Public Health Assessment for

BLACKWELL ZINC SMELTER SITE

BLACKWELL, KAY COUNTY, OKLAHOMA

EPA FACILITY ID: OKD980796023

SEPTEMBER 21, 2018

For Public Comment

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
Agency for Toxic Substances and Disease Registry

Comment Period Ends:

NOVEMBER 5, 2018

THE ATSDR PUBLIC HEALTH ASSESSMENT: A NOTE OF EXPLANATION

This Public Health Assessment-Public Comment Release was prepared by ATSDR pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) section 104 (i)(6) (42 U.S.C. 9604 (i)(6), and in accordance with our implementing regulations (42 C.F.R. Part 90). In preparing this document, ATSDR has collected relevant health data, environmental data, and community health concerns from the Environmental Protection Agency (EPA), state and local health and environmental agencies, the community, and potentially responsible parties, where appropriate. This document represents the agency's best efforts, based on currently available information, to fulfill the statutory criteria set out in CERCLA section 104 (i)(6) within a limited time frame. To the extent possible, it presents an assessment of potential risks to human health. Actions authorized by CERCLA section 104 (i)(11), or otherwise authorized by CERCLA, may be undertaken to prevent or mitigate human exposure or risks to human health. In addition, ATSDR will utilize this document to determine if follow-up health actions are appropriate at this time.

This document has previously been provided to EPA and the affected state in an initial release, as required by CERCLA section 104 (i)(6) (H) for their information and review. Where necessary, it has been revised in response to comments or additional relevant information provided by them to ATSDR. This revised document has now been released for a 45-day public comment period. Subsequent to the public comment period, ATSDR will address all public comments and revise or append the document as appropriate. The public health assessment will then be reissued. This will conclude the public health assessment 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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1-800-CDC-INFO
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Visit our Home Page at: http://www.atsdr.cdc.gov

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Prepared by:

Division of Community Health Investigations
U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry

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Executive Summary

INTRODUCTION	A Blackwell citizen requested the Agency for Toxic Substances and Disease Registry (ATSDR) determine if exposure to contaminated soil from the Blackwell Zinc Smelter site could harm people's health. The Blackwell Zinc Smelter (BZS) site is one-half mile west of downtown Blackwell, Kay County, Oklahoma. The Blackwell Zinc Smelting facility operated from 1916 until 1974. The soil, at various locations, throughout the Blackwell community is contaminated with high levels of lead and other metals from past site activities. ATSDR's top priority for the Blackwell Zinc Smelter site is to ensure that people living near the site have the best information possible to safeguard their health. ATSDR prepared this public health assessment (PHA) to evaluate exposure to contaminants at and near the Blackwell Zinc Smelter site and provide recommendations aimed at reducing harmful exposures for people in this community. Based on ATSDR's evaluation of sampling records for samples collected July 2007 through March 2017, we concluded that exposure to contamination from this site poses a current and past public health hazard for the Blackwell community.

CONCLUSION #1	**ATSDR concludes that Blackwell residents are exposed (now and in the past) to lead, arsenic, and cadmium in the soil, at various locations, throughout the community at levels that could harm their health. Persons residing on properties that have not been sampled or remediated are at increased risk of harmful effects from exposure. Children (especially those exhibiting pica behavior) and the developing fetuses of pregnant women, are at greatest risk for harmful health effects from lead exposure. Also, past, present, and future exposure to lead-contaminated paint and a number of other lead sources may harm individuals' health, especially the health of children and fetuses. Currently, the health of children exhibiting pica behavior and residing on properties with elevated concentrations of soil lead, arsenic or cadmium, may be at greatest risk of harmful health effects from exposure.**

BASIS FOR CONCLUSION #1	Cleanup actions are ongoing, but soil at some properties in this community is still contaminated. In addition, permission to sample some properties could not be obtained. The extent of contamination may not be fully defined and therefore the potential exists for contaminants to re-contaminate previously remediated soil in some locations. Although the Oklahoma Department of Environmental Quality's (ODEQ) site cleanup actions to date in the City of Blackwell has reduced the levels of lead, cadmium, and arsenic in community soils, the potential for harmful exposures to contaminants still remain in this community. As of March 2017, soil arsenic concentrations at approximately 5% and soil cadmium concentrations at about 2% of the sampled properties remain at concentrations which could harm a person's health. ATSDR scientists used mathematical computer models to estimate blood lead levels for children and the developing fetuses of pregnant women who could be exposed to lead in contaminated soils. The models predict that if young children (less than age 6) are regularly exposed to the soils of over 30% of the non-remediated properties, their blood lead levels could rise above the reference level. ATSDR uses CDC's reference level, currently 5 micrograms per deciliter (µg/dL), to represent the blood lead level that is above most children's levels[1]. Based upon ATSDR's analysis of residential soil sampling data, lead concentrations in many of the sampled residential areas are high enough to harm the health of area children if they are exposed for a long period of time. The health of the developing fetuses of women exposed during pregnancy could also be harmed. Repeated contact with lead that results in a measured blood lead level in children can: • slow growth and development • damage hearing • affect ability to pay attention and learn. ATSDR scientists estimated how much arsenic and cadmium people, especially children, could swallow from hand-to-mouth activity and windblown dust. We also reviewed how much could

[1] The reference level is based on the highest 2.5% of the U.S. population of children ages 1-5 years. That level is currently 5 µg/dL and based on the 2009-2010 National Health and Nutrition Examination Survey (NHANES). The current (2011-2012) geometric mean level for that age group is 0.97 (µg/dL). CDC will periodically update the reference level.

	be absorbed into the skin from touching the soil. The arsenic exposure in some areas may put people at risk for developing skin problems such as hyperpigmentation and hyperkeratosis. Long term exposure to arsenic at concentrations found in some areas of this community may put people at an increased risk of cancer. 95% of the sampled properties with arsenic concentrations that exceeded the target action level had been remediated by March 2017. Several scientific studies show that female children may be at risk for decreased bone minerals from exposures to cadmium in soils from certain areas. This can cause the bones to become fragile and break easily. 98% of the sampled residential properties with cadmium concentrations that exceeded the target action level had been remediated by March 2017. Experimental studies suggest that exposure to mixtures of lead and arsenic, and lead and cadmium, can cause additive or greater than additive toxicity for health effects. Exposure to mixtures of these metals can result in increased toxicity and harmful health effects.
NEXT STEPS	ATSDR recommends the following: **To Blackwell Zinc Corporation:** • Continue with its plans to remediate additional properties to reduce arsenic, cadmium, and lead levels in residential surface soil. • Offer or continue to offer educational services/information to the local population about the hazards posed by exposure to lead and other heavy metals in Blackwell soils. **To ODEQ:** • Continue with oversight of activities related to the remediation of residential, recreational and commercial properties in the community to reduce human exposure to lead, arsenic and cadmium in community soils. This will also reduce recontamination of properties previously remediated, and • Provide educational services/information to the local population about the hazards posed by exposure to lead and other heavy metals in Blackwell soils, in oversight capacity, via partnership with the Blackwell Zinc Corporation Community Outreach Center and the Kay County Health Department.

	To the City of Blackwell: To reduce potential exposures to lead and other heavy metals, maintain roadways that were constructed or maintained using smelter debris. **To Blackwell residents:** Allow ODEQ access to conduct soil sampling and removal activities, as needed. Become informed about soil pica behavior and how to reduce potential exposures in children. If you are consuming produce from a home garden, consider having the soil tested, if you have not done so previously. Blackwell residents can reduce their exposure to contaminants in soil by taking the following steps: • Regularly wash children's hands, especially before eating. • Regularly use a damp mop or damp duster to clean surfaces. • Remove shoes before going in the house and ask others to do the same. • Use walk-off mats at exterior doorways. • Cover bare soil with mulch or vegetation (grass, etc.) or add a layer of clean soil over existing soil to minimize contact with lead and other contaminants. • Create a raised bed and fill with clean soil for gardening to reduce exposures from gardening and digging. Rinse produce well to remove garden soil. • Create safe play areas for children with appropriate and clean ground covers. Consider covered sand boxes for children that like to dig. • Watch children to identify any hand-to-mouth behavior or excessive intentional dirt eating – these behaviors should be modified or eliminated. • Make sure your child does not have access to peeling paint or chewable surfaces painted with lead-based paint. Pregnant women and children should not be present in housing built before 1978 that is undergoing renovation. • Frequently bathe your pets since they can also track contaminated soil into your home.

CONCLUSION #2	**ATSDR reviewed blood lead level (BLL) data from the Kay County Health Department and the Oklahoma State Department of Health and found that BLLs in Blackwell children were not statistically different compared to children in Kay County (as a whole) and both are much higher when compared to children in the state. ATSDR identified multiple factors associated with the increased risk of higher BLLs, in the Blackwell community. These include age of housing, contaminated soil, poverty, and race.**
BASIS FOR CONCLUSION #2	ATSDR reviewed blood lead data from 2010 through 2016 for children ages six months to six years living in Blackwell, Kay County, and the entire state. The percent of children living in Blackwell with BLL exceeding CDC's blood lead reference level of 5 µg/dL was not significantly higher than expected based on comparison with county test results (except in 2010). However, both Blackwell and Kay County test results were higher compared to state test results. In addition to contact with contaminated soil, water, and air, multiple factors have been associated with increased risk of higher BLLs. Children who are black or Hispanic, in lower income groups, and living in older houses have traditionally had higher BLLs. About 8% of the population in Blackwell is Hispanic. People born in Mexico traditionally are more vulnerable for higher blood lead levels. Lead-based paint was removed from household use in 1978. Almost 90% of the housing units in Blackwell were built before 1978. If the paint is deteriorating, children in those homes are at greater risk for higher BLLs. All of these factors put this population at increased risk for higher BLLs and the lead contaminated soil could add to their risk.
NEXT STEPS	**<u>To Community members, ATSDR recommends the following:</u>** **Test Blood for Lead:** People living or routinely visiting Blackwell who meet the following criteria should get a blood test for lead as soon as practical: • Pregnant • Wanting to become pregnant, • Adults at risk for occupational exposure, or • Any child less than six years of age at 1 year, 2 years, and any time before 6 years of age if not previously tested or if lead exposure risk has significantly changed.

	Screening is offered by primary care physicians and the KCHD. **Reduce Exposure:** No safe blood lead level in children has been identified. ATSDR and CDC recommend reducing lead exposure wherever possible. ATSDR recommends that parents or guardians immediately reduce their own and their children's contact with lead in soil and from other sources such as flaking or peeling lead paint and indoor dust. We recommend practical ways to reduce exposure in this document. **Reduce lead absorption.** Proper nutrition is particularly important for children and pregnant women. Once ingested, you can help decrease lead absorption by eating a nutritious diet, including several small meals per day (appropriate for age and growth) rich in iron, calcium, vitamins C & D and zinc from such foods as dairy products, green vegetables, and lean meats. **To Kay County Health Department:** **Educate people on the need for blood lead testing to increase participation.** The Kay County Health Department (KCHD) provides screening and testing for lead exposure for eligible children 6-72 months of age and follow-up for children with blood lead levels that are 5 µg/dL or greater. However, there has been low community participation in these screening events (less than 20% of the children in Blackwell have had their blood tested). ATSDR recommends KCHD, and as appropriate EPA, and ODEQ, take steps to increase the participation rate of eligible children in the blood lead screening events as soon as possible.

FOR MORE INFORMATION	If you have concerns about your health, you should contact your health care provider. For more information about this public health assessment, please call ATSDR at 1-800-CDC-INFO and ask for information about the "Blackwell Zinc Smelter site in Blackwell, Oklahoma."

