pregnant and Lactating Women. Atlanta: US Department of Health and Human Services. Available at: http://www.cdc.gov/nceh/lead/publications/leadandpregnancy2010.pdf

[CDCb] Centers for Disease Control and Prevention. 2010b. Lead (web page) for pregnant women. Last Updated November 29, 2010. Available online at: http://www.cdc.gov/nceh/lead/tips/pregnant.htm

[CDCa] Centers for Disease Control and Prevention. Lead (web page). 2012a. Update on Blood Lead Levels in Children. Last Updated October 30, 2012. Available online at: http://www.cdc.gov/nceh/lead/ACCLPP/blood_lead_levels.htm

[CDCb] Centers for Disease Control and Prevention. 2012b. Low Level Lead Exposure Harms Children: A Renewed Call for Primary Prevention: Report of the Advisory Committee on Childhood Lead Poisoning Prevention, Centers for Disease Control and Prevention. U.S. Department of Health and Human Services, January. Available at: http://www.cdc.gov/nceh/lead/acclpp/final_document_010412.pdf

[CDCc]Centers for Disease Control and Prevention. 2012c. CDC Response to Advisory Committee on Childhood Lead Poisoning Prevention Recommendations in "Low Level Lead Exposure Harms Children: A Renewed Call of Primary Prevention". Centers for Disease Control and Prevention, June 7, 2012. Available at: http://www.cdc.gov/nceh/lead/ACCLPP/CDC_Response_Lead_Exposure_Recs.pdf

[CDC15] Centers for Disease Control and Prevention. 2013. Fourth National Report on Human Exposure to Environmental Chemicals updated Tables. Atlanta: US Department of Health and Human Services; 2013 Available online at: http://www.cdc.gov/exposurereport/pdf/FourthReport_UpdatedTables_Sep2013.pdf

[CDC] Centers for Disease Control and Prevention. Morbidity and Mortality Weekly Report (MMWR). 2007. Interpreting and Managing Blood Lead Levels less than10 µg/dL in Children and Reducing Childhood Exposure to Lead: Recommendations of CDC's Advisory Committee on Childhood Lead Poison Prevention (ACCLPP).

[CDC] Centers for Diseases Control and Prevention. Morbidity and Mortality Weekly Report (MMWR). 2007. Lead Exposure Among Females of Childbearing Age—Unites States, 2004. April 27, 2007/56(16); 397-400. Available at: http://pediatrics.aappublications.org/content/112/6/1308.full.pdf

[CDC] Centers for Diseases Control and Prevention. Blood Lead Levels in Children 1-5 Years-U.S. 1999-2010 (April 5, 2013) MMWR: Morbidity and mortality Weekly Report, 62913);245-248. Available at: http://www.cdc.gov/immigrantrefugeehealth/pdf/lead-guidelines.pdf

[CDC] Centers for Diseases Control and Prevention. Emergency Preparedness and Response. Case Definition: Arsenic (Inorganic). Clinical Description. Available at: http://www.bt.cdc.gov/agent/arsenic/casedef.asp Last updated April 22, 2013. Accessed 10/09/2014.

[CDPHE] Colorado Department of Public Health and the Environment. 2008. Preliminary Assessment

Colorado Smelter Pueblo, Colorado April 28, 2008.

[CDPHE] Colorado Department of Public Health and Environment. 2010. Sample and Analysis Plan.

[CDPHE] Colorado Department of Public Health and Environment. 2011. Analytic Results Report.

Colorado Smelter, Pueblo, Colorado

[CDPHE] Colorado Department of Public Health and the Environment. March 2012. Rules and Regulations Pertaining to the Detection, Monitoring and Investigation of Environmental and Chronic Disease (6 CCR 1009-7).

Diawara MD, Lift JS, Unis D, et al. Arsenic, Cadmium, Lead, and mercury in surface soils, Pueblo, Colorado: Implications for population health Risk. Environmental Geochemistry and health (2006) 28:297-315.

