# Health Consultation

## Exposure Investigation

Biological Testing for Exposure to Lead

FORMER UNITED ZINC & ASSOCIATED SMELTERS

IOLA, KANSAS

AUGUST 15, 2018

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

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## Abbreviations and Acronyms

| | |
|---|---|
| ATSDR | Agency for Toxic Substances and Disease Registry |
| BLL | blood lead level |
| CDC | Centers for Disease Control and Prevention |
| DHHS | Department of Health and Human Services |
| DLS | Division of Laboratory Sciences |
| EI | Exposure Investigation |
| EPA | (U.S.) Environmental Protection Agency |
| KDHE | Kansas Department of Health and Environment |
| µg/dL | micrograms per deciliter |
| mg/kg | milligrams per kilogram |
| NCEH | National Center for Environmental Health |
| NHANES | National Health and Nutrition Examination Survey |
| OMB | Office of Management and Budget |
| PEHSU | Pediatric Environmental Health Specialty Unit |
| SEKMCHD | Southeast Kansas Multi-County Health Department |
| WIC | Women, Infants and Children Program |

## Executive Summary

The Agency for Toxic Substances and Disease Registry (ATSDR) conducted an Exposure Investigation (EI) in Iola, Kansas with two sampling events in December 2016 and August 2017. Iola is home to the Former United Zinc and Associated Smelters site, which is included on the Superfund National Priority List (NPL). This hazardous waste site resulted from historical smelting operations in Iola from 1902 to 1925. Residential and non-residential properties are contaminated with elevated levels of lead in soil due to previous smelting operations. As a result, there is potential for exposure to lead in the community. The U.S. Environmental Protection Agency (EPA) is in the process of remediating the soil in Iola based on lead levels reported from sampling conducted in 2006 and 2013.

At the request of EPA, the ATSDR EI team collected blood samples from participants living within the city limits of Iola and analyzed the samples for lead. Children and women who were pregnant or of childbearing age had their blood tested for lead. The most vulnerable populations include young children with hand-to-mouth behavior and children with pica behaviors (i.e., craving to eat nonfood items, such as dirt, paint chips and clay). Pregnant women and women who may become pregnant were also tested because of effects lead can have on a developing fetus.

The Centers for Disease Control and Prevention (CDC) adopted a blood lead reference value of 5 micrograms per deciliter (µg/dL) in 2012 to identify children who require case management [CDC 2012a]. There is no identified threshold or “safe” blood lead level, and some studies indicate that even very low BLLs can cause neurological, cognitive, and attention-related behavioral issues in children [CDC 2012b]. In this EI, ATSDR used 5 µg/dL as the investigation follow-up level for lead for all ages, including children older than 6 years, pregnant women, and women of childbearing age.

The EI was conducted in two sampling events, one in December 2016 and one in August 2017. The December 2016 event offered blood lead testing to people living in homes with the highest levels of lead in soil. Homes with soil lead greater than 800 milligrams per kilogram (mg/kg) that had not been remediated by EPA were identified and residents were sent a letter inviting them to participate. The EI team followed up the letter by visiting these homes to provide information about the testing and to sign up participants. Although this group of residents were specifically recruited for the testing, any eligible resident of Iola was welcome to be tested. In the December testing event, 7 participants were tested (5 children and 2 women). None of the participants had blood lead levels (BLL) greater than 5 µg/dL. All participants were notified of their results by phone and were sent a letter that provided the results of the testing as well as recommendations on how to reduce exposure to lead in soil both outside and inside the home.

For the August 2017 event, ATSDR completed a more comprehensive recruitment effort that invited all eligible Iola residents to participate and raised awareness of lead issues in Iola.

Recruitment included sending an informational postcard to all homes with soil lead greater than 400 mg/kg followed by door-to-door recruitment at the homes. Outreach also included raising awareness of lead issues in Iola by providing information on lead to local physicians, daycares, and schools, and by hanging posters detailing the testing event at key locations around the community. As with the December testing event, all eligible residents of Iola were welcome to be tested. In the August event, 54 participants were tested: 36 children and 18 women. One child younger than 6 years old had a BLL greater than 5 µg/dL. The parent was notified of the results by phone and retesting was recommended. All participants were provided a letter with their results that also outlined recommendations for reducing exposure to soil both inside and outside the home.

The EI results in Iola indicated that the median BLL for children aged birth to 11 years were approximately two to three times higher compared to what would be expected based on the National Health and Nutrition Examination Survey (NHANES) data [birth to 5 years: 1.35 µg/dL for Iola (0.74 µg/dL for NHANES); 6-11 years: 1.5 µg/dL for Iola (0.53 µg/dL for NHANES)] . The BLL results for older children (12 to 19 years) and female adults tested in Iola were comparable the NHANES data for those age groups. NHANES represents the median BLL for people in the general U.S. population.

Residents of Iola have a higher potential for exposure to lead given elevated concentrations of lead in soil: average of 333 mg/kg in Iola [EPA 2018] compared to 21 mg/kg lead for background soil in Kansas [Smith et al. 2014]. In addition, the majority of homes in the community were built prior to 1978, when lead was allowed in paint. An additional risk factor for the Iola community is an elevated level of poverty (27% of residents below the poverty line) [American Fact Finder 2018]. All participants tested had measurable lead in the blood (level of detection = 0.07 µg/dL) and BLLs were higher in children as compared to adults. The EI results indicating that children have higher blood lead than adults are consistent with the increased absorption of lead by children compared to adults [Bearer 1995] and the higher potential for children to have contact with contaminated soil and lead paint due to outside play and mouthing activities in young children. The results of the questionnaire administered to participants documented the amount of time that participants spent outside and mouthing activity of the children.

The results of the EI are limited since they are only applicable to the individuals tested and cannot be generalized. The results do not provide information to determine when the exposure occurred or the specific source of exposure. Given the age of homes in Iola, lead in paint, indoor air and drinking water may be significant contributors to potential lead exposure.

**Recommendations**

EPA is in the process of removing lead-contaminated soils in Iola and installing seed or sod to provide grass cover in residential yards. ATSDR supports the remedial actions taken by EPA that will result in lower exposure of the Iola community to lead. ATSDR recommends primary prevention efforts to avoid exposure to lead in soil. Therefore, ATSDR supports the following public health actions:

1. Try to prevent exposure to potentially contaminated soil outside the home during outdoor activities.
2. Try to prevent exposure to potentially contaminated soil inside the home, e.g, tracking soil into the home that becomes indoor dust.
3. Take additional measures to protect children younger than 6 years of age by ensuring that painted surfaces are maintained to reduce exposure to lead paint and practicing good hygiene to reduce exposure to soil and dust.
4. Educate health professionals about the impact on the community of past smelting activities and the importance of reducing lead exposure and conducting appropriate lead testing.

## Background and Purpose of the Exposure Investigation

Iola is the county seat of Allen County and is located along the Neosho River in southeastern Kansas. In the 2010 census, the population of Iola was 5,875 (Appendix A). Smelting operations resulted in lead contamination of soil at both residential and commercial locations in Iola (Appendix B). Lead exposure may also result from lead in house paint since the majority of the homes in Iola (77%) were built before 1978, when lead was allowed in house paint (Appendix A).

### Environmental Sampling Data

The Kansas Department of Health and Environment (KDHE) was involved in sampling and cleanup activities starting in the 1990's. EPA began testing soil in Iola in 2005 at residential homes, daycare facilities, schools, and commercial areas. Maximum concentrations of lead in soil were 2,290 mg/kg in residential yards and 6,433 mg/kg at commercial properties. In 2015, the mean level for lead in soil in Iola prior to remediation was 333 mg/kg (median 223 mg/kg) [EPA 2015]. This value represents all samples taken by EPA in Iola from a database of soil data using on-site XRF (X-ray fluorescence) and laboratory analysis. The data consist of 17,550 soil lead results from 3,540 unique properties (residential, commercial, and vacant lots). The samples were taken by separating the yards into quadrants and analyzing up to four samples per yard. In addition, driplines (the location where rain runs off a roof onto the ground) were analyzed where appropriate. The soil sampling data used to evaluate a potential correlation between BLL tested for the EI and soil levels reflect the maximum soil concentration found at the home of the participant.

EPA's soil testing indicates that soil lead levels in Iola are well above the mean background level of 21 mg/kg in Kansas [Smith et al. 2014]. Appendix B provides a historical map of the Iola area and EPA results for lead in soil prior to remediation. Bioaccessibility studies for soil in Iola indicate that the bioavailability of lead in soil and dust was estimated at 31% [EPA 2016].