Statement of Issues and Background

Introduction

The Agency for Toxic Substances and Disease Registry (ATSDR) is a federal agency within the U.S. Department of Health and Human Services (DHHS). The agency is authorized by the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) to conduct public health assessments of hazardous waste sites.

Some community members in Blackwell, Kay County, Oklahoma became concerned about what appeared to be old waste products (see Photo 1, Appendix A) from the old Blackwell Zinc Smelting site scattered throughout their community. At their request, ATSDR prepared this public health assessment. The purpose of the public health assessment is to determine if exposures to site-related contaminants including arsenic, cadmium, and lead, in residential and community surface soils near the site could harm people's health.

Site History and Timeline

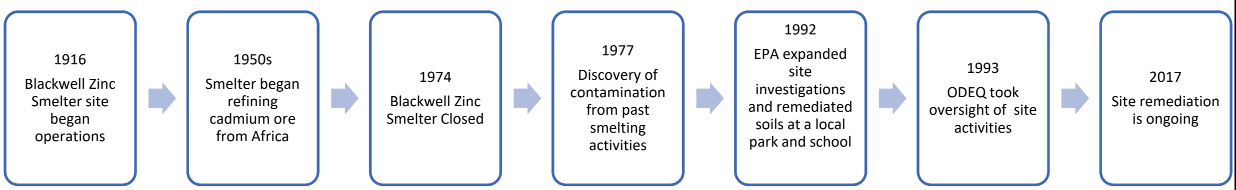


Figure 1 - Site History Timeline

Site Description and History

The Blackwell Zinc Smelter (BZS) site (Appendix B, Figure 4) is defined as the city limits of Blackwell, Kay County, Oklahoma plus a one-mile buffer zone. The site includes a 160-acre industrial property currently operated by the Blackwell Industrial Authority (BIA) as well as many residential, recreational, and commercial/industrial properties. For purpose of this document, ATSDR will focus on contamination of local soils.

The Blackwell Zinc smelting facility operated from 1916 until 1974. Activities at the site included

	refining zinc ore concentrates (Appendix A; Photo 2) which were delivered by rail car and starting in the 1950s, refining cadmium ore from Africa. Once the facility closed, the buildings on the property were demolished. The land was then graded and donated to the BIA. In 1977, it was discovered that contamination problems resulting from past smelter operations and practices was likely. (ODEQ 2003) (Appendix A; Photo 1) (Figure 1). From natural processes and human intervention, the contaminated smelter waste materials have moved throughout the community in different media where exposure has occurred. In 1992, the Environmental Protection Agency (EPA) conducted additional site investigations and cleaned up soil at a local school and park. In 1993, the Oklahoma Department of Environmental Quality (ODEQ) took oversight of activities related to the site previously overseen by the Oklahoma State Department of Health (OSDH). Remedial investigations began at the site in 1993 and the ODEQ signed a memorandum of understanding (MOU) with EPA to assure a CERCLA quality investigation and remediation of the site. Soil remediation efforts are ongoing. The investigation and remediation of the Blackwell Zinc Smelter site has been accomplished in several phases. The Soil Remediation Unit and Supplemental Soil Program are overseen by ODEQ. Also, a representative of the Courts oversees the Coffey Settlement Program cleanup which is a result of a class action lawsuit. The ODEQ is not a party to the settlement program. In August 2012, the City of Blackwell passed an ordinance whose stated purpose as an institutional control regulation is to prevent recontamination of remediated and non-contaminated areas.
Site Visits and Community Health-Related Concerns	During the early part of its investigation, ATSDR staff maintained regular contact with the petitioners via telephone and in-person meetings to keep them abreast of ATSDR's activities and progress. ATSDR headquarters staff and ATSDR regional

	staff based in Dallas, Texas have visited the BZS site several times over the past few years. In 2010, ATSDR staff met with several community members to determine their public health information needs and to determine the best methods to address the community's needs. From June 20-24, 2011, ATSDR site team members for the Blackwell Zinc site travelled to Blackwell, Oklahoma to: • Meet with State and local stakeholders • Get a first-hand view of the site • Gather additional environmental data • Meet with community members and address any site related questions they may have • Provide health education opportunities to the community for which they had previously expressed interest. Site team members also travelled to Oklahoma City, Oklahoma to meet with state partners and representatives of the potentially responsible parties (PRP) at the Oklahoma Department of Environmental Quality (ODEQ) offices. During site visits, representatives from EPA, ODEQ and the Blackwell Zinc Corporation contractors showed ATSDR staff areas throughout the City of Blackwell where remediation actions had occurred or were in progress. The petitioner also showed ATSDR staff areas of the city which the petitioner believed had not been adequately remediated. ATSDR staff observed what appeared to be smelter waste materials (Appendix A; Photo 1) along fence-lines, in various yards and on public roads. ATSDR took note of these locations and notified appropriate ODEQ and EPA staff that follow up actions were needed. Visible smelter waste material has been removed as discovered. ODEQ continues to work closely with the City of Blackwell, the Blackwell Industrial Authority, and the Blackwell Zinc Corporation to ensure that smelter waste material is removed as it is discovered. Some residents told ATSDR staff that they had disturbed buried waste materials in order to take

	samples to show that the smelter waste materials were present throughout the town. ATSDR staff informed the citizens they should discontinue those actions because they were increasing their risk of exposure by bringing potentially contaminated materials to the surface. Some residents also expressed that they did not feel that their yards were adequately tested. Some residents said that in some instances, the locations that the homeowner believed should be tested did not meet the state's sampling protocol criteria. It should be noted that the intent of the on-going investigation and remediation overseen by ODEQ is to delineate and remove the metals contamination related to the former Blackwell Zinc smelter. Criteria were established to sample yards to determine the presence of lead, arsenic, and cadmium related to smelter activities. Given the age of a majority of the housing in Blackwell, areas close to a house, such as beneath windows, were not sampled as lead-based paint would be the most likely contributor to elevated soil lead in those areas.
Demographics	Demographic information helps identify and define the size, characteristics, locations (distance and direction), and possible susceptibility of known populations related to the site. Demographic information alone does not define exposure. However, since demographic data sets do provide information on potentially exposed populations, they can provide important information for determining the ways people may come in contact with site contamination. Using 2010 Census of Population and Housing data and an area-proportion spatial analysis technique, approximately 7,300 persons reside within the city of Blackwell [U.S. Census Bureau 2010]. Of these, about 16% are minorities. About 18% of the population are age 65 and older, approximately 10% (about 712) are children 6 years or younger and about 18% (1,295) are females of child-bearing age. Figure 4, Appendix B, provides additional demographic statistics.

Land Use	Residential properties are located to the east of the former smelting site. The former smelting site is surrounded on the north, south, and west by a mixture of residential and agricultural properties. There are approximately 3,529 housing units in Blackwell, OK. Approximately 87% of the housing units are occupied. The median age of a home in Blackwell is 62 years old, so more than half were built before 1954.
Natural Resource Use	Surface water drainages surrounding the former smelter site enters the Ferguson Avenue Tributary which leads to the Chikaskia River [ODEQ SI 11232010]. Cadmium concentrations within the Ferguson Avenue Tributary were elevated, however, concentrations of dissolved cadmium in the Chikaskia River located downgradient of the tributary were below detection limits. Contamination in the Ferguson Avenue Tributary has been addressed via the groundwater treatment system that was constructed for the Blackwell Zinc site. A pond located on the corner of West Ferguson Avenue and South O Street is reportedly used by local children as a swimming hole [ODEQ SI 06222009]. According to ODEQ the pond being referred to is a low spot next to the intersection of Ferguson and O Street—which is located to the east of the Chikaskia and above the level of the river. It is not directly connected to the Ferguson Tributary. The only source of water is runoff from the surrounding fields. Groundwater is not used as a source of residential drinking water because of previous presence of high total dissolved solids. In 1992, a letter of notification was included in the city water bills urging well owners to discontinue their use until further notice. A survey of private wells conducted at that time indicated that all but four were out of service and none were used as potable water supplies. According to ODEQ, all private water wells in the City of Blackwell were taken out of service and closed by 2015. Drinking water is provided by the City of Blackwell from the treated surface waters of the Chikaskia River.

Exposure Pathway Evaluation

Introduction	Exposure to, or contact with, environmental contaminants drive ATSDR's Public health assessments (PHAs). Contaminants released into the environment have the potential to cause harmful health effects. Nevertheless, a release does not always result in exposure. People can only be exposed to a contaminant if they come in contact with that contaminant – if they breathe, eat, drink, or come into skin contact with a substance containing the contaminant. If no one comes in contact with a contaminant, then no exposure occurs, and thus no health effects could occur. Often the general public does not have access to the source area of contamination or areas where contaminants are moving through the environment. This lack of access to these areas becomes important in determining whether people could come into contact with the contaminants. The route of a contaminant's movement is a *pathway*. ATSDR identifies and evaluates exposure pathways by considering how people might come in contact with a contaminant. An exposure pathway could involve air, surface water, groundwater, soil and airborne soil particles, or even plants and animals. Exposure can occur by breathing (inhaling), eating (ingesting), drinking (ingesting), or by skin (dermal) contact with a substance containing the chemical contaminant. ATSDR identifies an exposure pathway as completed or potential, and in some cases eliminates the pathway from further evaluation.

An exposure pathway has five elements: (1) a source of contamination, (2) an environmental media, (3) a point of exposure, (4) a route of human exposure, and (5) a receptor population.

The source is the place where the chemical was released. The environmental media (such as groundwater, soil, surface water, or air) transport the contaminants. The point of exposure is the place where people come into contact with the contaminated media. The route of exposure (for example, ingestion, inhalation, or dermal contact) is the way the contaminant enters the body. The people actually exposed are the receptor population. Exposures could have occurred in the past, could be occurring, or could occur in the future.

Complete Exposure Pathways	Completed exposure pathways exist for a past, current, or future exposure if contaminant sources can be linked to a human receptor population. All five elements of the exposure pathway must be present. In other words, people have contact or are likely to come in contact with site-related contamination at a particular exposure point via an identified exposure route. As stated above, a release of a chemical into the environment does not always result in human exposure. For an exposure to occur, a completed exposure pathway must exist. Completed exposure pathways require further evaluation to determine whether exposures are sufficient in magnitude, duration, and frequency to result in harmful health effects.
Potential Exposure Pathways	Potential exposure pathways indicate that exposure to a contaminant could have occurred in the past, could be occurring currently, or could occur in the future. A potential exposure pathway exists when one or more of the five elements of an exposure pathway is missing or uncertain. A potential exposure pathway is one which ATSDR cannot rule out, even though not all of the five elements are identifiable.
Eliminated Exposure Pathways	An eliminated exposure pathway exists when one or more of the elements are missing. Exposure pathways can be ruled out if the site characteristics make past, current, and future human exposures extremely unlikely. If people do not have access to contaminated areas, the pathway is eliminated from further evaluation. Also, an exposure pathway is eliminated if site monitoring reveals that media in accessible areas are not contaminated.