Dixon SL, Gaitens JM, Jacobs DE, Strauss W,Nagaraja J, Pivets T, Wilson JW, Ashley PJ. 2009 Exposure of U.S. Children to Residential Dust Lead, 1999-2004: II. The contribution of lead contaminated dust to children's blood lead levels. Environmental Health Perspective 117:468-474. Available at: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2661919/

[EHP] Environmental Health Perspectives. Recommendations for Medical Management of Adult Lead Exposure. 2007 March; 115(3): 463–471. Published online 2006 December 22. doi: 10.1289/ehp.9784 http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1849937

[EPA] Environmental Protection Agency Takes Final Steps in Phase-out of Leaded Gasoline. Press Release January 29th, 1996.

[EPA] US Environmental Protection Agency. 2012. Lead in air: health effects. Webpage last updated 13 March 2012. Office of Air and Radiation. Research Triangle Park, NC. Available at: http://www.epa.gov/airquality/lead/health.html.

[EPA] US Environmental Protection Agency. 2013. Integrated science assessment for lead. Office of Research and Development, National Center for Environmental Assessment. Research Triangle Park, NC. EPA/600/R-10/075F.

Hinwood, A et al, 2002. Are 24-hour urine samples and creatinine adjustment required for analysis of inorganic arsenic in urine in population studies? Environ Res Section A. 88, 219–224.

Hughes MF et al, 2011. Arsenic Exposure and Toxicology: A Historical Perspective. Toxicological Sciences 123(2), 305-332 (2011).

Jeffery M et al 2007. Total Urine Arsenic Measurements Using Inductively Coupled Plasma Mass Spectrometry With a Dynamic Reaction Cell", Atomic Spectroscopy, 28(4), 2007, 113-122. DLS Method 3018A.3 (ICP-DRC-MS).

Jones R, Homa D, Meyer P, et al. Trends in Blood Lead Levels and Blood Lead Testing Among U.S. Children aged 1- 5 Years, 1988-2004. Pediatrics 2009. Mar; 123(3):e376-385 Available at: http://pediatrics.aappublications.org/content/123/3/e376.full.pdf+html

[NAS] National Academy of Sciences, 2013. Critical Aspects of EPA's IRIS Assessment of Inorganic Arsenic: Interim Report. http://www.nap.edu/catalog.php?record_id=18594

Naujokas MF, Anderson B, Ahsan H, Aposhian HV, et al. The Broad Scope of Health Effects from Chronic Arsenic Exposure: Update on a Worldwide Public Health Program. EHP Volume 121/Number 3/March 2013.

[NHANESa] National Health and Nutrition Examination Survey. 2007-2008a. [DLS method 1003.1] Available online at: http://www.cdc.gov/nchs/data/nhanes/nhanes_07_08/ALB_CR_e_met_urinary_creatinine_CX3.pdf

[NHANESb] National Health and Nutrition Examination Survey 2007-2008b. Statist. Med. 2008; 27:4094–4106. Analysis of NIST (National Institute of Standards Technology)

[NHANES] National Health and Nutrition Examination Survey 2009-2010. Blood Lead Cadmium Mercury ICPDRCMS. Method No: 3001.1 http://www.cdc.gov/nchs/data/nhanes/nhanes_09_10/pbcd_f_met.pdf

[NRC] National Research Council (NRC). Arsenic in Drinking Water. Washington, DC: National Academy Press, 1999

[NTP] National Toxicology Program. Health Effects of Low-Level Lead. U.S. Department of Health and Human Services, June 2012.

[NTP] National Toxicology Program. The National Toxicology Program announces the release of the 11th Report on Carcinogens, January 31, 2005.

Kosnett MJ, Wedeen RP, Rothenberg SJ et al. Recommendations for Medical Management of Adult Lead Exposure. EHP, Volume 115, No 3, March 2007.

Orloff K, Mistry K, Metcalf S. 2009. Biomonitoring for Environmental Exposures to Arsenic. Journal of Toxicology and Environmental Health, Part B: Critical Reviews. 12:7, 509-524. Available at http://dx.doi.org/10.1080/10937400903358934