EPA has divided the site into three categories called operable units (OUs). EPA often portions a site into smaller units, or OUs, to assist in site management and ultimate cleanup at a site. The criteria for the categorization into OUs are described in Table 1.

**Table 1. EPA Operational Units (OUs) in Iola, KS**

| OU | Criteria | Remedial Action |
|---|---|---|
| **OU-00** | 1. Residential properties with soil lead greater than 800 mg/kg,<br>2. High Impact sensitive population areas such as schools and daycares where composite sample results exceed 400 mg/kg,<br>3. Residential properties with soil lead between 400 and 800 mg/kg where a child with a BLL greater than 10 µg/dL resides. BLL from any testing, including the EI, may be used by EPA to identify these residential locations. | 479 properties identified to date<br>• 129 residential properties remediated in 2005-2006<br>• Two emergency removal actions were completed at Iola schools in 2005 (maximum soil level of 5,500 mg/kg)<br>• Approximately 250 residential properties were remediated between September 2015 and August 2017.<br>• Remainder will be scheduled for remediation |
| **OU-01** | Residential properties with soil lead between 400 and 800 mg/kg | 763 properties identified to date<br>• To be remediated after EPA chooses a remedy (in progress as part of the RI/FS process) |
| **OU-02** | Commercial properties | Lead in soil will be remediated in the future using to-be-determined criteria |

## Previous Blood Lead Testing

Blood testing efforts in Iola from 2006 to 2012 are shown in Table 2. The blood testing in Iola and Allen County from 2007 to 2012 indicate 14.1% (Iola) and 14.6% (Allen County) of children tested during that period exceeded the current CDC's reference level for children's blood lead (Table 2). It should be noted that, during that timeframe, the CDC reference level was 10 µg/dL and not the current 5 µg/dL. Similar exceedances of the reference level were reported in 2011 and 2012 in Iola (14.6% and 13.8%) and Allen County (13.2% and 15.5%) (Table 2). The State of Kansas has not had a CDC-funded child blood lead surveillance system in place since 2012. The Southeast Kansas Multi-County Health District (SEKMCHD) performed limited testing in association with the Women, Infants and Children (WIC) program from 2015 to 2016 and observed that 5.6% of the children tested under the program had blood lead levels in excess of 5 µg/dL. The sharp difference in exceedance rates between these data sets gave rise to concerns that the WIC dataset may reflect differences in collection methods or characteristics of the tested population (e.g., age, gender, socioeconomic class).

Because high lead levels are present in the soil in Iola, the potential for human exposure to lead 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 latter two groups are a vulnerable population because of leads effects on the developing fetus.

**Table 2. Blood Lead Testing Results in Iola, KS**

| Year | Location | Total number tested (<6 yrs old) | BLL results in children (number of children) | | % ≥ 5 µg/dL** |
|---|---|---|---|---|---|
| | | | 5 to <10 µg/dL | ≥10 µg/dL | |
| **2007-2010*†‡** | Allen County total | 574 | 64 | 20 | 14.6% |
| | • Iola | 391 | 43 | 12 | 14.1% |
| | • Rest of Allen County | 183 | 21 | 8 | 15.8% |
| **2011*†‡** | Allen County total | 144 | 14 | 5 | 13.2% |
| | • Iola | 96 | 11 | 3 | 14.6% |
| | • Rest of Allen County | 48 | 3 | 2 | 10.4% |
| **2012*†‡** | Allen County total | 181 | 24 | 4 | 15.5% |
| | • Iola | 116 | 13 | 3 | 13.8% |
| | • Rest of Allen County | 65 | 11 | 1 | 18.5% |
| **2015-2016§** | Iola (WIC) | 160 | 9 | 0 | 5.6% |

* [KDHE 2018] Kansas Department of Health and Environment. 2018. Personal communication between Farah Ahmed and Spencer Williams, ATSDR, February 1, 2018.

† The number sampled for Allen County includes the number for Iola plus the number for the rest of Allen County. The numbers reflect individual children and do not include followup testing, if completed.

‡ Statistics for the data from KDHE and SEKMCHD for Allen County and Iola include capillary samples >5 µg/dL that were not later tested by venous sample. Of 21 capillary samples from Iola children subjected to confirmation by venous sampling from 2007-2010, only 2 were found to not represent an elevated blood lead level finding. All elevated blood lead level findings subjected to venous sampling in 2011 and 2012 were confirmed. Statistics for 2007-2010 treat children tested in different years as independent samples.

§ [SEKMCHD 2016] 2016. Southeast Kansas Multi-County Health Department. Personal communication between Chardel Hastings and Spencer Williams, ATSDR, October 17, 2016.

** The value of 5 µg/dL was selected because it is the CDC reference level based on the 97.5% BLL for children 1 to 5 years of age.

Abbreviations: KS = Kansas; BLL = Blood Lead Level; WIC = Women, Infants and Children; µg/dL = micrograms of lead per deciliter of blood

### Risk Factors for Lead Exposure in Iola

In addition to the potential exposure to contaminated soil, people living in the area have multiple factors associated with increased risk of lead exposure. The census tract has a large percentage of homes built before 1978 (77%) that may have lead-based paint and lead pipes that may impact drinking water [U.S. Census Bureau 2010] (Appendix A). In addition, approximately 27% of residents in Iola were below the poverty line in 2015 [American Fact Finder 2018] (Appendix A). Poverty is an additional risk factor for increased BLL [Dixon et al. 2009, Jones et al. 2009, Bernard et al. 2003].

## Agency Roles

A number of activities are conducted during an EI. ATSDR, the lead agency for the EI, collaborated with EPA, the KDHE, the SEKMCHD, and the CDC National Center for Environmental Health (NCEH) Division of Laboratory Sciences (DLS) to complete these activities. The roles of each agency are described in Table 3.

| Table 3. Exposure Investigation Activities and Agency Roles | | |
|---|---|---|
| **Activity** | **Agency** | **Agency Role** |
| EI protocol and PRA/OMB submittal | ATSDR | Completed the EI protocol which included Fact Sheets, Flyers, Posters, Questionnaire, Parental Permission, Consent and Assent Forms, Sampling and Analysis Plan<br>Submitted the Paperwork Reduction Act (PRA) forms to the Office of Management and Budget (OMB) for approval to administer the questionnaire and consent forms. This package also included an Institutional Review Board (IRB) exemption since the EI is not considered to be research. |
| Identification of properties based on soil lead levels | EPA | Provided information regarding soil lead levels and the status of remediation at residential homes in Iola in order to identify a mailing list for recruitment materials.<br>• December 2016: identified homes with ≥ 800 mg/kg in soil that had not been remediated.<br>• August 2017: identified all homes with ≥ 400 mg/kg in soil. |
| Provided ATSDR with BLL for children in Iola | KDHE and SEKMCHD | Both state agencies provided ATSDR with BLL data for children in Iola. The agencies will continue to engage the community regarding potential lead contamination in Iola. |
| Participant recruitment | ATSDR, EPA | Conducted door-to-door recruiting and scheduled appointments. |
| Blood sample collection | ATSDR | Administered parental permission/assent/consent forms to participants and their parent/guardian.<br>Hired licensed phlebotomists to draw blood from participants. |
| Blood sample analysis | NCEH/DLS | Used approved laboratory methods to analyze biological samples for lead and provide results to ATSDR. |

| Table 3. Exposure Investigation Activities and Agency Roles | | |
|---|---|---|
| **Activity** | **Agency** | **Agency Role** |
| Reporting of results | ATSDR | Prepared and mailed letters with results to all participants.<br>Contacted the participants in the EI who had BLL greater than 5 µg/dL to recommend followup with their physician.<br>Evaluated data and prepared the Exposure Investigation (EI) report. |
| Abbreviations: ATSDR, Agency for Toxic Substances and Disease Registry; EPA, Environmental Protection Agency; KDHE, Kansas Department of Health and Environment; SEKMCHD, Southeast Kansas Multi-County Health Department; NCEH/DLS, National Center for Environmental Health/Division of Laboratory Services | | |

## Methods

The methods used to identify and recruit participants, collect blood samples, and perform laboratory analyses are provided below.

### Criteria for Participation

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

- Children younger than 6 years of age
- Women who are pregnant or of childbearing age
- Siblings of children younger than 6 years of age at the parent's request

In Iola in 2010, there were 489 children 6 years of age and younger and 1,140 females of childbearing age (aged 15-44 years) [U.S. Census Bureau 2010] (Appendix A).