Exposure Pathways at the Blackwell Zinc Smelter Site

Introduction	Site-specific characteristics are used to determine whether completed, potential, or eliminated exposure pathways exist at a site. This section identifies and discusses completed, potential, and eliminated exposure pathways associated with past, present, and future use of the Blackwell Zinc site and surrounding areas.
Completed Exposure Pathways	The unintentional swallowing of soil in various areas of the BZS site is a completed exposure pathway (past, current, future). The results of soil analyses throughout the former Blackwell Zinc Smelter (BZS) site over a number of years indicate the presence of lead, arsenic, and cadmium contamination. Smelter waste continues to be found, at various locations, throughout the City of Blackwell. These waste products have the potential to be contaminated with heavy metals such as lead. Exposure occurs when people have direct contact with contaminated soils. For instance, when children play outside or when adults work in yards and gardens, contaminated soil particles can cling to their hands and be unintentionally swallowed when they eat, drink, or touch their mouths directly. Factors affecting whether people have contact with contaminated soils include: • Vegetative cover – Vegetation reduces contact with contaminated soil when it is fairly dense, but contact with soil increases when vegetative cover is sparse or bare ground is present; • Weather conditions – Certain conditions generally reduce contact with outside soil. For instance, during cold months, people stay indoors more often. However, they may have increased exposures to contaminated soils which have been tracked indoors. Dry, dusty conditions outside may also increase exposures. Loose soils can be blown indoors by winds. Wet weather conditions may result in increased tracking of muddy soils into homes. • Personal habits when outside – for instance, children who play in the dirt are likely to have greater exposure than children who do not; and • Hygiene – both personal and housekeeping. Sweeping, vacuuming, or wet mopping floors to keep levels of soil tracked indoors low and ensuring children and adults

	wash their hands will help to reduce the amount of soil particles they ingest. Vacuuming should be done with a properly maintained HEPA filter as other vacuums may suspend the particles during the vacuuming process making the contaminated particles breathable. In addition, more frequent filter changes may be necessary. Large amounts of smelter material were created during the operation of the Blackwell Zinc smelter. In many instances, the smelter material contained heavy metals such as zinc, arsenic lead and/or cadmium. Kay County used some of the smelter material in the construction of its roads, bridges, and associated right-of-ways. In some places the smelter material is now visible. The potential for exposure to the smelter material is being assessed by local and state environmental authorities and the contractors so that appropriate action can be taken, if needed. Some residents will be exposed to contaminated soils and soil particles as long as they live on properties where contaminated soils have not been completely remediated. Recontamination of residential properties is possible because soil with elevated concentrations of metals remains in this community. Other sources of lead exposure are also possible. Given the age of many of the homes in Blackwell it is possible that older homes contain lead-based paint. Lead pipes and lead-containing solder may also exist in some homes. ATSDR considers the unintentional ingestion of and direct contact with surface water a completed pathway (in the past). A pond located on Ferguson Avenue connects to a tributary that leads to the Chikaskia River. The pond had elevated concentrations of cadmium. To address the contamination issue, the Blackwell Zinc Smelter site/facility, constructed a groundwater treatment facility to decrease the contaminant concentrations. ODEQ conducts quarterly monitoring and the cadmium concentrations are well below the maximum contaminant level (MCL), as of 2012. All streams in Blackwell have been evaluated and visible smelter material that could be removed has been excavated and disposed of. The ODEQ continues to work closely with the city of Blackwell, and the Blackwell Zinc Corporation to document and remove smelter material as it is discovered.

Potential Exposure Pathways	Private wells are located in the vicinity of the contaminated groundwater plume located under and around the former smelting facility. Some of these wells were used for irrigation and non-potable purposes. According to ODEQ all private wells in the City of Blackwell were taken out of service and closed by 2015. Unrestricted use of the groundwater in its current state could present an unacceptable risk to anyone who consumes the water. Restrictions are in place to prevent residents from constructing new wells in the vicinity of the contaminant plume. This pathway is considered potential (past). Results from testing of surface soil samples taken from rural and urban agricultural areas were not above the target action levels for the Blackwell site. However, vegetables grown on untested parcels may have become contaminated with lead, cadmium, and arsenic in the soil. No vegetable sampling was done at this site. Residents who eat vegetables grown on properties with contaminated soil may have been or could be exposed to site-related contaminants. Although produce grown in contaminated soil can take up certain contaminants in their roots [Thornton 1996; Samsøe-Petersen et al. 2002; ATSDR 2007a; ATSDR 2007b; and ATSDR 2012], there is more concern about lead, cadmium, and arsenic contamination from soil adhering to unwashed produce than from actual uptake by the plant itself. People who wash and peel their produce before eating them are at less risk for exposure.
Eliminated Exposure Pathways	Results of a well inventory survey indicate that groundwater in the vicinity of the site is not used as a potable drinking water source. Drinking water is provided through the City of Blackwell. [ODEQ ROD 08152003] A groundwater treatment facility has been constructed for the Blackwell Zinc Smelter site to address the contaminant plume. This pathway is considered eliminated with regard to human consumption as a domestic water source. Therefore, use of contaminated groundwater as a drinking water source is an eliminated exposure pathway (past, present, future). As stated previously, runoff from the site contributed to elevated concentrations of cadmium in the pond located on Ferguson Avenue. In Blackwell, the shallow groundwater system is hydraulically interconnected with surface water in the Ferguson Avenue tributary. A groundwater treatment system was constructed and is operational for the BZS site. Quarterly

	monitoring of surface waters indicate that the cadmium concentrations are on the decline and as of 2012 the detected concentrations have been below the MCL. This pathway is considered eliminated (present and future) with regard to human exposure to cadmium.

Table 1 - Environmental Exposure Pathways for the Blackwell Zinc Smelter site, Blackwell, OK

Source	Environmental Medium	Timeline	Pathway Status	Point of Exposure	Route of Exposure	Exposed Population	Contaminant
Past smelting activities	Groundwater used as a potable water source	Past	Eliminated	Potable water taps within the city of Blackwell	Ingestion, direct contact	Residents and town visitors	Cadmium and zinc
Blackwell Zinc Smelting Facility	Ambient Air	Past	Complete	Within the city of Blackwell	Inhalation	Residents and town visitors	Total suspended particulates including lead and cadmium
Past smelting activities	Surface water and runoff	Past	Complete	Water bodies and runoff within the city of Blackwell	Unintentional ingestion and direct contact	Residents and town visitors	Cadmium, zinc, lead
Smelting wastes	Airborne soil particles	Past, Present, Future	Complete	Vicinity of deteriorating roadways within the city of Blackwell that were constructed or maintained using smelter debris	Inhalation	Residents and town visitors	Lead, cadmium, and arsenic
Smelting wastes	Residential Soil	Past, Present, Future	Complete	Various residential locations throughout the city of Blackwell	Unintentional ingestion, direct contact	People with contaminated yard soils that are not adequately covered to prevent erosion	Lead, cadmium, and arsenic
Smelting wastes	Indoor dusts	Past, Present, Future	Complete	Various residential locations throughout the city of Blackwell while the smelter site was in operation	Inhalation, unintentional ingestion	People in households where contaminated soils were or could be tracked in	Lead, cadmium, and arsenic
Lead-based paint	Paint chips	Past, Present, Future	Potential	Homes with pre-1978 peeling paint	Ingestion	Persons who unintentionally or deliberately ingest paint chips	Lead

Source	Environmental Medium	Timeline	Pathway Status	Point of Exposure	Route of Exposure	Exposed Population	Contaminant
Smelting wastes	Homegrown produce	Past, Present, Future	Potential	Locally harvested produce with adhering soil	Ingestion	People in community who consume local produce grown in contaminated spaces (i.e., yards)	Lead and other metals
Past smelting activities	Groundwater used as a non-potable water source	Past	Potential	Water exit points from wells in vicinity of contaminant plume prior to construction of water treatment facility	Unintentional ingestion, direct contact	Residents and town visitors	Cadmium and zinc

Discussion of Environmental Contamination

Introduction	During the public health assessment process, ATSDR reviews environmental data and evaluates these data in the context of its site-specific exposure pathway assessment. Environmental sampling for the former Blackwell Zinc Smelter site began in the early 1990s and is ongoing. Information provided by the petitioner, the Oklahoma Department of Environmental Quality (ODEQ), and summaries of data from reports prepared for the Blackwell Zinc Smelter (BZS) site [OSDH BLS 2011; EPS HHRA 11052013; and EPS RA 10112012]; were used in preparation of this public health assessment (PHA). In late 2014-early 2015, ATSDR received access to a surface soil sampling results dataset [CRA 2014]. The dataset contained over 36,000 soil sampling records representing more than 2,000 properties. Since remedial efforts at the site are ongoing ATSDR continues to receive periodic updates to the original dataset. ATSDR reviewed and evaluated sampling records for samples collected from July 2007 through March 2017 [CRA 2017] for this public health assessment. Lead, cadmium, and arsenic are the contaminants of potential concern (COPCs) in local soils. The current target action levels (TALs) developed by ODEQ for local soil cleanup: • 540 parts per million (ppm) for lead • 75 ppm for cadmium • 37 ppm for arsenic ODEQ oversees the remedial actions for the site under a consent order with the Blackwell Zinc Corporation. Contractors collected composite soil samples throughout the former facility grounds and from properties believed to be impacted by site waste products. For this PHA, ATSDR has focused its health evaluation on arsenic, cadmium, and lead levels in residential surface soil. The following text and tables summarize the arsenic and cadmium results for surface soil samples collected from July 2007 through March 2017. Environmental lead sampling results and their public health implications will be discussed in a later section of this PHA. ATSDR considers surface soil as 0-3 inches up to 0-6 inches below ground surface (bgs) for both past and current exposures

to arsenic, cadmium, and lead as 0-6 inches bgs. ATSDR decided that each sample area was a separate exposure point. For descriptive statistics of each chemical, ATSDR provided information based on both sample areas[2] and properties[3]. Table 2, defines the mathematical terms used in the tables that follow it.

- Sample areas: For its metals screening analysis of each sample area, ATSDR selected the maximum composite sample value to represent that area regardless of whether that maximum value was from a field sample or a field duplicate, from a sample that was sieved or unsieved, or from an x-ray fluorescence (XRF) measurement or laboratory analysis.
- Property: For each property, ATSDR selected the grid with the maximum value to represent that property.

Definition of Statistical Terms

Table 2 – Definition of Statistical Terms[4]

Term	Definition
Minimum	The minimum is the lowest value in the data set.
Maximum	The maximum is the highest value in the data set.
Mean	The mean, also called the average, is a measure of the center of the data. The mean is obtained by adding all of the data values together and dividing the total by the number of data values.
Median	The median, also known as the 50th percentile, is another measure of the center of the data. If the data were ordered from highest to lowest, the median is the value that is in the middle of the data. For any given data set, 50% of the data will be above the median and 50% of the data will be below the median. Because the median is less affected by extreme values in the data, it can be a better-or more robust-central measure than the average.

Table 3 and Table 4 provide descriptive statistics for arsenic and cadmium, respectively. ATSDR notes that changes in descriptive statistics when comparing the past and current exposure scenarios are dependent on several factors including that:

1. Time critical removal actions (TCRAs) only target those properties with the highest levels of contamination,
2. The TALs chosen for each chemical varied for each phase of the remedial effort, and

[2] Location on property where a sample was collected.
[3] Each property consists of one or more sample areas.
[4] Reference Table 3 - Table 4 for application of these terms to the site-related soil data

3. Some property owners allowed access for sampling activities, but then denied access for removal activities.

Descriptive Statistics for Arsenic in Surface Soil

Table 3 - Descriptive Statistics for Arsenic in Residential Surface Soils (with concentrations at and above the Target Action Level (TAL)), Blackwell, OK, 2007-2017

Descriptive Statistics		Past Exposure Scenario[5]	Current Exposure Scenario[6]
Number of samples		513	21
Number of properties		294	16
Concentrations	Maximum	3770	74
	Minimum	37	37
	Average[7]	81	44

Table 3 presents the descriptive statistics for arsenic in residential surface soils. Overall, 11,252 composite samples were collected for analysis. The concentration in 513 of those samples exceeded the TAL (37 ppm). Samples with arsenic levels above the TAL were collected from 294 properties scattered throughout Blackwell, OK. As of March 2017, 278 (95%) of the sampled properties have been remediated.