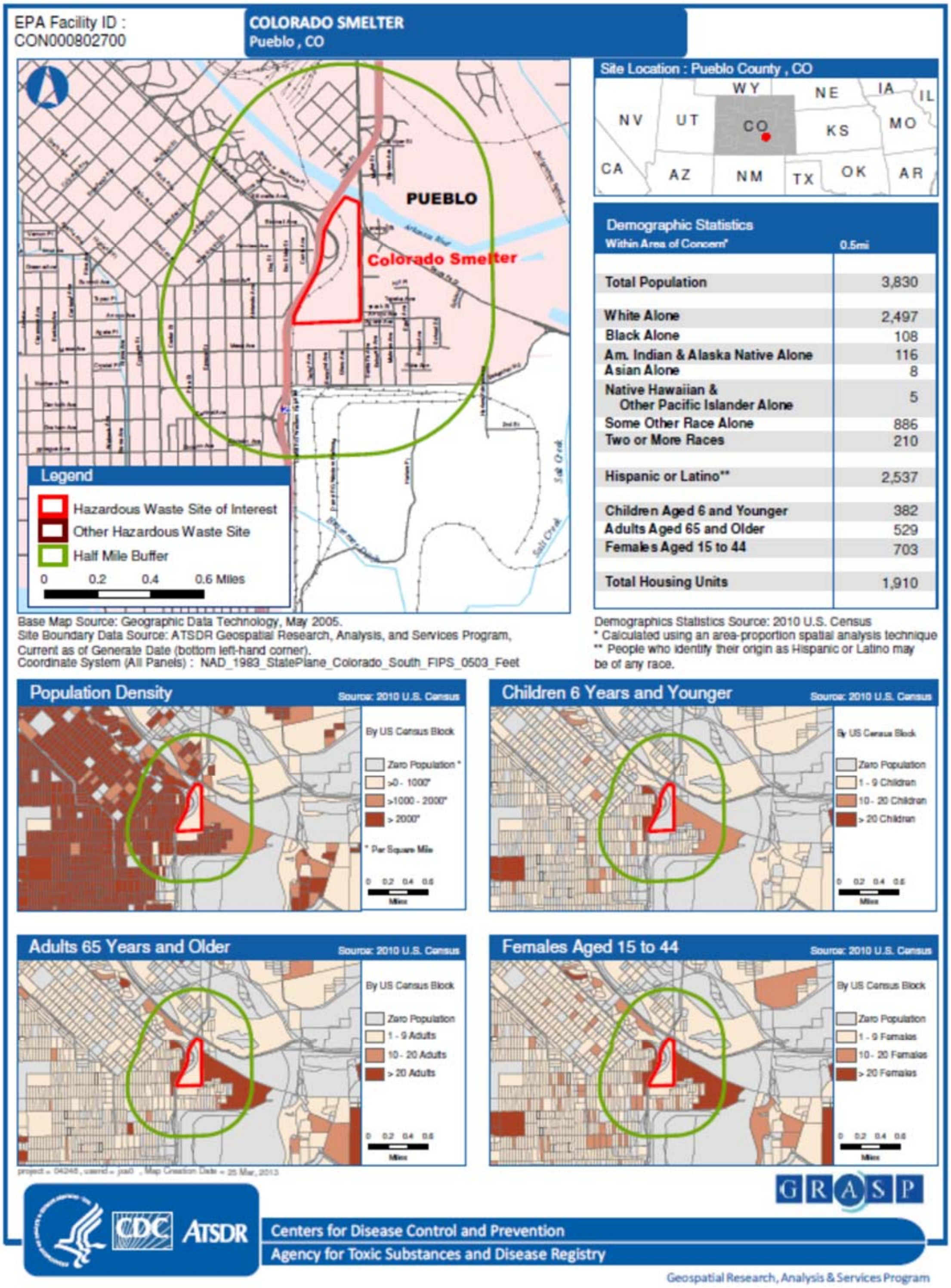
U.S. Census Bureau; American Community Survey, 2010. American Community Survey. Available at: http://www.census.gov/acs/www/

USEPA (U.S. Environmental Protection Agency), 2013. Integrated Science Assessment for Lead. EPA/600/R-10/075F/June 2013. Available at: http://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=255721#Download

Verdon CP. Determination of seven arsenic compounds in urine by HPLC-ICP-DRC-MS: a CDC population Biomonitoring method. Anal Bioanal Chem (2009) 393:939–947). DLS Method 3000.11 (HPLC-ICP-DRC-MS)

Appendices

Appendix A: Colorado Smelter Exposure Investigation Map and Demographics



Appendix B: Meteorological data

The Pueblo Municipal Airport station, located 7 miles east of the site, is the closest meteorological station with high quality, long-term, wind measurements. The National Oceanic and Atmospheric Administration's (NOAA's) National Climatic Data Center (NCDC) aggregated the wind measurements for this station from 30 years of hourly measurements. These data are high quality and of sufficient length (30-year record) to produce a reliable estimate of the general wind patterns for the area. Wind speed and direction at the Pueblo smelter site are probably similar to the summary data from the Pueblo station.