### Participant Recruitment

Residents that met the above criteria were recruited for the two phases of the EI as follows:

- December 2016: ATSDR recruited eligible people living at residences with yard soil lead ≥ 800 mg/kg (identified by EPA) that had not been remediated to offer blood lead testing. The residents in these homes are potentially the most highly exposed persons in the community.
- August 2017: ATSDR recruited all eligible people living in Iola for testing and provided a comprehensive outreach program to educate the community about the potential health impacts of lead in soil in Iola.

The goals of the EI, the recruitment efforts, and the results for each phase of the EI are presented in Table 4:

| Table 4: Goals, Recruitment Efforts and Results for the Iola EI | |
|---|---|
| **Testing Date** | |
| **December 2016** | **August 2017** |
| **Goal** | |
| Test eligible children/women in Iola homes with the highest levels of lead in soil (≥ 800 mg/kg). The goal was to provide immediate BLL testing for those residents with the highest potential for exposure and to provide follow-up as needed. | Test eligible children/women in Iola homes. In addition, provide all Iola residents with education and awareness of lead issues in the community |
| **Recruitment Effort** | |
| • Invited all Iola residents that met the recruitment criteria to be tested for BLL<br>• Mailed 216 recruitment letters and fact sheets to addresses with ≥ 800 mg/kg lead in soil that had not been remediated. Approximately 37% of the letters were returned as undeliverable.<br>• Went door to door to each of the homes that received recruitment letters, even if they were returned, to provide information on the testing and make appointments for testing. | • Invited all Iola residents that met the recruitment criteria to be tested for BLL<br>• Provided information to the community on the testing event, including how to sign up, using numerous methods<br>• Mailed 987 recruitment postcards to homes with ≥ 400 mg/kg lead in soil, including those that received the letter/fact sheet for the December event. Approximately 30% of the postcards were returned as undeliverable.<br>• Went door to door to each of the homes that received postcards, even if they were returned, to recruit participants and make appointments for testing<br>• Provided information packets for lead and testing information to local physicians<br>• Visited daycares/schools, and religious and community organizations in Iola and provided fact sheets and recruitment materials |

| Table 4: Goals, Recruitment Efforts and Results for the Iola EI | |
|---|---|
| **Testing Date** | |
| **December 2016** | **August 2017** |
| | • Visited local government offices to make them aware of testing and provide them with fact sheets<br>• Placed posters throughout the city in public locations to make community aware of testing effort<br>• Staffed a booth at the county fair the weekend of recruitment providing information to fair goers<br>• Attended the city farmer's market to hand out informational and recruiting materials to citizens<br>• Filmed a public service spot on SeeHearIola – a local television channel in Iola<br>• Announced the testing in a press release in local Iola newspaper |
| **Results** | |
| • 12 appointments made for testing<br>• 7 participants tested<br>o 5 children (birth to 19 years)<br>o 2 women (20 years and older) | • Approximately 100 appointments made for testing<br>• 54 participants tested*<br>o 36 children (birth to 19 years)<br>o 18 women (20 years and older) |

* - Ten participants (6 children younger than 6 years old and 4 women of childbearing age) that lived outside of Iola were included because they reported frequent contact with the contaminated soil in Iola while visiting family. One family recently moved outside of Iola and requested testing because they resided in Iola for many years.
Abbreviations: EI = Exposure Investigation; BLL = Blood Lead Level

Given the goals of the two EI events, information sharing and recruitment efforts for the August 2017 event were much more extensive than the December 2016 effort. Although the recruitment effort was extensive in August 2017, it did not result in a large number of participants. The recruitment effort, however, resulted in a greater awareness of lead issues within the community and in the surrounding area. Area physicians were provided information regarding potential effects of lead in young children and pregnant women and were encouraged to share information with their patients and recommend BLL testing. Several families that live outside Iola but spend time in Iola (e.g., at grandparents homes, etc.) requested testing as a result of the increased awareness of lead issues in the Iola area during the recruitment process. These participants were included in the EI since they had exposure to lead in soil in Iola.

### Biologic Sample Collection and Analytic Procedures

ATSDR administered Consent/Assent/Parental Permission forms prior to collecting the blood samples. Blood samples were collected on December 12, 2016 and from August 3-6, 2017.

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. Federal rules require that ATSDR maintain confidentiality of the information gathered through interviews as well as the results of laboratory tests. An adult from each household completed a questionnaire to assess potential exposures to lead resulting from daily activities.

Blood lead sampling is the most reliable method for measuring lead exposure from all sources [Barbosa 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 NCEH/DLS. To maintain privacy, the samples were labeled with a unique identification number.

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

The NCEH/DLS laboratory performed blood lead testing in Atlanta, Georgia using NHANES Method 2009-2010 [CDC 2009-2010] and Quality Assurance/Quality Control for lead according to NHANES 2007-2008 [CDC 2007-2008a,b].

All participants in the EI were sent a letter that contained their BLL results and provided information on how to reduce lead exposure both inside and outside the home.

## Results

### Participants in the Exposure Investigation

Sixty-one people participated in the EI: 7 people in December 2016 and 54 people in August 2017 (Table 5). Adults evaluated in the Iola EI were women 20 years of age or older. The participants by age and gender are reported in Table 5.

| Table 5. Summary of Participants by Age and Gender | | | |
|---|---|---|---|
| **Age Group** | **Total number of participants with Blood Lead Testing (n=61)** | | |
| | **Males** | **Females** | **Total** |
| Birth to 5 years old | 15* | 9* | 24 |
| 6 to 11 years old | 8 | 4 | 12 |
| 12 to 19 years old | 3 | 2 | 5 |
| ≥ 20 years old | 0 | 20[†] | 20 |

* 4 males and 2 females in this age range were from outside Iola city limits
[†]4 women were from outside Iola city limits

Based on the questionnaire responses, 73% (30/41) of the child participants (aged birth to 19 years) and 100% (20/20) of the adults are non-Hispanic and identify as white. The remaining children identified as mixed race (11/41 = 27%) including white/black, white/Hispanic or white/native American. The majority of the participants lived in single-family homes that were older than 1978, the year that lead-based paint was no longer manufactured. Eighty percent of the families had lived in their homes 5 years or less. Participants were asked how often they and their children took their shoes off before entering their home, how often they washed their hands and cleaned their homes, and if their children exhibited mouthing or pica behavior (e.g., eating dirt). Pica behavior was reported by the parents in approximately 23% of the children, including the child that had the elevated BLL. They were also asked whether they regularly use items that may contain lead, such as Mexican pottery or candy or home remedies that may contain lead.

Studies have reported that blood lead levels may be elevated when indoor dust contains elevated levels of lead resulting from lead based paint and the tracking of lead-containing soil into the home [Dixon et al. 2009]. Indoor dust samples were not available for households in Iola so it was not known what contribution lead in indoor dust, if any, would have on BLL in Iola residents.

**Blood Lead Results**

In 2012, CDC adopted the 97.5 percentile of the NHANES as a blood lead reference level; the current level is 5 µg/dL. This 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 [CDC 2012a,b,c]. For this investigation, ATSDR used 5 µg/dL of blood lead as the investigation level to identify participants for follow-up (including children, pregnant women, and women who may become pregnant).

One child younger than 6 years old had a BLL (6.3 µg/dL) that exceeded the investigation follow-up level of 5 µg/dL. The child with the BLL above the reference level was reported to play in the yard up to 6 hours per day and has exhibited pica behavior. ATSDR contacted the family by phone and recommended that the child receive follow-up blood lead testing.

Figure 1 provides the results of the blood lead testing in Iola in December 2016 and August 2017. It also includes participants that were located outside of the Iola city limits, but were included because they spend a lot of time in Iola and are likely exposed to contaminated soil. Higher BLLs were observed in children as compared to adults (Figure 1). In August 2017, one child had a BLL that exceeded the investigation follow-up level of 5 µg/dL; no adults had BLLs greater than 5 µg/dL. Results were comparable between the December 2016 and August 2017 testing events and between residents living within the Iola city limits and those that resided outside Iola but were exposed to soil in Iola. In the state of Kansas, a BLL of 10 µg/dL or greater is reportable to the state health department, therefore, no BLL for EI participants were reportable.