Descriptive Statistics for Cadmium in Surface Soil

Table 4 - Descriptive Statistics for Cadmium in Residential Surface Soils (with concentrations at and above the Target Action Level (TAL)), Blackwell, OK, 2007-2017

Descriptive Statistics		Past Exposure Scenario	Current Exposure Scenario
Number of samples		143	1
Number of properties		47	1
Concentrations	Maximum	816	78
	Minimum	75	78
	Average	138	78

Data Source: ODEQ 2017

[5] The "Past Exposure Scenario" column provides descriptive statistics for chemical levels found in surface soil prior to ODEQ activities; these statistics are for all available surface soil data for the site.
[6] The "Current Exposure Scenario" column provides descriptive statistics for chemical levels found in surface soil following removal activities as of March 2017; these statistics are for surface soil data of sample areas/properties that did not undergo or are not scheduled to undergo removal actions (i.e., statistics for the chemical levels that remain at the site following ODEQ actions). This includes properties scheduled to be remediated in response to court decision.
[7] Estimate for the average concentration was obtained using bootstrap methods.

	In the past 47 sampled properties were found to have surface soil cadmium at concentrations above ODEQ's TAL (75 ppm). As of March 2017, 98% of the sampled properties have been remediated.

Public Health Implications

Introduction	In this section, ATSDR addresses the question of whether exposure to arsenic, lead, and cadmium at the concentrations detected would result in adverse health effects. While the relative toxicity of a chemical is important, the human body's response to a chemical exposure is determined by several additional factors. These factors include • the concentration (how much) of the chemical the person is exposed to, • the amount of time the person is exposed (how long), and • the way the person is exposed (through breathing, eating, drinking, or direct contact with something containing the chemical).
Determinants of Physiological Response	Lifestyle factors (for example, occupation and personal habits) have a major impact on the likelihood, magnitude, and duration of exposure. Individual characteristics such as age, sex, nutritional status, overall health, and genetic constitution affect how a human body absorbs, distributes, metabolizes, and eliminates contaminants. A unique combination of all these factors will determine the individual's physiologic response to chemical contaminants and any harmful health effects the individual may suffer from exposure.
ATSDR's Evaluation Process	As part of its evaluation, ATSDR typically derives exposure contaminant doses for children and adults. Estimating an exposure dose requires estimating how much, how often, and how long a person may come in contact with some concentration of the contaminant in a specific medium (like soil). Exposure doses help ATSDR determine the likelihood that exposure to a chemical might be associated with harmful health effects. Overall, assessing the relevance of available epidemiologic and experimental studies with respect to site-specific exposures requires both technical expertise and professional judgment. Because of uncertainties regarding exposure conditions and the harmful effects associated with environmental levels of chemical exposure, definitive answers about whether health effects will or will not occur are not feasible. However, providing a framework that puts site-specific exposures and the potential for harm in perspective is possible [ATSDR 2005].

Uncertainties	ATSDR's public health evaluation has several known limitations.
	• **Exposure assumptions:** Estimating an exposure dose required estimating how much, how often, and how long a person may come in contact with the contaminant in a specific medium. ATSDR made several assumptions for the site-specific exposure scenarios. Although ATSDR's assumptions were conservative, each person's exposure might be higher or lower depending on his or her lifestyle and individual characteristics that influence contact with contaminated media.
	• **Missing data:** Although sample location, collection, and quality assurance procedures were established and resulted in a consistent, well-documented data set, ATSDR notes that not all property owners allowed access for sampling activities.
	• **Reliance on data from animal studies:** ATSDR's evaluation required the examination and interpretation of reliable, substance-specific, health effects data. The evaluation included a review of epidemiologic (human) and experimental (animal) studies. A study based on human data would hold the greatest weight in describing relationships between a particular exposure and a human health effect. However, in some cases, only animal studies were available.
	• **Dose assumptions:** Substance-specific health effects data are generally expressed in terms of "ingested dose" rather than "absorbed dose." With regard to heavy metal exposure in soil, however the distinction between ingested dose and absorbed dose is important. In general, a lower percentage of the metals in contaminated soil are absorbed than those ingested in contaminated drinking water or food.
	• **Reliance on model predictions:** The IEUBK model depends on reliable estimates of site-specific information for several key parameters that include the following:
	  o Lead concentration in outdoor soil (fine fraction) and indoor dusts,
	  o Soil/dust ingestion rates,
	  o Lead concentration in deteriorating paint and indoor paint dust,
	  o Individual variability in child blood lead concentrations affecting the Geometric Standard Deviation (GSD), and
	• **Model assumptions:** Limitation of the IEUBK model is that the model was designed to evaluate relatively stable exposure situations, rather than rapidly varying exposures

	or exposure occurring for less than a year. The IEUBK model was also not developed to assess lead risks for age groups older than 7 years. The model does not take into account the soil cover (e.g., vegetation) and whether there is limited contact with the bare soil. The model assumes that children do not have any nutritional challenges or intentionally eat soil. Overall, there are recognized uncertainties in ATSDR's evaluation. But providing a framework that puts site-specific exposures and the potential for harm into perspective is one of the primary goals of this health evaluation process.

Table 5 - Exposure Dose Calculation Assumptions

Group	**Soil Intake** (milligrams/day)		**Exposure Frequency**	**Body Weight** (kilograms)	**Exposure Duration for Cancer Risk** (years)
	Reasonable Maximum Exposure	**Central Tendency Exposure**			
Child 6 weeks to < 1 year	100	60	1	8.2	0.88
Child 1 to < 2 years	200	100	1	11.4	1
Child 6 to < 11 years	200	100	1	31.8	5
Child 11 to < 16 years	200	100	1	56.8	5
Child 16 to < 21 years	200	100	1	71.6	5
Child (who intentionally eats soil) 1 < 2 years	Not applicable	5,000	0.429[8]	11.4	Not applicable
Child (who intentionally eats soil)2 < 6 years	Not applicable	5,000	0.429	17.4	Not applicable
Adults ≥ 21 years	100	50	1	80	33

Source: ATSDR 2016

[8] Assumes a frequency of 3 days a week

Arsenic: Interpretation and Health Significance for Non-Cancer Effects	Site specific bioavailability data were not found to estimate arsenic exposure doses. Therefore, based on EPA reports [EPA 2012a, 2012b], ATSDR used 60% as the default bioavailability value. Other assumptions made are listed in Table 5. Based on sampling data reviewed, arsenic concentrations currently range from not detected to a maximum concentration of 769 ppm in residential surface soil. The average concentration of arsenic in the past was 81 ppm. ATSDR calculated exposure doses over a range of concentrations to conduct its initial evaluation for long-term exposures. The concentrations ranged from 30 ppm to 769 ppm. The estimated exposure doses from ingestion ranged from about 0.0007 mg/kg/day for adults to as high as 0.009 mg/kg/day for children. However, the estimated dose range for children who intentionally eat soil (known as soil pica[9] behavior) is 0.003 to 0.088 mg/kg/day. The study effect level is the amount of a substance that leads to an adverse effect. The estimated doses, for non-pica children exposed to soil arsenic at the maximum concentration detected exceeded the study effect level (0.002 mg/kg/day) shown to cause hyperpigmentation and hyperkeratosis. The study effect level is exceeded for non-pica children at concentrations greater than 167 ppm. The study effect level is exceeded for children displaying pica behavior exposed to soil arsenic at concentrations greater than 15 ppm. The on-going remedial efforts have reduced contamination levels at the Blackwell Zinc site significantly. The current concentration of arsenic in residential surface soils should not pose a threat to non-pica children. However, almost 300 properties contain arsenic at concentrations of concern for children displaying pica behavior.
Arsenic: Interpretation and Health Significance for Cancer Effects	To determine cancer risk from exposure to arsenic, ATSDR evaluated two exposure populations: children exposed from birth to 21 years of age and adults exposed for 33 years. For children, exposure to surface soil with levels of arsenic ≥ 60 mg/kg may result in elevated estimated cancer risks at and exceeding 1×10^{-4} (one extra cancer case in ten thousand persons exposed) which ATSDR considers a level of concern for lifetime cancer risk [ATSDR 2004]. For adults, arsenic surface soil levels ≥ 175 mg/kg indicate levels at and exceeding a cancer risk estimate of 1×10^{-4}.

[9] Pica is a condition that makes you want to eat paint chips, dirt, and other things that aren't food. Because children have pica behavior, they may swallow harmful substances.

Table 6 - Estimated Doses for Various Ranges of Arsenic Concentrations, Blackwell, OK

Arsenic Concentration Range (parts/million)	**Child Dose Range**[10] (milligrams/kilogram/day)	**Child who intentionally Eats Soil Dose Range**[11] (milligrams/kilogram/day	**Adult Dose Range**[12] (milligrams/kilogram/day)	**Number of Samples**		**Number of Properties**[13]	
				Past Exposure Scenario[14]	**Current Exposure Scenario**[15]	**Past Exposure Scenario**	**Current Exposure Scenario**
Not Detected - 30	Not Applicable - 0.00035	Not Applicable – 0.0034	Not Applicable – 0.000027	11,070	9,815	2,172	2,393
31-60	0.00036 – 0.00070	0.0035 – 0.0068	0.000028 – 0.000054	544	97	311	69
61-90	0.00072 – 0.0011	0.0070 – 0.010	0.000055 – 0.000082	94	1	79	1
91-120	0.0011 – 0.0014	0.010 – 0.014	0.000083 – 0.00011	34	0	29	
121-150	0.0014 – 0.0018	0.014 – 0.017	0.00011 – 0.00014	16	0	12	0
151-300	0.0018 – 0.0035	0.017 – 0.034	0.00014 – 0.00027	20	0	11	
301-600	0.0035 – 0.0070	0.034 – 0.068	0.00027 – 0.00054	6	0	0 4	0
601-769	0.0071 – 0.0090	0.069 – 0.088	0.00055 – 0.00070	4	0	4 0	0

[10] The child doses provided are for the most highly exposed group, i.e., RME for children aged 1 to > 2 years of age who are considered to have the highest ingestion rate of soil per body weight.
[11] The child doses provided use 5,000 milligrams/event for the amount of soil ingested and a frequency of 3 days a week. Note that 5,000 milligrams/event probably represents the central tendency intake; no reliable upper percentile intake rate is available [ATSDR 2014].
[12] The adult doses provided are for the most highly exposed group, i.e., RME for women ≥ 21 years of age
[13] ATSDR notes that not all property owners allowed access for sampling activities, and these untested properties may have elevated levels of lead. Also, some property owners allowed access for sampling activities, but then denied access for remedial activities. For each property listed in the "Number of Properties" columns, ATSDR notes it chose the sampling area with the maximum detected concentration to represent that property. In addition, when sample areas/properties are indicated in the "Remedial Areas" column in the lower concentration ranges, this is because in some cases remediation activities for the sample area/property were completed based on another chemical's level in surface soil.
[14] The "Past Exposure Scenario" column provides the number of sample areas or grids that fall within the row's concentration range prior to ODEQ remedial activities.
[15] The "Current Exposure Scenario" column provides the number of sample areas or properties that fall within the row's concentration range following remedial activities (as of March 2017).