The average wind speed and wind direction data for the Pueblo station for the period 1981–2010 are summarized in a single wind rose in Figure A1. The same data are shown in Figure A2 by month. These graphical summaries, representing 30-year average wind speed and direction data, indicate the following:

- The prevailing wind direction in the area of the site is toward the southeast (40% frequency), with wind speeds up to 4 miles per hour (mph) (Figure A1). About 15% of the time, winds are toward the northwest at speeds of up to 6 or 7 mph.

- On a monthly basis, winds are predominantly toward the southeast for much of the year (Figure A2). During the summer months, there's a strong secondary wind component toward the northwest.

The wind data used for Figures A1 and A2 are publicly available from the NOAA NCDC internet site at www.ncdc.noaa.gov/cdo-web/datasets. ATSDR downloaded the wind data and created the wind rose graphics in Figure A1 and A2 using R statistical software (R Core Team 2014) and the R package open air (Carslaw and Ropkins 2012, Carslaw and Ropkins 2014). Both of these software tools are open source and publicly available for free at www.r-project.org/.

References

R Core Team. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. 2014. Available at www.R-project.org/.

Carslaw DC and Ropkins K. openair --- an R package for air quality data analysis. Environmental Modelling & Software. 2012; 27-28: 52-61.

Carslaw D and Ropkins K. openair: Open-source tools for the analysis of air pollution data. R package version 0.9-2. 2014.

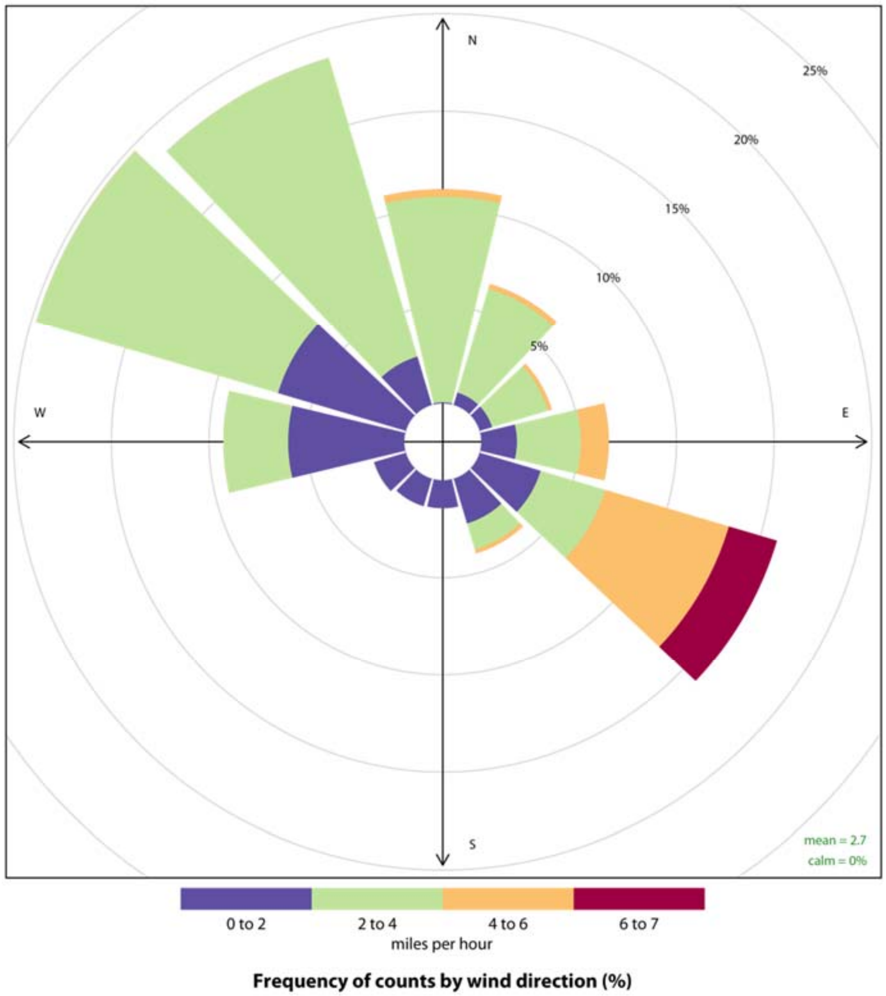


Figure A1. Average wind speed and wind direction for a 30 year period (1981–2010), Pueblo Municipal Airport meteorological station, Pueblo, Colorado