**Figure 1**
**Blood Lead Levels by Age in the Iola, Kansas EI**

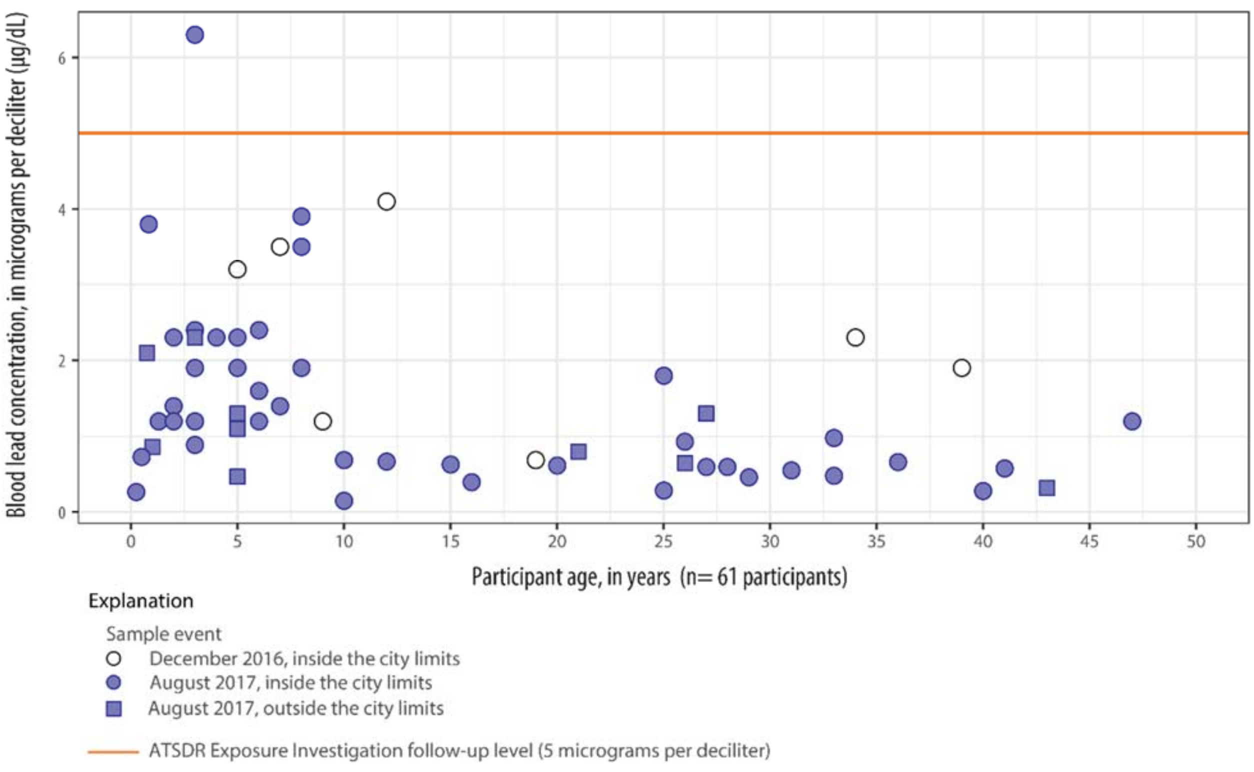
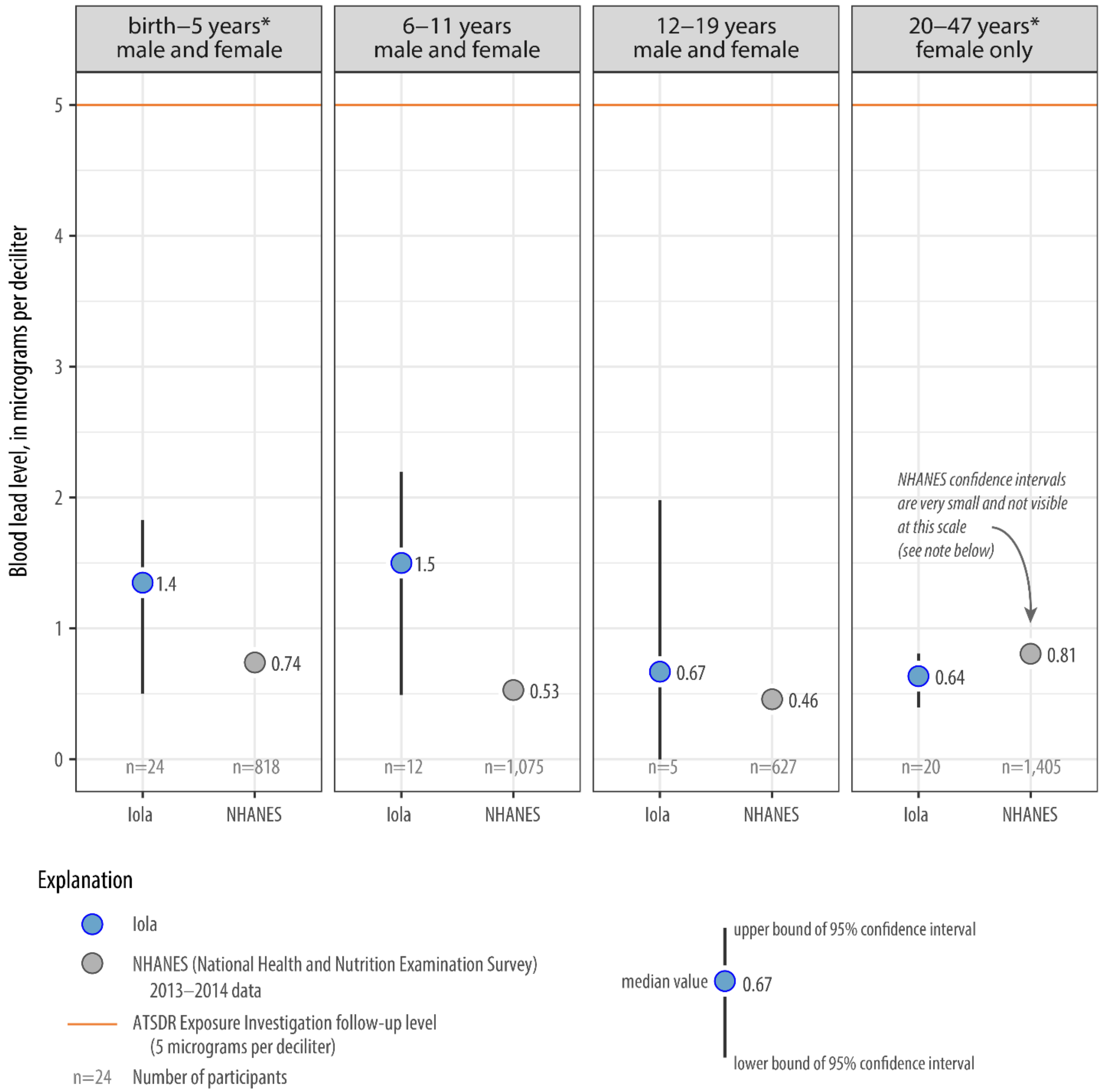



Figure 2 and Table 6 provide the median BLL found in the Iola EI for various age groups (birth to 5 years, 6 to 11 years, 12 to 19 years and 20 to 47 years) compared to the median BLL for the

U.S. population (NHANES) [CDC 2017]. For children up to age 19, the NHANES values are provided for both males and females, and a female-only comparison was completed for women of childbearing age older than 20 years old. The U.S. population (NHANES) results are provided here primarily for context; comparisons between the EI participant results and U.S. population (NHANES) results should be interpreted with caution for a number of reasons. The small sample size (number of people) and demographic bias (children and female adults of child-bearing age were preferentially recruited) of the EI participant group make statistical comparisons between the EI results and the U.S. population inappropriate.

**Figure 2**
**Comparison of Median BLL in Iola EI to NHANES**




* The Exposure Investigation age groups are as shown, but the corresponding NHANES age groups are 1–5 years and 20 years and older.
Note: Confidence intervals for the NHANES median values are very small and are not visible at the scale of this graphic; refer to Table 6 for the median and confidence interval values for both the NHANES and Iola data.
Data source: 2013–2014 NHANES data available at *http://www.cdc.gov/exposurereport/*

**Table 6: Median Values and Confidence Intervals for Blood Lead Results, by Age**

| Age Group | Gender | Median BLL and 95% confidence interval for ATSDR EI results* µg/dL | Median BLL and 95% confidence interval for corresponding NHANES results, in µg/dL |
|---|---|---|---|
| birth to 5 years | Male and female | 1.35 (0.5–1.83)† | 0.74 (0.68-0.80) |
| 6-11 years | Male and female | 1.5 (0.49-2.20)† | 0.53 (0.50-0.57) |
| 12-19 years | Male and female | 0.67 (0.00-1.98) | 0.46 (0.42-0.50) |
| 20 to 47 years | Female only | 0.64 (0.40-0.81) | 0.81 (0.78-0.85) |

*Confidence intervals for the EI data are calculated using bootstrap methods, n=2,000, with replacement.
†These median values are above the corresponding U.S. population (NHANES) value, however the EI has a number of inherent limitations that make comparison difficult (e.g. the EI sample size is small, there are methodological and demographic differences between the EI and U.S. population results). The U.S. population results should be used primarily for context.
Abbreviations: BLL = blood lead level; BLL = Blood Lead Level; ATSDR = Agency for Toxic Substances and Disease Registry; EI = Exposure Investigation; NHANES = National Health and Nutrition Survey (CDC 2013-2014 data); µg/dL = micrograms of lead per deciliter of blood.