Cadmium: Interpretation and Health Significance for Non-Cancer Effects	Long-term exposure to cadmium in soil at concentrations greater than 5 ppm could harm a child's health. Affected individuals may experience stomach problems or kidney damage. The symptoms could also appear in adults if the soil cadmium exposure level exceeds 75 ppm. For children displaying pica behavior the symptoms may happen with exposure to soil cadmium levels less than 5 ppm. The past concentration of cadmium in residential surface soil ranged from not detected to 816 ppm on 47 sampled properties. The estimated doses for exposure to cadmium in soil ranged from 0 mg/kg/day to 0.016 mg/kg/day for non-pica children. The estimated dose range for children displaying pica behavior is up to 0.15 mg/kg/day. The adult dose ranged from 0 mg/kg/day to 0.0012 mg/kg/day. Exposure to lower levels of cadmium for a long time can also cause bones to become fragile and break easily. Decreases in bone mineral density, increases in the risk of fractures, and increases in the risk of osteoporosis have also been observed in populations living in cadmium-polluted areas. [ATSDR 2012] Currently surface soil cadmium concentrations on more than 1,000 properties are at levels which could harm the health of children with prolonged exposure. The level of cadmium is high enough at about 10 of those properties to harm the health of an exposed adult.

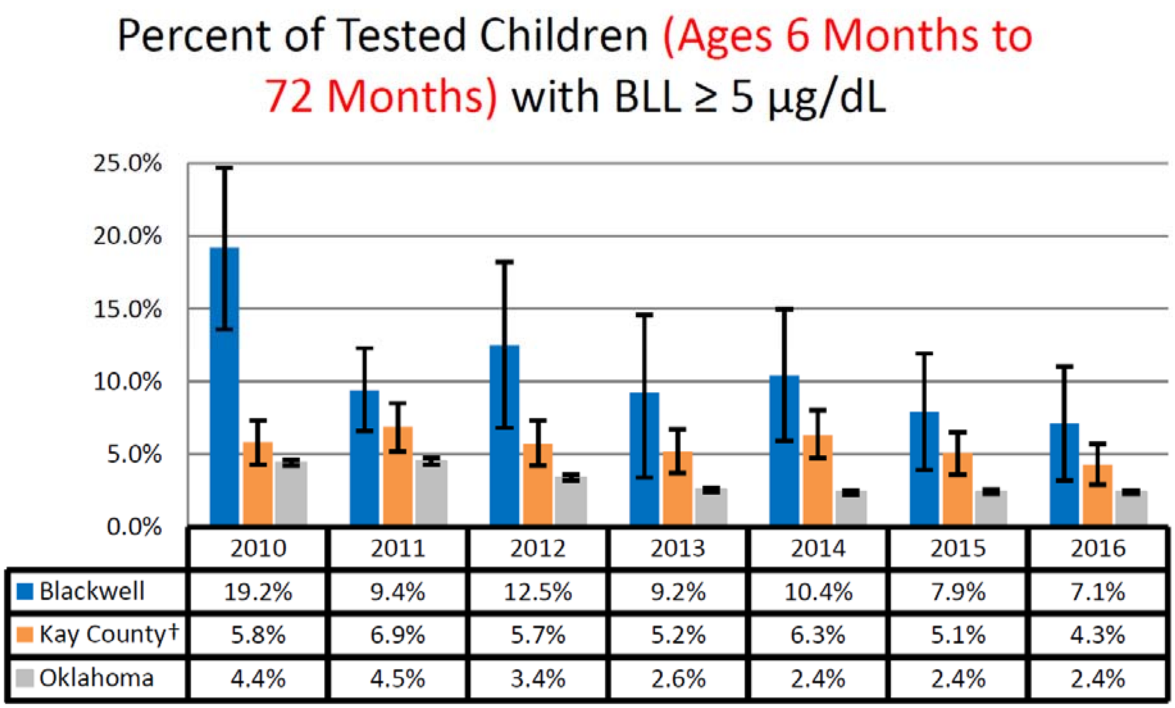
Table 7 - Estimated Doses for Various Ranges of Cadmium Concentrations in Residential Surface Soils, Blackwell, OK

Cadmium Concentration Range (parts/million)	**Child Dose Range**[16] (milligrams/kilogram/day)	**Child who intentionally Eats Soil Dose Range**[17] (milligrams/kilogram/day)	**Adult Dose Range**[18] (milligrams/kilogram/day)	**Number of Samples**		**Number of Properties**[19]	
				Past Exposure Scenario[20]	**Current Exposure Scenario**[21]	**Past Exposure Scenario**	**Current Exposure Scenario**
Not Detected - 5	Not Applicable – 0.000096	Not Applicable – 0.00095	Not Applicable – 0.0000073	4,962	5,562	1,348	1,690
6-30	0.00011 – 0.00057	0.0011 – 0.0057	0.0000088 – 0.000044	5,168	3,377	1,680	1,341
31-60	0.00059 – 0.0011	0.0059 – 0.011	0.000045 – 0.000088	547	194	239	106
61-75	0.0012 – 0.0014	0.012 – 0.014	0.000089 – 0.00011	75	12	40	
76-100	0.0015 – 0.0019	0.014 – 0.019	0.00011 – 0.00015	70	3	31	1
101-200	0.0019 – 0.0038	0.019 – 0.038	0.00015 – 0.00029	55	0	25	
201-400	0.0039 – 0.0077	0.038 – 0.078	0.00029 – 0.00058	10	0	7 9	0
401-600	0.0077 – 0.011	0.076 – 0.11	0.00059 – 0.00088	3	0	2	0
601-817	0.012 – 0.016	0.11 – 0.15	0.00088 – 0.0012	3	0	3 0	0

[16] The child doses provided are for the most highly exposed group, i.e., RME for children aged 1 to > 2 years of age who are considered to have the highest ingestion rate of soil per body weight.
[17] The child doses provided use 5,000 milligrams/event for the amount of soil ingested and a frequency of 3 days a week. Note that 5,000 milligrams/event probably represents the central tendency intake; no reliable upper percentile intake rate is available [ATSDR 2014].
[18] The adult doses provided are for the most highly exposed group, i.e., RME for women ≥ 21 years of age
[19] ATSDR notes that not all property owners allowed access for sampling activities, and these untested properties may have elevated levels of cadmium. Also, some property owners allowed access for sampling activities, but then denied access for remedial activities. For each property listed in the "Number of Properties" columns, ATSDR notes it chose the sampling area with the maximum detected concentration to represent that property. In addition, when sample areas/properties are indicated in the "Remedial Areas" column in the lower concentration ranges, this is because in some cases remediation activities for the sample area/property were completed based on another chemical's level in surface soil.
[20] The "Past Exposure Scenario" column provides the number of sample areas or grids that fall within the row's concentration range prior to ODEQ remedial activities.
[21] The "Current Exposure Scenario" column provides the number of sample areas or properties that fall within the row's concentration range following remedial activities (as of March 2017).

Public Health Interpretation and Significance for Lead Exposure

Introduction	Neither ATSDR nor U.S. EPA has developed a minimal risk level (MRL) or reference dose (RfD) for human exposure to lead. Therefore, ATSDR cannot use the usual approach of estimating a human exposure dose to an environmental contaminant and then comparing this dose to a health-based screening value (such as an MRL or RfD) [ATSDR 2005]. Instead, human exposure to lead is evaluated using a biological model that predicts a blood lead concentration resulting from exposure to environmental lead contamination. There are different biological models to estimate lead exposure of children and adults.
Nutritional Status and Other Considerations	Lead uptake, especially from the gastrointestinal (GI) tract, is influenced by nutrients such as calcium, iron, phosphate, vitamin D, fats, etc., as they occur in meals or with intermittent eating. Lead uptake generally increases as dietary levels of these nutrients decrease. [ATSDR 2007] In addition, uptake is a function of developmental stage (age), ingested/inhaled dose, the chemical species and particle size of the lead-containing media. ATSDR did not have garden produce sampling data to evaluate, however, exposure to lead can occur through garden produce grown in lead-contaminated soil. A scientific study showed that all garden vegetable plants grown in contaminated soil accumulate lead to some level, and that the majority of the contamination is in the plant root. Smaller levels of lead were found in the plant shoot, with low to non-detectable levels in the edible fruit (e.g., tomatoes, peppers, beans, and zucchini) [Finster et al. 2004]. Most lead compounds are relatively insoluble; therefore, natural plant uptake is minimal [Barocsi et al. 2003].
Review of Blood Lead Data	ATSDR reviewed available blood lead data from two sources: the Kay County Health Department (KCHD) and the Oklahoma State Department of Health (OSDH). The Kay County Health Department offers blood lead screening for children less than six years of age throughout the year. The Oklahoma State Department of Health, at ATSDR's request, provided 2010-2016 BLL data for children in OK, Kay County, and in the ZIP code 74631, the ZIP code for Blackwell, OK. Figure 2 and Table 8 summarize the data.



Data Source: Oklahoma Childhood Blood Lead Surveillance Data, January 2018
Excludes children who were residents of Blackwell, OK at the time of specimen collection

Figure 2 - Provisional Childhood Blood Lead Levels

Number of Children Tested for Blood Levels 2010-2016

Table 8 - Number of Children Tested for Blood Lead Levels 2010-2016

Year	Area	Number Tested
2010	Blackwell	193
	Kay County[22]	901
	Oklahoma	41,216
2011	Blackwell	404
	Kay County	901
	Oklahoma	41,118
2012	Blackwell	128
	Kay County	872
	Oklahoma	40,680
2013	Blackwell	109
	Kay County	866
	Oklahoma	42,483
2014	Blackwell	173

[22] Excludes Blackwell testing results

	Oklahoma	43,637
2015	Blackwell	177
	Kay County	869
	Oklahoma	41,058
2016	Blackwell	169
	Kay County	809
	Oklahoma	45,471

Parameters for Blood Lead Level Testing	Blood lead screening results for Blackwell are based on convenience sampling, a type of non-probability sampling which is vulnerable to selection bias and sampling error. Surveillance data are rarely representative of the general population. Results may vary based on factors other than lead levels in the environment such as perceived risk by the health care provider, level of parental concern, or both, which may result in those children at higher risk being screened. Annual results for children living in Blackwell were compared to children living in Kay County outside of Blackwell and the children in Kay County living outside of Blackwell with BLL exceeding 5 µg/dL was not statistically significant for any year except for 2010. Results for children living in Kay County, not only those who live in Blackwell, exceeded the statewide level for Oklahoma for each year, except in 2010.
Overview of Blood Lead Models	**Children 6 months to 7 years** The most widely used model to estimate blood lead levels in children is the U.S. EPA's Integrated Exposure Uptake and Biokinetic (IEUBK) model. The IEUBK model is designed to integrate lead exposure from soil with lead exposures from other sources, such as air, water, dust, diet, and paint with pharmacokinetic modeling to predict blood lead concentrations in children 6 months to 7 years of age. The model estimates a distribution of blood lead concentrations centered on the geometric mean blood lead concentration [USEPA 2002]. **Pregnant Women** The Adult Lead Methodology (ALM) can be used to estimate blood lead levels (BLLs) in the developing fetus. The method is often used for women of child-bearing age to estimate BLLs in the developing fetus because the developing fetus is likely to be more sensitive to lead than adult women. More information about U.S. EPA's adult lead methodology can be found at this U.S. EPA web address: *http://www.epa.gov/superfund/lead/products.htm* [USEPA 2009]

Estimating BLLs from Exposure to Soil, Indoor Dust, Drinking Water, and Foods	We considered the following exposure scenarios for this community: • Young children exposed to lead in soil by hand-to-mouth activities especially when playing in areas with bare soil. • Pregnant women in the community exposed to lead in soil by unintentional ingestion of contaminated soil by conducting daily activities such as gardening. The blood lead exposure models predict that over 30% of the non-remediated properties have lead concentrations that could result in elevated BLLs in young children and the developing fetuses of pregnant women exposed to the contaminated soil. Chronic exposure to those soils could elevate BLLs above the current CDC reference level of 5 µg/dL. Many factors can influence lead exposure and uptake, and therefore the estimates of BLLs. Those include the lead bioavailability and individual nutritional status, model limitations, lead exposure risk factors, seasonality, exposure age, and multiple sources of lead exposure. The model does not identify actual elevated BLLs but the information is used to guide ATSDR's public health recommendations.