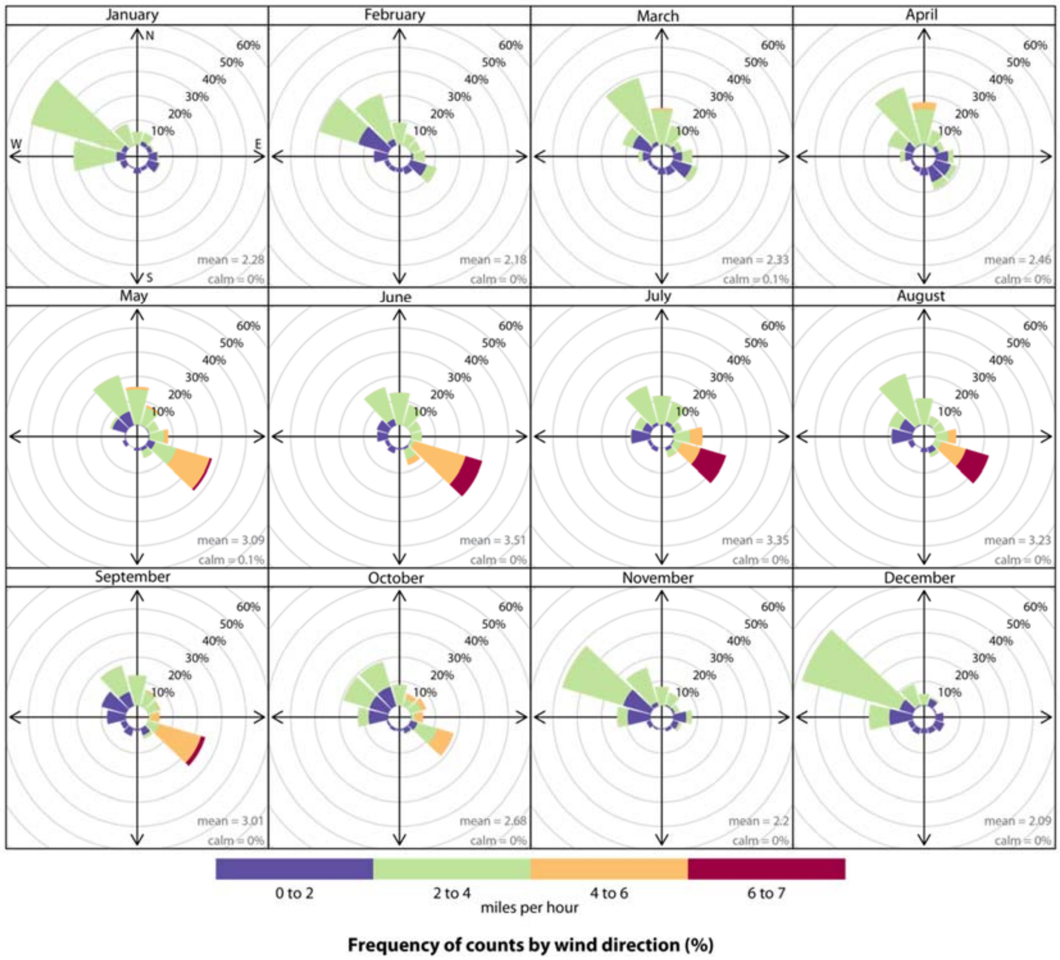


Figure A2. Wind speed and wind direction data summarized by month for a 30 year period (1981–2010), Pueblo Municipal Airport meteorological station, Pueblo, Colorado

Appendix C: Interpreting Boxplots

What is a boxplot?

A boxplot is a useful way to visualize the distribution of a data set, including its shape, center, and spread (Figure 1). Boxplots are sometimes referred to as "box and whisker" plots.