An analysis comparing the soil lead levels in the yards of the participants (EPA data) and their BLL reported in this EI is provided in Appendix C. For all ages and for selected individual age groups, the relationship between BLL and measured lead in soil is statistically significant but the effect levels are fairly low. In other words, it takes a big increase in lead in soil (1,000 mg/kg) to produce a small increase in BLL (0.4 +/- 0.15 µg/dL). It should be noted that because of the small sample sizes, a few very high soil lead and BLL results strongly influenced the outcome of the analysis.

The low effect levels between BLL and measured lead in soil could be interpreted as reinforcing the concept that there could be many different sources and pathways of exposure to lead in the environment at the site, e.g., lead in tap water or indoor dust resulting from lead in soil and lead paint in the home.

**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 banned as an additive to gasoline in 1996 and from paint in 1978. 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 2007]. Because of this, lead is often found in the body at 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.

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 2007]. Lead can stay in bones for decades. Lead can leave bones and re-enter the blood and deposit in organs under certain circumstances: during pregnancy and lactation, after a bone is broken, and during menopause in women due to osteoporosis [ATSDR 2007].

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 2007].

Depending on the level of exposure, lead can adversely affect the nervous system, kidney function, immune system, reproductive system, cardiovascular system and development. Lead exposure also affects the oxygen carrying capacity of the blood. The lead effects most commonly encountered are neurological effects in children, and cardiovascular effects (e.g., high blood pressure and heart disease) in adults.

The primary impacts of lead are found on infants and the fetus, therefore, this EI focused primarily on the testing of children younger than 6 years old and women who were pregnant or of childbearing age. The emphasis on pregnant women and children younger than 6 years is because epidemiologic cohort studies suggest that prenatal lead exposure, even with maternal BLLs <10 µg/dL, is inversely related to fetal growth and neurodevelopment independent of the effects of postnatal lead exposure. Lead exposure can also cause a miscarriage. Infants and young children are especially sensitive to even low levels of lead, which may contribute to behavioral problems, learning deficits, and lowered IQ (intelligence quotient) [Lanphear et al. 2005, Crump et al. 2013, EPA 2013]. The exact mechanism(s) by which low-level lead exposure, whether incurred prenatally or postnatally, may adversely affect child development remains uncertain [DHHS, 2010].

No acceptable BLL has been identified that is free from deleterious health effects in children from 1 to 5 years of age and [CDC 2012a,b,c]. This value is the 97.5 percentile for the distribution of blood lead levels of U.S. children 1 – 5 years old [CDC 2012 a,b,c]. Studies conducted in pregnant women, developing fetuses, children and adults substantiate there is sufficient evidence of health effects at BLL <5 µg/dL [Lanphear et al. 2005, Crump et al. 2013]. In Kansas, the reportable blood lead level is ≥10 µg/dL for children.

BLL should be kept as low as possible and below the level of 5 ug/dL since no safe blood lead level in children has been identified. Young children and the developing fetus are particularly sensitive to the effects of lead. The Pediatric Environmental Health Specialty Units (PEHSU) provide recommendations for medical management of children exposed to lead at all BLLs

(Appendix D). CDC also provides a guide for recommended actions based on BLL (https://www.cdc.gov/nceh/lead/acclpp/actions_blls.html).

In 2015, the National Institute for Occupational Safety and Health (NIOSH) and the Occupational Safety and Health Administration (OSHA) also recommended that BLLs in adults should be <5 µg/dL. (http://www.cdc.gov/niosh/topics/ables/description.html). Therefore, the value of 5 µg/dL was used as a reference level for the women of childbearing age tested in this EI.

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. The U.S. Department of Health and Human Services classifies lead as "reasonably anticipated" to cause cancer and EPA considers lead a "probable" cancer causing substance [ATSDR 2007]. Because of the absence of any clear threshold for some of lead's more sensitive health effects [EPA 2013], ATSDR has not established guidelines for a low or no risk lead intake dose.

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

In 2010, the population in the census track of Iola (Appendix A) was predominantly white (over 90%) [U.S. Census 2010]. The age of the homes and the high percentage of poverty in Iola increases the likelihood for higher BLLs in the community. The majority of the homes (77%) were built prior to 1978 and may contain lead paint since lead paint was sold prior to 1978. Approximately 90% of participants reported that their homes were built prior to 1978. Approximately 27% of the Iola community were below the poverty level in 2015 [American Fact Finder 2018].

In this exposure investigation, the BLL in one child younger than 6 years was greater than 5 µg/dL (6.3 µg/dL). Levels such as these can adversely affect the child's health [NTP 2012]. The child with the BLL greater than 5 ug/dL exhibited pica behavior (i.e., eating dirt) and lived in a home built in the 1970s, indicating it may contain lead-based paint. The BLL for all women of childbearing age were below 5 µg/dL.

BLLs in EI participants were higher in children as compared to adults. The median BLL for EI participants were higher than the median BLL for the U.S. population for children (aged birth to 11 years) but not for adults (Table 6 and Figure 2). The higher BLLs in children indicate that behavior in children (e.g., hand to mouth activity, playing in dirt) likely results in higher exposure to contaminants, including lead, in soil. Lead gastrointestinal absorption in children is also many times higher than in adults [ATSDR 2007].

**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 populations.
- ATSDR conducted blood lead testing for a small fraction of the eligible population. This sample size may not yield results representative of the area population.
- Comparisons between the participant age groups and corresponding U.S. population age groups should be interpreted with caution due to a number of methodological (sample design) and demographic (gender and age) differences between the EI participant and U.S. population groups.
- ATSDR used bootstrap methods (n = 2,000 repetitions, with replacement) to calculate the confidence intervals for the median blood lead levels; for small sample sizes (the relatively small number of people in each age group), this method produces narrow confidence intervals.
- The results cannot be used to predict the future occurrence of disease in individuals.
- Elevated blood lead indicates there was exposure to lead. However, results do not provide information to determine when the exposure occurred.

## Conclusions

ATSDR found that young children living in Iola are at increased risk of lead exposure from soil and had elevated BLLs as compared to the background NHANES data; this exposure can harm children's health.

One child had a BLL greater than 5 µg/dL and five children had BLL between 3.5 and 4.1 µg/dL. No safe BLL in children has been identified, and even low lead levels can have adverse health effects. Median (i.e., $50^{th}$ percentile) blood lead levels for the youngest age groups (birth to 5 years and 6 to 11 years) are higher than corresponding national averages.

In addition to the potential exposure to contaminated soil, people living in the area have factors associated with increased risk of higher blood lead levels. The census tract showed approximately 27% of Iola residents living in poverty in 2015 and a high percentage of homes built before 1978 (77%), which may have lead-based paint (Appendix A). Studies have indicated that these are all risk factors for higher BLLs [Dixon et al. 2009, Jones et al. 2009, Bernard et al. 2003].

## Recommendations

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

1. **Take the following actions to prevent exposure to potentially contaminated soil outside the home:**
    - 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 modify or eliminate hand-to-mouth behavior or intentional eating of dirt (pica behavior).
    - Keep children's hands clean, wash frequently, especially before eating. Do not eat food or chew gum when playing or working in the yard.

2. **Take the following actions to prevent exposure to potentially contaminated soil inside the home:**
    - Remove shoes before going in the house to prevent tracking of contaminated soil into 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 or working outside.
    - Frequently bathe your pets as they could also track contaminated soil into your home.

3. **Take additional measures to protect children younger than 6 years of age:**
    - Ensure that painted surfaces in the home are maintained and do not have peeling paint so children will not be exposed to lead in paint chips. Homes built before 1978 may contain lead paint.
    - Supervise children closely to prevent children from eating large amounts of dirt (i.e., pica behavior).
    - Practice good hygiene with frequent hand washing, especially before meals.
    - Wash children's bottles, pacifiers, and toys frequently.
    - Offer nutritious age-appropriate meals rich in calcium, iron and vitamin C. Children who eat healthy diets absorb less lead.
    - Have eligible children evaluated in the Women, Infant and Children (WIC) program for blood lead.