U.S. EPA's IEUBK Model

The IEUBK model is designed to integrate exposure from lead in air, water soil, duct, diet, paint, and other sources with pharmacokinetic modeling to predict blood lead concentrations in children 6 months to 7 years of age. The model estimates a distribution of blood lead concentrations centered on the geometric mean blood lead concentration [USEPA 2002].

A detailed description of the model and supporting documentation is available on the U.S. EPA's web site (http://www.epa.gov/superfund/lead/products.htm#guid)

Bioavailability	There are absolute and relative (comparative) bioavailabilities. Absolute bioavailability, for example, is the amount of substance entering the blood via a particular biological pathway relative to the absolute amount that has been ingested. Relative bioavailability of lead is indexed by comparing the bioavailability of one chemical species or form of lead with that of another form of lead [USEPA 1994].

	The EPA default for bioavailability of soil/dust in the IEUBK model is 30%. For the IEUBK model, soluble lead in water and food is estimated to have 50% absolute bioavailability. The model presumes that the relative bioavailability of lead in soil is 60%, thus producing an absolute bioavailability for soil lead of 30% (i.e., 60% x 50% = 30%) [USEPA 1999]. However lead absorption from soil decreases with time and increasing pH [ATSDR 1992]. In fact, less than 10% of lead was bioavailable in soil with a pH>4 [ATSDR 1992]. **Bioavailability for this Evaluation**: For the lead exposures in this evaluation, we used a site-specific absolute bioavailability of 35% [EPS RA 10112012].

Table 9 - IEUBK Estimated Probabilities and Estimated Mean Blood Lead Levels (BLLs) for Various Ranges of Lead Concentrations in Residential Surface Soils, Blackwell, OK, 2007-2017

Lead Concentration Range (parts/million)	**Estimated Probability (%) of exceeding BLL of 5 micrograms per deciliter**)	**Estimated Mean BLL** (micrograms/deciliter)	**Number of Samples**		**Number of Properties**[23]	
			Past Exposure Scenario[24]	**Current Exposure Scenario**[25]	**Past Exposure Scenario**	**Current Exposure Scenario**
Not Detected - 100	Not applicable – 3	NA - 2.1	4,303	5,671	1,030	1,534
101 - 200	3 - 17[26]	2.1 - 3.2	3,181	2,508	1,427	1,326
201 - 300	17 - 36	3.2 - 4.2	2,011	1,091	1,247	737
301 - 400	37 - 54	4.2 - 5.3	981	514	708	409
401 - 600	54 - 78	5.3 - 7.1	765	128	568	113
601 - 800	78 - 89	7.2 - 8.9	267	12	222	12
801 - 1,000	89 - 94	8.9 - 10.5	105	1	94	1
1,001 - 2,000	94 - 99	10.5 – 17	166	0	118	0
2,001 - 3,000	99 - 100	17 – 22	28	0	19	0
3,001 - 33,500	100 - Not applicable[27]	22 – 90	33	0	24	0

[23] ATSDR notes that not all property owners allowed access for sampling activities, and these untested properties may have elevated levels of lead. Also, some property owners allowed access for sampling activities, but then denied access for remedial activities. For each property listed in the "Number of Properties" columns, ATSDR notes it chose the sampling area with the maximum detected concentration to represent that property. In addition, when sample areas/properties are indicated in the "Remedial Areas" column in the lower concentration ranges, this is because in some cases remediation activities for the sample area/property were completed based on another chemical's level in surface soil.
[24] The "Past Exposure Scenario" column provides the number of sample areas or grids that fall within the row's concentration range prior to ODEQ remedial activities.
[25] The "Current Exposure Scenario" column provides the number of sample areas or properties that fall within the row's concentration range following remedial activities (as of March 2017).
[26] For example, the value of 10 means 10% of the BLLs are estimated to be ≥ 5 micrograms per deciliter (μg/dL).
[27] At elevated soil lead concentrations, the IEUBK model provides a warning that the predicted BLLs (>30 μg/dL) are above the range of values that were used in the calibration and empirical validation of the model [USEPA 2002a]. Therefore, EPA states that the model should not be relied upon to predict BLLs above 30 μg/dL [USEPA 2002a, USEPA 2002b].

Lead: Interpretation and Significance for Non-Cancer Effects	Although lead can affect almost every organ and system in the body, the main target for lead toxicity is the nervous system, both in adults and children. In general, the level of lead in a person's blood gives a good indication of recent exposure to lead and correlates well with harmful health effects [ATSDR 2007b, 2007c]. Repeated contact with lead that results in a measured blood lead level in children can: • slow growth and development • damage hearing • affect ability to pay attention and learn. See *Appendix C* for more discussion on the harmful effects of prolonged exposure to lead. In May 2012, the Centers for Disease Control and Prevention (CDC) updated its recommendations on children's BLLs. By shifting the focus to primary prevention of lead exposure, CDC wants to reduce or eliminate dangerous lead sources in children's environments before they are exposed. Currently the blood lead reference level is 5 micrograms lead per deciliter of blood (5 µg/dL). Based upon ATSDR's analysis of residential soil sampling data, lead concentrations in many of the sampled residential areas are high enough to harm the health of area children if they are exposed for a long period of time. The health of the developing fetuses of women exposed during pregnancy could also be harmed.
Combined Health Effects	ATSDR has released a report that evaluates the possibility of interactive effects from exposure to several metals, including arsenic, cadmium, and lead. This report is called the Interaction Profile for Arsenic, Cadmium, Chromium, and Lead [ATSDR 2004]. A review of blood lead data indicates that some children living near the former Blackwell Zinc Smelter site have been exposed to lead at doses that could harm their health. Blood lead testing has identified children with BLLs in excess of 5 µg/dL-a level at which adverse neurological, hematological, and other health effects may occur. Experimental studies suggest that exposure to mixtures of lead and arsenic, and lead and cadmium, can cause additive or greater than additive toxicity for health effects. If the combined exposure to arsenic and lead are high enough,

	evidence suggests that there might be a greater potential for developing neurological effects than exposure to lead or arsenic alone [ATSDR 2004]. For example, children exposed to arsenic displayed decreases in reading and spelling performance, which was further decreased in children with arsenic and lead exposure [Marlow 1985, Moon 1985]. Therefore exposure to mixtures of these metals can result in increased toxicity and harmful health effects.

Discussion of Child Health Considerations

Introduction	To ensure that the health of the nation's children is protected, ATSDR requires that public health assessments determine whether children are being exposed to site-related hazardous wastes and whether contaminants may affect children's health. In communities faced with air, water, or food contamination, the many physical differences between children and adults demand special emphasis. Children could be at greater risk than are adults from certain kinds of exposure to hazardous substances. Children play outdoors and sometimes engage in hand-to-mouth behaviors that increase their exposure potential. Children are shorter than are adults; this means they breathe dusts, soil, and vapors close to the ground. A child's lower body weight and higher intake rate results in a greater dose of hazardous substance per unit of body weight. If toxic exposure levels are high enough during critical growth stages, the developing body systems of children can sustain permanent damage. Finally, children are dependent on adults for access to housing, for access to medical care, and for risk identification. Thus, adults need as much information as possible to make informed decisions regarding their children's health.
ATSDR's Findings	Information reviewed by ATSDR indicates that children six years of age and less are at greatest risk of adverse effects from exposure to lead.
Steps Being Taken Locally to Address Childhood Blood Lead Poisoning	The Kay County Health Department (KCHD) offers blood lead screening for children less than six years of age throughout the year. A blood lead prevalence study of children residing in Blackwell was conducted by KCHD in 2011 prior to the new reference level. The study showed 0.8% of children younger than six years of age tested had a result of ≥10 µg/dL. The geometric mean blood lead level of all study participants in Blackwell was 1.9 µg/dL. Statewide surveillance data showed 4.5% of children had BLL ≥5 µg/dL. Multiple potential sources of lead exposure were identified in the study which means that the increased BLLs cannot be attributed to BZS site alone. For more information contact OSDH: *Oklahoma Childhood Lead Poisoning Prevention Program*

Discussion of Community Health-Related Concerns

Introduction	ATSDR conducted public availability sessions in the Blackwell community. The purpose of these public availability sessions was to solicit community concerns and inform and educate residents living near in the BZS site.
Concern with Exposure to Heavy Metals	Residents have expressed concerns about how their exposure to heavy metals has or will affect their health and the health of their families. ATSDR recognizes the increased potential susceptibility of children to heavy metals, particularly lead. For young children, the primary source of exposure to lead is in the home. Efforts should be made to keep areas frequented by young children as free of metal contamination as possible. If the child spends time out in the yard, efforts should be made to ensure adequate groundcover and barriers to contaminated soil are in place.
Lupus Concern	Some local residents expressed concerns about what they perceive to be disease clusters (namely Lupus) and asked about health investigations looking into possible clusters. Typically, health studies are unable to make statistically significant links between diseases and environmental exposures unless the population under study is quite large or the exposures are very high. Physicians are not required to report lupus cases to health authorities, so health outcome data were not obtained. ATSDR explained that the population living in the area of concern is simply not large enough to detect elevated rates of disease using standard health study methodologies. ATSDR did not find any studies in the literature that definitively links Lupus to exposure to lead, arsenic, or cadmium. However, to address this concern ATSDR conducted a community health workshop and invited representatives from the Lupus Foundation of America, Oklahoma Chapter to conduct an interactive session. The sessions were well attended and many of the attendees' concerns were addressed.

Concerns Related to Worker Safety	Some residents expressed concern that workers carrying out remedial activities may not be properly protecting themselves from exposure to contaminants while working. ATSDR explained that ATSDR does not have regulatory authority. However, ATSDR noted the specific concerns and brought them to the attention of the ODEQ. ODEQ oversees remedial activities for the former Blackwell Zinc Smelter site and can address and implement corrective actions necessary to improve worker safety.