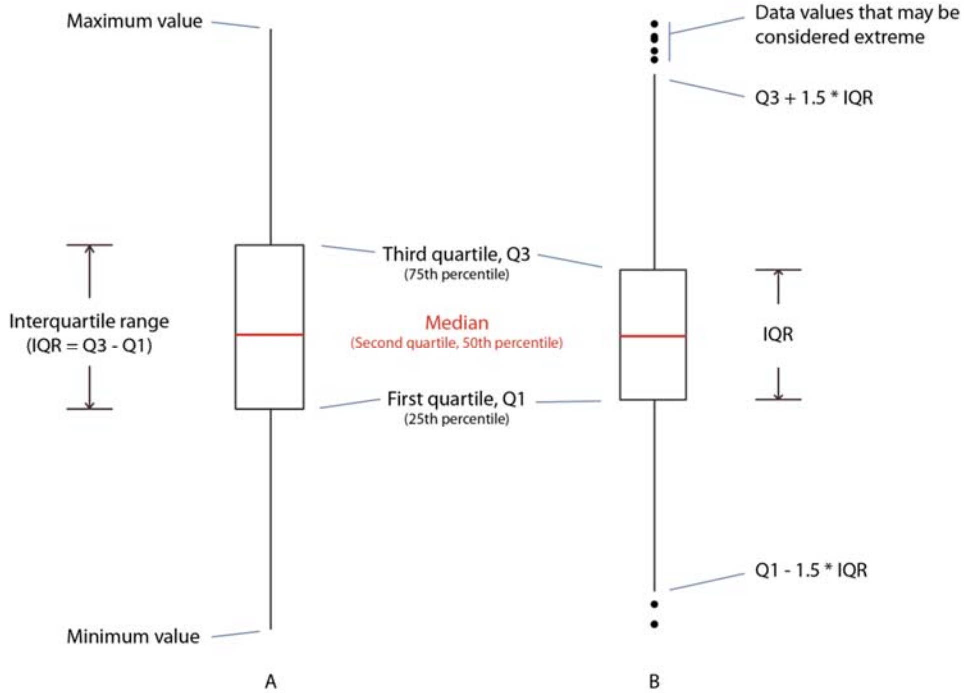


Figure 1. Boxplot with whiskers (vertical lines above and below the box) representing (A) maximum and minimum data values, and (B) an extent defined as 1.5 times the IQR.

How can I read a boxplot?

The components of the boxplot illustrate what is often called the five-number summary of a data set: the median, minimum, maximum, and first and third quartiles.

- The **median**, also called the second quartile or 50th percentile, is a measure of the center of the data. The median is the value that is in the middle of the data, so 50% of the data will be above the median and 50% of the data will be below the median. The average–which is another measure of the center of the data–is obtained by summing together all of the data values and dividing by the number of values (n). Because the median is less affected by extreme values in the data, it can be a better central measure than the average. The average often is not shown on a boxplot.
- The **minimum** and **maximum** refer to the lowest and highest values, respectively.
- The **first** and **third quartiles,** or 25th and 75th percentiles, respectively, correspond to the outer edges of the box and represent the mid-points between the median and the minimum and maximum values in the data. Specifically, 25% of the data are below the first quartile and 25% of the data are above the third quartile.

The **interquartile range** (IQR) is the range between the first and third quartiles (Q3-Q1) and corresponds to the span or the extent of box itself. The extent of the box visually represents 50% of the data. The lines extending from the box can represent different quantities. Sometimes the lines are extended to the minimum and maximum values of the data. Alternately the lines may extend to the last data value that is within 1.5 times the IQR from the first and third quartiles (e.g., Q3 + 1.5 *IQR). In the latter case, any data values outside of the defined extent are shown as data points that are considered more extreme values.

What can a boxplot tell me about my data?

Boxplots can be used to quickly identify whether a particular data set is normally distributed or obviously skewed (Figure 2). A boxplot for a normal data distribution is symmetrical, with the median bisecting the box and whiskers of approximately equal length (Figure 2A). Skewed data have boxplots that are not symmetrical; the median may be located off-center in the box or the whiskers are of unequal length. Extreme values are individual data points outside of the whiskers. Boxplots are useful for comparing several data sets side-by-side (Figure 3A).