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

- Impact of past smelting activities on levels of lead in soil in Iola.
- Prevention or reduction of lead exposure from soil and other sources, such as lead-based paint.
- Importance of conducting blood lead screening and confirmatory venous blood lead testing.
- ATSDR has a Case Studies in Environmental Medicine (CSEM) for lead that provides a self-instructional primer designed to increase primary health care providers knowledge of lead to aid in patient treatment. https://www.atsdr.cdc.gov/csem/csem.asp?csem=34&po=0

## Public Health Action Plan

The Public Health Action Plan for Iola contains a description of actions completed and proposed actions by ATSDR 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 will follow-up on this plan to ensure these actions are carried out.

### Actions Completed

1. In December 2016, 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. In September 2017, ATSDR sent each participant a letter informing them of their BLL results and called the household with the child that had an elevated BLL.

3. Educational materials containing information regarding impacts of lead on young children and pregnant women were provided to physicians in the area to assist with patient management.

4. EPA continues to remediate yard soil per their remediation plan.

### Actions Proposed

1. ATSDR will conduct a public availability session after this report is released to provide information to the public regarding how to reduce exposure to lead in soil.

2. ATSDR will be available to community leaders and physicians in Iola to continue to provide information and recommendations regarding how to reduce exposure to lead in Iola.

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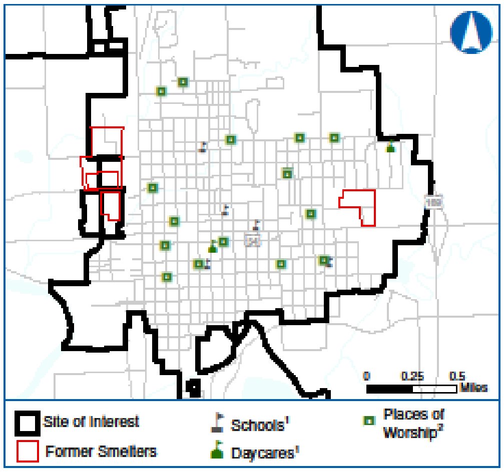
# Appendix A: Iola Exposure Investigation Map and Demographics

## Iola, KS
### Allen County, KS
**SITE PROFILE - LEAD EXPOSURE**

### Iola City Limit



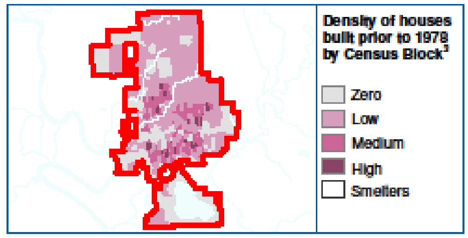

The Site Location Map depicts the former smelter locations along with schools, daycares and places of worship. Community demographic information is provided below.

### Demographic Statistics[3,4]
Within 0.1 Miles buffer of site boundary

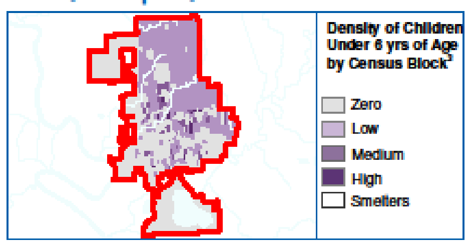
| Measure | 2000 | 2010 | Change |
|---|---|---|---|
| Total Population | 6,500 | 5,875 | -9% |
| White Alone | 6,099 | 5,359 | -12% |
| Black Alone | 181 | 187 | +3% |
| Am. Indian & Alaska Native | 45 | 47 | +4% |
| Asian Alone | 14 | 46 | +228% |
| Native Hawaiian & Other Pacific Islander Alone | 0 | 0 | +0% |
| Some Other Race Alone | 47 | 47 | +0% |
| Two or More Races | 115 | 188 | +63% |
| Hispanic or Latino[5] | 115 | 181 | +57% |
| Children Under 6 Years of Age | --- | 489 | --- |
| Females Aged 15 to 44 | 1,349 | 1,140 | -15% |
| Housing Units | 2,971 | 2,709 | -8% |
| Housing Units Pre 1978 | --- | 2,082 | --- |

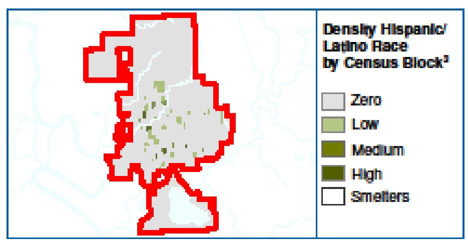
Poverty Status as of 2015: 27% below the poverty line.[6]

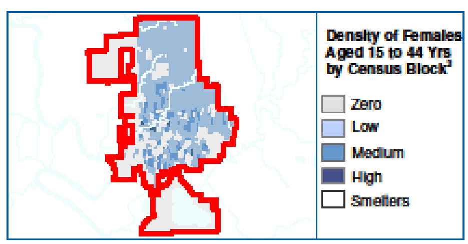
### Aged Housing Density




### Sensitive Populations



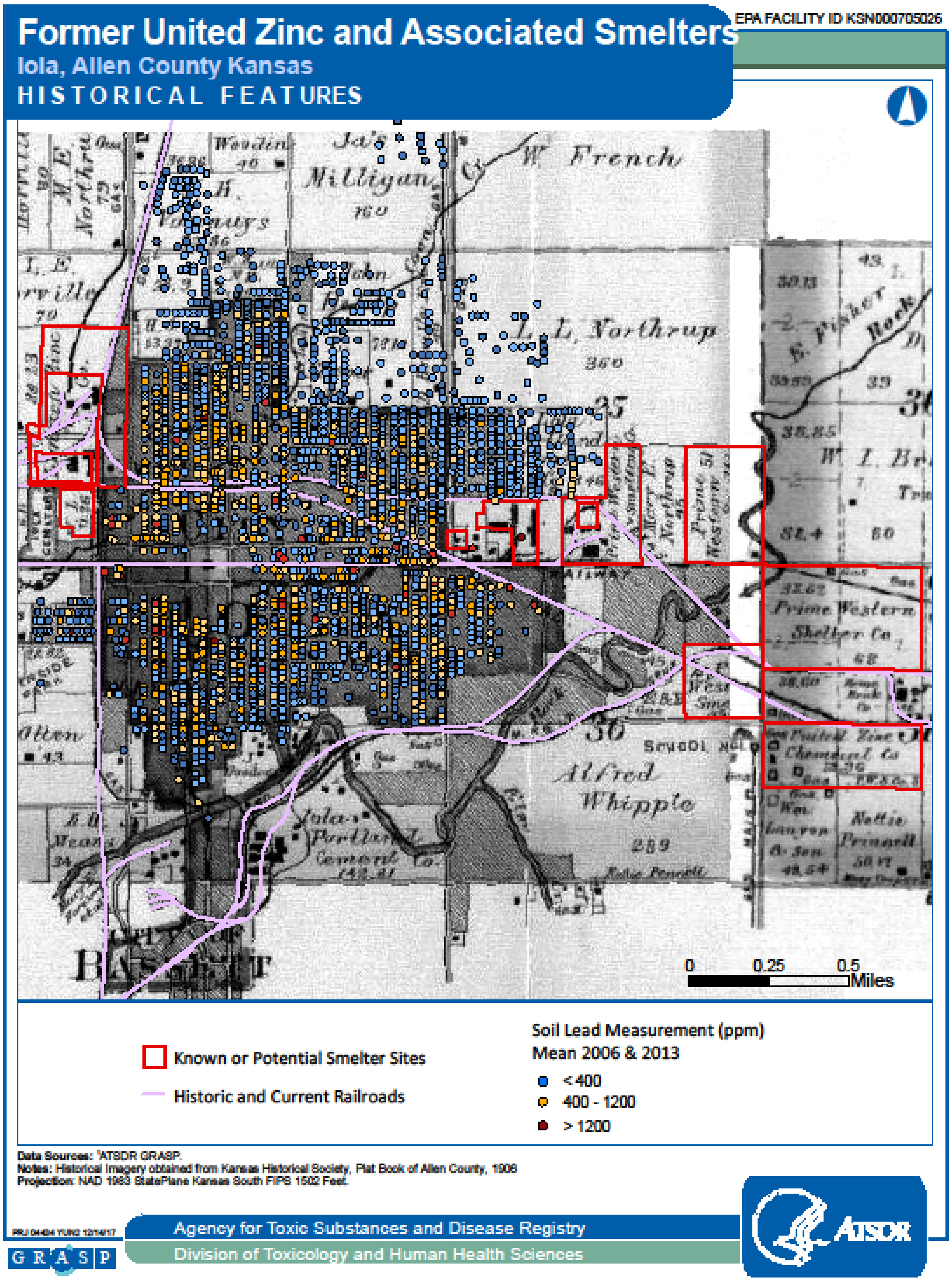




**Data Sources:** [1]Homeland Security Infrastructure Program 2015. [2]TomTom International BV (2012). [3]US Census 2010. **Notes:** [4]Calculated using area-proportion spatial analysis method. [5]Individuals identifying origin as Hispanic or Latino may be of any race. [6] American Community Survey 5 Year Estimates.
**Projection:** Projection used for all map panels is NAD 1983 StatePlane Kansas South FIPS 1502 Feet.