Conclusions

Introduction	Based on ATSDR's evaluation, we concluded that exposure to contaminants at the Blackwell Zinc Smelter site could harm peoples' health. The site poses a current and past public health hazard for the Blackwell community.
Conclusion #1	**ATSDR concludes that Blackwell residents are exposed (now and in the past) to lead, arsenic, and cadmium in the soil, at various locations, throughout the community at levels that could harm their health. Persons residing on properties that have not been sampled or remediated are at increased risk of harmful effects from exposure. Children (especially those exhibiting pica behavior) and the developing fetuses of pregnant women, are at greatest risk for harmful health effects from lead exposure. Also, past, present, and future exposure to lead-contaminated paint and a number of other lead sources may harm individuals' health, especially the health of children and fetuses. Currently, the health of children exhibiting pica behavior and residing on properties with elevated concentrations of soil lead, arsenic or cadmium, may be at greatest risk of harmful health effects from exposure.**
Basis for Conclusion #1	Cleanup actions are ongoing, but soil at some properties in this community is still contaminated. In addition, permission to sample some properties could not be obtained. The extent of contamination may not be fully defined and therefore the potential exists for contaminants to re-contaminate previously remediated soil in some locations. Although the Oklahoma Department of Environmental Quality's (ODEQ) site cleanup actions to date in the City of Blackwell has reduced the levels of lead, cadmium, and arsenic in community soils, the potential for harmful exposures to contaminants still remain in this community. As of March 2017, soil arsenic concentrations at approximately 5% and soil cadmium concentrations at about 2% of the sampled properties remain at concentrations which could harm a person's health. ATSDR scientists used mathematical computer models to estimate BLLs for children and the developing fetuses of pregnant women who could be exposed to lead in contaminated soils. The models predict that if young children (less than age 6) are regularly exposed to the soils of over 30% of the non-

	remediated properties, their BLLs could rise above the reference level. ATSDR uses CDC's reference level, currently 5 micrograms per deciliter (µg/dL), to represent the blood lead level that is above most children's levels[28]. Based upon ATSDR's analysis of residential soil sampling data, lead concentrations in many of the sampled residential areas are high enough to harm the health of area children if they are exposed for a long period of time. The health of the developing fetuses of women exposed during pregnancy could also be harmed. Repeated contact with lead that results in a measured blood lead level in children can: • slow growth and development • damage hearing • affect ability to pay attention and learn. ATSDR scientists estimated how much arsenic and cadmium people, especially children, could swallow from hand-to-mouth activity and windblown dust. We also reviewed how much could be absorbed into the skin from touching the soil. The arsenic exposure in some areas may put people at risk for developing skin problems such as hyperpigmentation and hyperkeratosis. Long term exposure to arsenic at concentrations found in some areas of this community may put people at an increased risk of cancer. 95% of the sampled properties with arsenic concentrations that exceeded the target action level had been remediated by March 2017. Several scientific studies show that female children may be at risk for decreased bone minerals from exposures to cadmium in soils from certain areas. This can cause the bones to become fragile and break easily. 98% of the sampled residential properties with cadmium concentrations that exceeded the target action level ad been remediated by March 2017. Experimental studies suggest that exposure to mixtures of lead and arsenic, and lead and cadmium, can cause additive or greater than additive toxicity for health effects. Exposure to mixtures of these metals can result in increased toxicity and harmful health effects.

[28] The reference level is based on the highest 2.5% of the U.S. population of children ages 1-5 years. That level is currently 5 µg/dL and based on the 2009-2010 National Health and Nutrition Examination Survey (NHANES). The current (2011-2012) geometric mean level for that age group is 0.97 (µg/dL). CDC will periodically update the reference level.

Conclusion #2	**ATSDR reviewed blood lead level (BLL) data from the Kay County Health Department and the Oklahoma State Department of Health and found that BLLs in Blackwell children were not statistically different compared to children in Kay County (as a whole) and both are much higher when compared to children in the state. ATSDR identified multiple factors associated with the increased risk of higher BLLs, in the Blackwell community. These include age of housing, contaminated soil, poverty, and race.**
Basis for Conclusion #2	ATSDR reviewed blood lead data from 2010 through 2016 for children ages six months to six years living in Blackwell, Kay County, and the entire state. The percent of children living in Blackwell with BLL exceeding CDC's blood lead reference level of 5 µg/dL was not significantly higher than expected based on comparison with county test results (except in 2010). However, both Blackwell and Kay County test results were higher compared to state test results. In addition to contact with contaminated soil, water, and air, multiple factors have been associated with increased risk of higher BLLs. Children who are black or Hispanic, in lower income groups, and living in older houses have traditionally had higher BLLs. About 8% of the population in Blackwell is Hispanic. People born in Mexico traditionally are more vulnerable for higher blood lead levels. Lead-based paint was removed from household use in 1978. Almost 90% of the housing units in Blackwell were built before 1978. If the paint is deteriorating, children in those homes are at greater risk for higher BLLs. All of these factors put this population at increased risk for higher BLLs and the lead contaminated soil could add to their risk..

Recommendations

Introduction	During the PHA process, ATSDR makes recommendations about public health actions that the agency believes should be conducted to protect public health. These recommendations may be directed to other agencies, to community members, or to ATSDR itself. In developing these recommendations, ATSDR consults with other agencies to ensure that someone is available to follow up on these recommendations, where appropriate. Following are ATSDR's recommendations for the Blackwell Zinc Smelter site.
Cease/Reduce Exposure	**To Blackwell Zinc Corporation:** • Continue with its plans to remediate additional properties to reduce arsenic, cadmium, and lead levels in residential surface soil. • Offer or continue to offer educational services/information to the local population about the hazards posed by exposure to lead and other heavy metals in Blackwell soils. **To ODEQ:** • Continue with oversight of activities related to the remediation of residential, recreational and commercial properties in the community to reduce human exposure to lead, arsenic and cadmium in community soils. This will also reduce recontamination of properties previously remediated, and • Provide educational services/information to the local population about the hazards posed by exposure to lead and other heavy metals in Blackwell soils, in oversight capacity, via partnership with the Blackwell Zinc Corporation Community Outreach Center and the Kay County Health Department. **To the City of Blackwell:** To reduce potential exposures to lead and other heavy metals, maintain roadways that were constructed or maintained using smelter debris. **To Blackwell residents:** Allow ODEQ access to conduct soil sampling and removal activities, as needed.

	Become informed about soil pica behavior and how to reduce potential exposures in children. If you are consuming produce from a home garden, consider having the soil tested, if you have not done so previously. Blackwell residents can reduce their exposure to contaminants in soil by taking the following steps: • Regularly wash children's hands, especially before eating. • Regularly use a damp mop or damp duster to clean surfaces. • Remove shoes before going in the house and ask others to do the same. • Use walk-off mats at exterior doorways. • Cover bare soil with mulch or vegetation (grass, etc.) or add a layer of clean soil over existing soil to minimize contact with lead and other contaminants. • Create a raised bed and fill with clean soil for gardening to reduce exposures from gardening and digging. Rinse produce well to remove garden soil. • Create safe play areas for children with appropriate and clean ground covers. Consider covered sand boxes for children that like to dig. • Watch children to identify any hand-to-mouth behavior or excessive intentional dirt eating – these behaviors should be modified or eliminated. • Make sure your child does not have access to peeling paint or chewable surfaces painted with lead-based paint. Pregnant women and children should not be present in housing built before 1978 that is undergoing renovation. • Frequently bathe your pets since they can also track contaminated soil into your home.
Blood Lead Testing	**To Community members, ATSDR recommends the following:** **Test Blood for Lead:** People living or routinely visiting Blackwell who meet the following criteria should get a blood test for lead as soon as practical: • Pregnant • Wanting to become pregnant, • Adults at risk for occupational exposure, or • Any child less than six years of age at 1 year, 2 years, and any time before 6 years of age if not previously tested or if lead exposure risk has significantly changed.

	Screening is offered by primary care physicians and the KCHD. **Reduce Exposure:** No safe blood lead level in children has been identified. ATSDR and CDC recommend reducing lead exposure wherever possible. ATSDR recommends that parents or guardians immediately reduce their own and their children's contact with lead in soil and from other sources such as flaking or peeling lead paint and dust. We recommend practical ways to reduce exposure in this document. **Reduce lead absorption.** Proper nutrition is particularly important for children and pregnant women. To help decrease lead absorption from any swallowed source, eat a nutritious diet including several small meals per day (appropriate for age and growth) rich in iron, calcium, vitamins C & D and zinc from such foods as dairy products, green vegetables, and lean meats. [ATSDR 2007] **<u>To Kay County Health Department:</u>** **Educate people on the need for blood lead testing to increase participation.** The Kay County Health Department (KCHD) provides screening and testing for lead exposure for eligible children 6-72 months of age and follow-up for children with blood lead levels that are 5 µg/dL or greater. However, there has been low community participation in these screening events (less than 20% of the children in Blackwell have had their blood tested). ATSDR recommends KCHD, and as appropriate EPA, and ODEQ, take steps to increase the participation rate of eligible children in the blood lead screening events as soon as possible.

Public Health Action Plan

Introduction	The purpose of the public health action plan is to ensure that this PHA not only identifies ATSDR's past activities at this site but also provides a course of action for mitigating or preventing exposures that may cause adverse human health effects.
Actions Completed or Ongoing at the Site	• During the early part of its investigation, ATSDR conducted quarterly telephone calls with the petitioners to provide updates on ATSDR's site-related activities and exchange information regarding the site. • ATSDR met with the petitioners on several occasions to discuss the petitioners concerns regarding the site. • ATSDR met with local residents to determine the community's public health information needs and determine the best way to deliver information to the community. • ATSDR conducted public availability sessions within the city of Blackwell in an effort to gather additional community health-related concerns. In addition, ATSDR met with various community leaders regarding conditions and health concerns within Blackwell. ATSDR attended meetings organized by other agencies involved with addressing issues at the Blackwell Zinc Smelter site. Representatives from ATSDR's Region 6 Office regularly attends meetings with groups organized to address environmental concerns at the site. • ATSDR conducted a Community Environmental Health Workshop in Blackwell. The workshop explained the ATSDR public health assessment process, provided attendees with opportunities to have their blood tested for lead, and included a presentation and interactive question and answer session on the topic of lupus. This addressed a need identified the Community Needs Survey ATSDR had completed at an earlier date. • ATSDR evaluated the results for a blood lead prevalence study conducted as part of the blood lead monitoring efforts for the Kay County Health Department and summarized the results in this report.
Actions Planned for the Site	ATSDR will consider evaluation of additional relevant site data for potential impacts on Blackwell residents, if requested.

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Appendix A — Photos

Photo 1 - Smelting waste material located above ground surface in Blackwell, OK

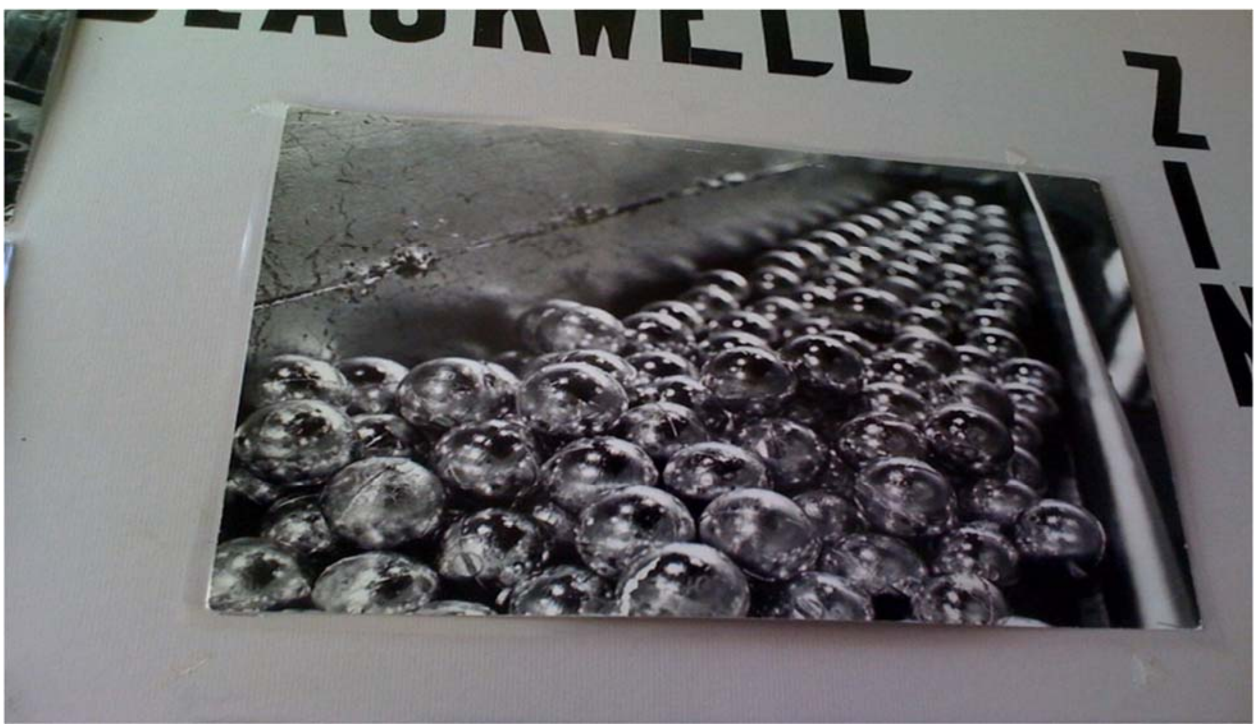


Photo 2 - Historical photo of zinc spheres produced at the former Blackwell Zinc Smelter facility.