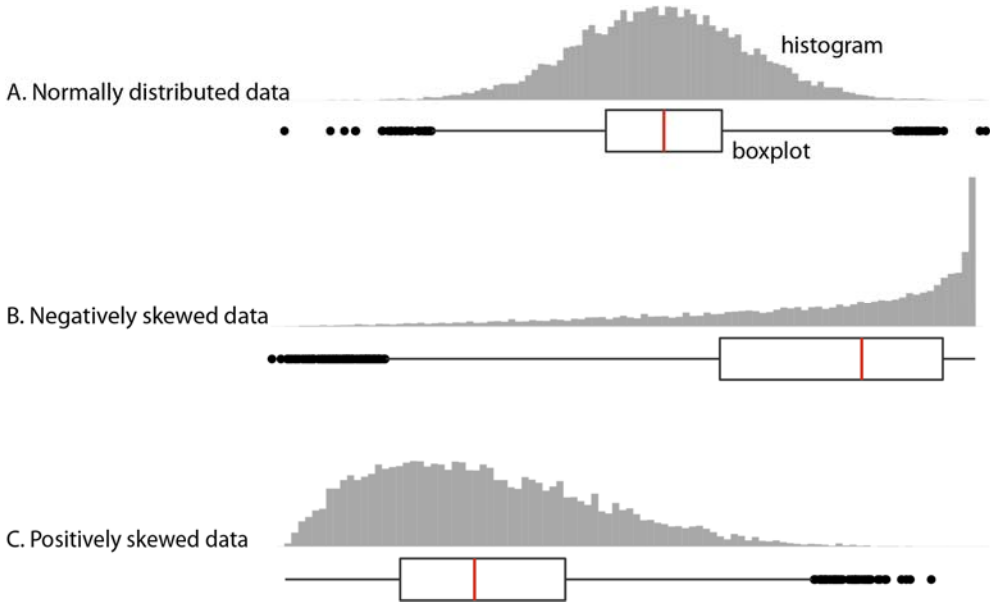


Figure 2. Boxplots and associated histograms illustrating data that are (A) normally distributed, (B) negatively skewed, and (C) positively skewed.

Different types of boxplots

There are many variations to the basic boxplot, including a minimalist version without the actual box depicted (Figure 3B), the notched boxplot with notch length corresponding to a 95% confidence interval on the median (Figure 3C), and the violin plot (Figure 3D), which has a width that varies according to the density of the data.

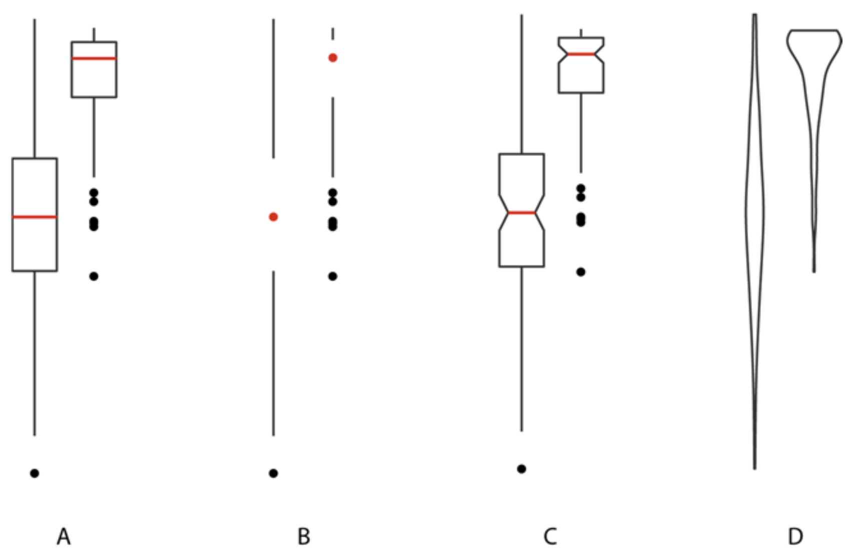


Figure 3. Different types of boxplots: (A) basic, (B) minimalist, (C) notched boxplot, and (D) violin plot.

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Completing the survey should take less than 5 minutes of your time. If possible, please provide your responses within the next two weeks. All information that you provide will remain confidential.

The responses to the survey will help ATSDR determine if we are providing useful and meaningful information to you. ATSDR greatly appreciates your assistance as it is vital to our ability to provide optimal public health information.

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