Agency for Toxic Substances and Disease Registry
Division of Toxicology and Human Health Sciences


**FINAL - FOR PUBLIC RELEASE**

## Appendix B: Site Map and Soil Lead Levels in Iola, Kansas



## Appendix C: Blood Lead Levels in Iola compared to Lead Soil Levels

ATSDR conducted several analyses of the relationship between measured lead in soil in residential yards and measured blood lead level (BLL) in residents. A linear regression across all of the data (all age groups) indicates a statistically significant relationship between blood lead level and maximum measured lead in soil, though the effect level is fairly low (Figure C.1). In other words, according to the regression results, it takes a big increase in measured lead in soil (1,000 mg/kg) to produce a small increase in BLL (0.4 +/- 0.15 µg/dL).

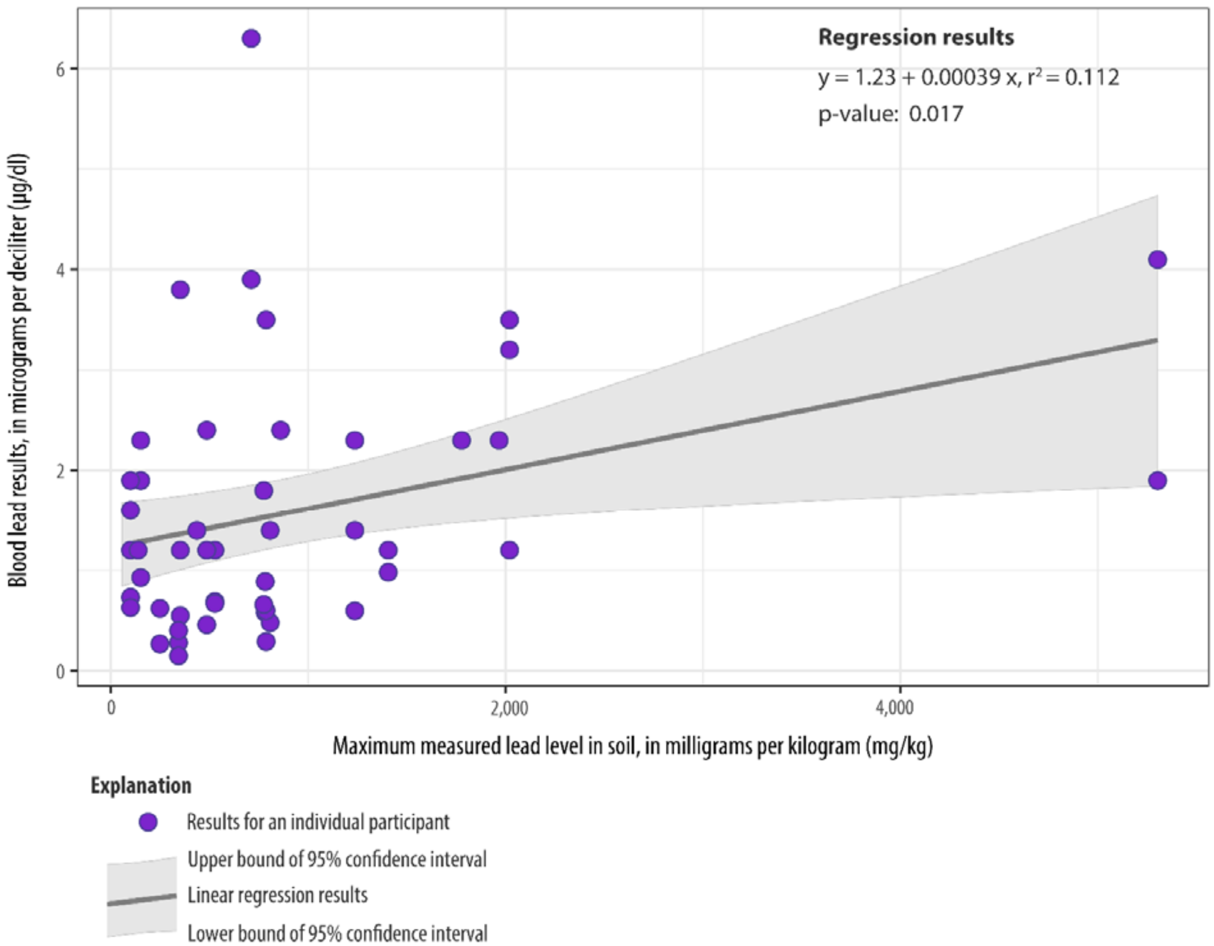
Results are mixed when we separate the data set into three age groups and run the same regression analysis (Figure C.2). The BLL-lead in soil relationship is not statistically significant for the youngest age group (birth to < 6 yrs), but it does appear to be significant for the older age groups (6 to 18 yrs and over 18 yrs). However, both of the older age groups have a very high (over 4,000 mg/kg) sample result for lead in soil that is likely exerting a lot of influence or leverage over the results.

The low effect levels between BLL and measured lead in soil reinforce the concept that there could be many different sources and pathways of exposure to lead in the environment at the site. It is appropriate to provide recommendations that highlight best practices for reducing or eliminating exposure to lead from any known or likely sources (e.g., lead in paint, lead in drinking water, airborne lead).

This analysis is limited by:

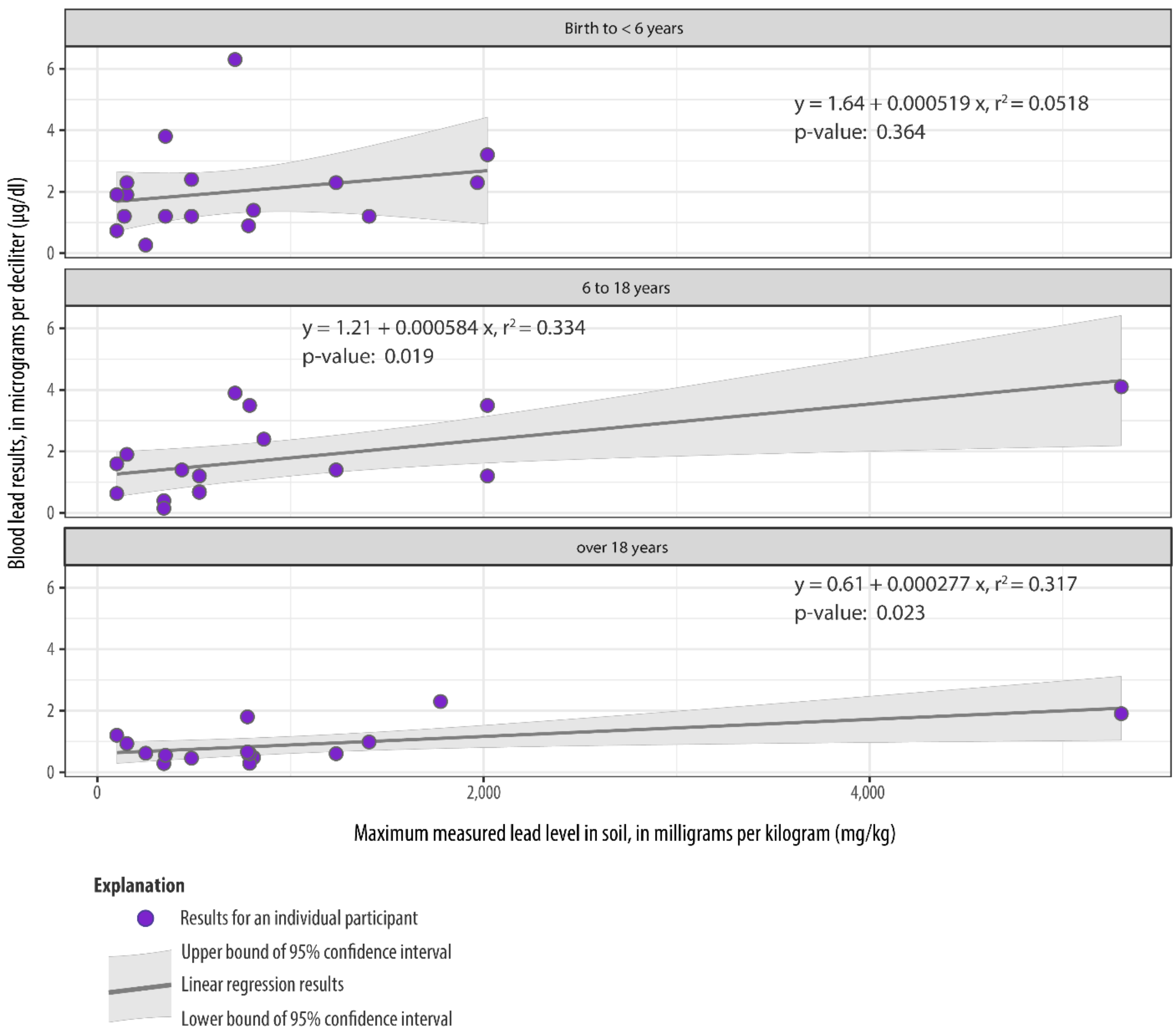
- the small data set available for analysis (n=50 participants with BLL and measured lead in soil results); when we separate the data into age groups for analyses, the data sets are even smaller.
- additional risk factors for higher BLL that are not accounted for (e.g., potential exposure to lead-based paint, potential exposure to lead in the drinking water system, potential exposure to airborne lead).

**Figure C.1: Regression and Correlation Results: All Age Groups vs. Maximum Soil Lead Level**




Results shown are from participants inside the city limits (n = 50); soil levels were not available from participants who live outside the city limits.

**Figure C.2: Regression and Correlation Results: Three Age Groups vs. Maximum Soil Lead Level**




Results shown are from participants inside the city limits (n = 50); soil levels were not available from participants who live outside the city limits.

## Appendix D: PESHU Recommendations for Lead

PEHSU
Pediatric Environmental Health Specialty Units

American Academy of Pediatrics
DEDICATED TO THE HEALTH OF ALL CHILDREN™

# Recommendations on Medical Management of Childhood Lead Exposure and Poisoning

No level of lead in the blood is safe. In 2012, the CDC established a new "reference value" for blood lead levels (5 mcg/dL), thereby lowering the level at which evaluation and intervention are recommended (CDC).

| Lead level | Recommendation |
|---|---|
| **< 5 mcg/dL** | 1. Review lab results with family. For reference, the geometric mean blood lead level for children 1-5 years old is less than 2 mcg/dL .<br>2. Repeat the blood lead level in 6-12 months if the child is at high risk or risk changes during the timeframe. Ensure levels are done at 1 and 2 years of age.<br>3. For children screened at age < 12 months, consider retesting in 3-6 months as lead exposure may increase as mobility increases.<br>4. Perform routine health maintenance including assessment of nutrition, physical and mental development, as well as iron deficiency risk factors.<br>5. Provide anticipatory guidance on common sources of environmental lead exposure: paint in homes built prior to 1978, soil near roadways or other sources of lead, take-home exposures related to adult occupations, imported spices, cosmetics, folk remedies, and cookware. |
| **5-14 mcg/dL** | 1. Perform steps as described above for levels < 5 mcg/dL.<br>2. Re-test venous blood lead level within 1-3 months to ensure the lead level is not rising. If it is stable or decreasing, retest the blood lead level in 3 months. Refer patient to local health authorities if such resources are available. Most states require elevated blood lead levels be reported to the state health department. Contact the CDC at 800-CDC-INFO (800-232-4636) or the National Lead Information Center at 800-424-LEAD (5323) for resources regarding lead poisoning prevention and local childhood lead poisoning prevention programs.<br>3. Take a careful environmental history to identify potential sources of exposures (see #5 above) and provide preliminary advice about reducing/eliminating exposures. Take care to consider other children who may be exposed.<br>4. Provide nutritional counseling related to calcium and iron. In addition, recommend having a fruit at every meal as iron absorption quadruples when taken with Vitamin C-containing foods. Encourage the consumption of iron-enriched foods (e.g., cereals, meats). Some children may be eligible for Special Supplemental Nutrition Program for Women, Infants and Child (WIC) or other nutritional counseling. |

| | |
|---|---|
| | 5. Ensure iron sufficiency with adequate laboratory testing (CBC, Ferritin, CRP) and treatment per AAP guidelines. Consider starting a multivitamin with iron.<br>6. Perform structured developmental screening evaluations at child health maintenance visits, as lead's effect on development may manifest over years. |
| **15-44 mcg/dL** | 1. Perform steps as described above for levels 5-14 mcg/dL.<br>2. Confirm the blood lead level with repeat venous sample within 1 to 4 weeks.<br>3. Additional, specific evaluation of the child, such as abdominal x-ray should be considered based on the environmental investigation and history (e.g., pica for paint chips, mouthing behaviors). Gut decontamination may be considered if leaded foreign bodies are visualized on x-ray. Any treatment for blood lead levels in this range should be done in consultation with an expert. Contact local PEHSU or PCC for guidance; see resources on back for contact information. |
| **>44 mcg/dL** | 1. Follow guidance for BLL 15-44 mcg/dL as listed above.<br>2. Confirm the blood lead level with repeat venous lead level within 48 hours.<br>3. Consider hospitalization and/or chelation therapy (managed with the assistance of an experienced provider). Safety of the home with respect to lead hazards, isolation of the lead source, family social situation, and chronicity of the exposure are factors that may influence management. Contact your regional PEHSU or PCC for assistance; see resources on back for contact information. |

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| **Principles of Lead Exposure in Children** |
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| • A child's blood lead concentration depends on their environment, habits, and nutritional status. Each of these can influence lead absorption. Children with differing habits or nutritional status but who live in the same environment can vary on blood lead concentration. Further, as children age or change residences, habits or environments change creating or reducing lead exposure potential. |
| • While clinically evident effects such as anemia, abdominal pain, nephropathy, and encephalopathy are seen at levels >40 µg/dL, even levels below 10 µg/dL are associated with subclinical effects such inattention and hyperactivity, and decreased cognitive function. Levels above 100 µg/dL may result in fatal cerebral edema. |
| • Lead exposure can be viewed as a lifelong exposure, even after blood lead levels decline. Bone acts as a reservoir for lead over an individual's lifetime. Childhood lead exposure has potential consequences for adult health and is linked to hypertension, renal insufficiency, and increased cardiovascular-related mortality. |
| • Since lead shares common absorptive mechanisms with iron, calcium, and zinc, nutritional deficiencies in these minerals promotes lead absorption. Acting synergistically with lead, deficiencies in these minerals can also worsen lead-related neurotoxicity. |

| Principles of Lead Screening |
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| • Lead screening is typically performed with a capillary specimen obtained by a finger prick with blood blotted onto a testing paper. Testing in this manner requires that the skin surface be clean; false positives are common. Therefore, elevated capillary blood lead levels should be followed by venipuncture testing to confirm the blood lead level. In cases where the capillary specimen demonstrates an elevated lead level but the follow-up venipuncture does not, it is important to recognize that the child may live in a lead-contaminated environment that resulted in contamination of the finger tip. Efforts should be made to identify and eliminate the source of lead in these cases. Where feasible, lead screening should be performed by venipuncture. |

| Principles of Iron Deficiency Screening |
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| • The iron deficiency state enhances absorption of ingested lead. |
| • Hemoglobin is a lagging indicator of iron deficiency and only 40% of children with anemia are iron deficient. |
| • Lead exposed children (≥ 5 mcg/dL) are at risk for iron deficiency and should be screened using CBC, Ferritin, and CRP. Alternatively, reticulocyte hemoglobin can be used, if available. |
| • Children with iron deficiency, with or without anemia, should be treated with iron supplementation. |

| Resources | |
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| • Pediatric Environmental Health Specialty Unit (PEHSU)Network | • www.pehsu.net or 888-347-2632 |
| • Poison Control Center (PCC) | • www.aapcc.org/ or 800-222-1222 |
| • Centers for Disease Control and Prevention | • www.cdc.gov/nceh/lead/ or 800-232-4636 |
| • U.S. Environmental Protection Agency | • www.epa.gov/lead/ or 800-424-5323 |

**Suggested Reading and References:**

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