Photo 3 - Historical photo of former Blackwell Zinc Smelter site in Blackwell, OK

Appendix B — Figures

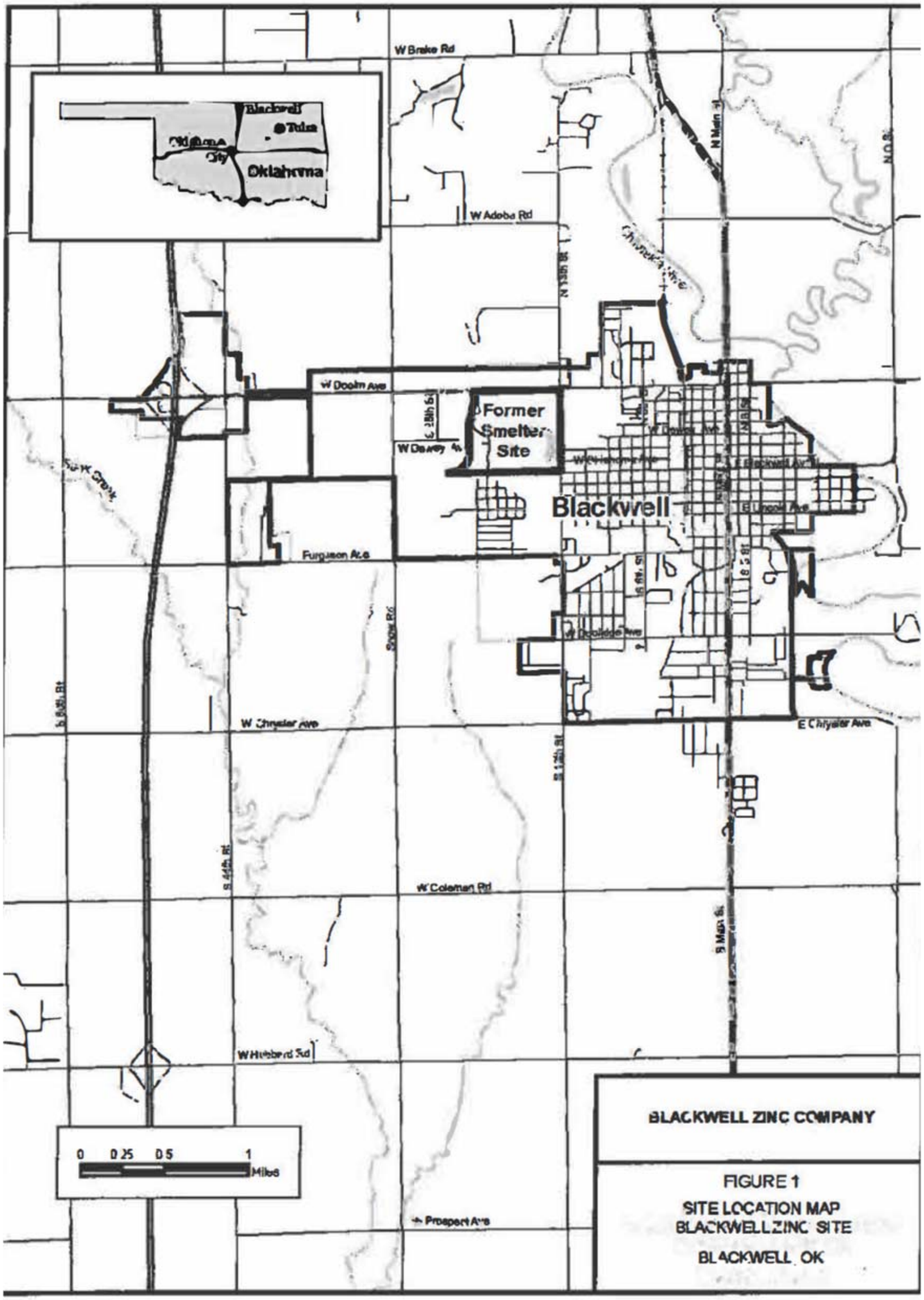


Figure 3 - Blackwell Area Location Map

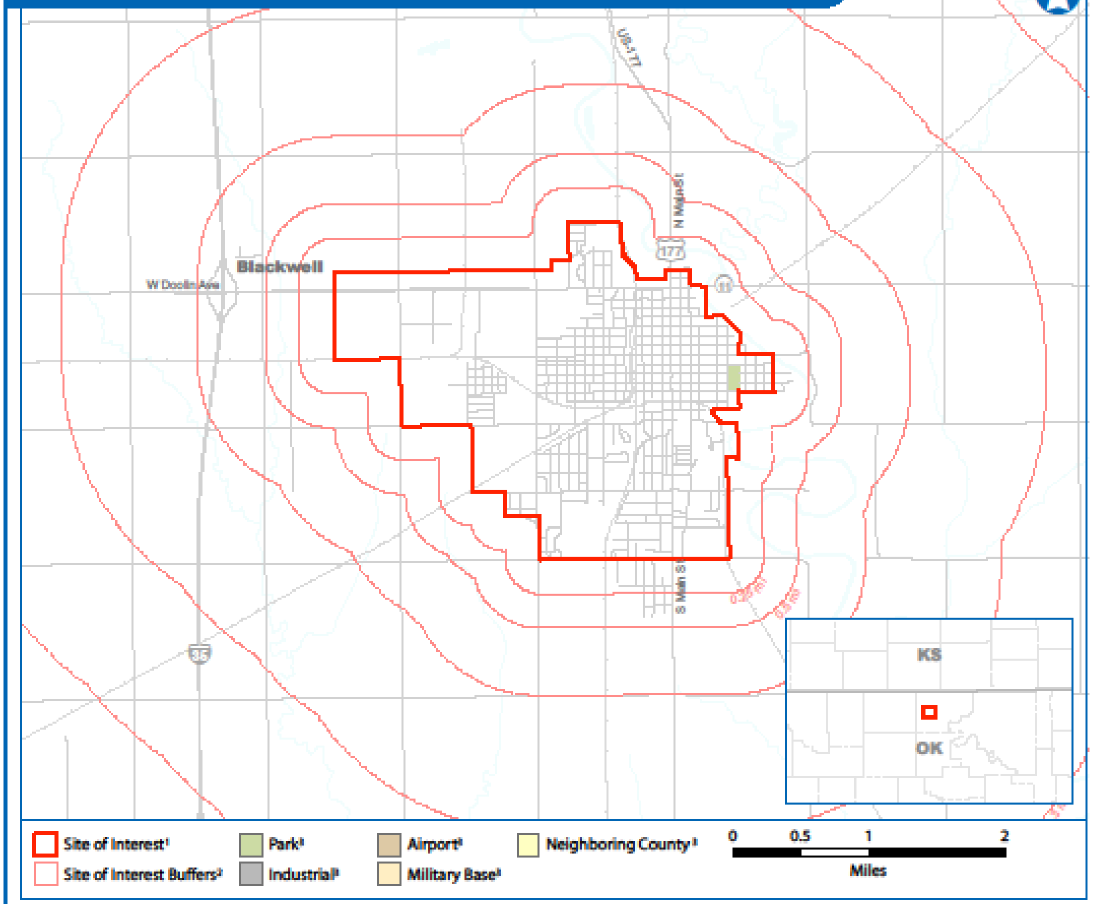
Blackwell Zinc

Blackwell, Kay County, OK

SITE AND DEMOGRAPHIC SNAPSHOT

EPA FACILITY ID OKD980796023

INTRODUCTORY MAP SERIES



Demographic Statistics[4,5]

Within 1 Miles buffer of site boundary

Measure	2000	2010	Change	Measure	2000	2010	Change
Total Population	7,899	7,306	-7%	Two or More Races	376	432	+14%
White Alone	6,904	6,140	-11%	Hispanic or Latino[6]	453	577	+27%
Black Alone	10	28	+180%	Children Aged 6 and Younger	785	712	-9%
Am. Indian & AK Native Alone	328	415	+26%	Adults Aged 65 and Older	1,459	1,304	-10%
Asian Alone	36	20	-44%	Females Aged 15 to 44	1,522	1,295	-14%
Native Hawaiian & Other Pacific Islander Alone	1	3	+200%	Housing Units	3,630	3,504	-3%
Some Other Race Alone	243	267	+9%	Housing Units Pre 1950	454	210	-53%

Data Sources: [1]ATSDR GRASP Hazardous Waste Site Boundary Database. [2]ATSDR GRASP. [3]TomTom International BV (2012). [4]US Census 2010.
Notes: [5]Calculated using area-proportion spatial analysis method. [6]Individuals identifying origin as Hispanic or Latino may be of any race.
Projection: NAD 1983 StatePlane Oklahoma North FIPS 3501 Feet.

GRASP

Agency for Toxic Substances and Disease Registry

Division of Toxicology and Human Health Sciences

FINAL - FOR PUBLIC RELEASE

Figure 4 –Demographic Statistics for Population within 1-mile of Blackwell Zinc Smelter site boundary

Appendix C — Derivation of and Intended Use of Screening Values, Overview of Contaminants of Concern

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

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

ATSDR health guidelines are substance-specific doses or concentrations derived using toxicologic information. Where adequate dose-response data exist, health guidelines are derived for both the ingestion or inhalation routes of exposure. Health guidelines include ATSDR's minimal risk levels (MRLs). No health guidelines have been developed by ATSDR for dermal exposures.

ATSDR environmental guidelines are media-specific substance concentrations derived from health guidelines using default exposure assumptions. ATSDR environmental guidelines include environmental media evaluation guides (EMEGs) and cancer risk evaluation guides (CREGs) that are available for contact with substances in water, soil, and air. These comparison values have been used to identify the contaminants of potential concern (COPCs) at this site. No environmental guidelines have been developed by ATSDR for contact with contaminants in food or biota.

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

Minimal Risk Levels (MRLs)

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

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

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

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

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

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

And exposure doses above the MRL do not necessarily mean that adverse health effects will occur.

Environmental Media Evaluation Guides (EMEGs)

ATSDR's environmental media evaluation guides (EMEGs) represent concentrations of substances in water, soil, and air to which humans might be exposed during a specified period of time (acute, intermediate, or chronic) without experiencing adverse health effects. EMEGs have been calculated for substances for which ATSDR has developed Toxicological Profiles. ATSDR uses information about the substance toxicity (MRLs) and default exposure assumptions.
ATSDR uses EMEGs during a screening analysis, particularly when conducting an environmental guideline comparison. Substances found at concentrations below EMEGs are not expected to pose public health hazards. Substances found at concentrations above EMEGs require further evaluation before arriving at a public health conclusion. EMEGs are screening values only—they are not indicators of adverse public health effects. Substances found at concentrations above EMEGs will not necessarily cause adverse health effects, but will require further evaluation.

Children are usually assumed to be the most highly exposed segment of the population because their soil ingestion rate is greater than adults' rate. Experimental studies have reported soil ingestion rates for children ranging from approximately 40 to 270 milligrams per day (mg/day), with 100 mg/day representing the best estimate of the average intake rate. ATSDR calculates an EMEG for a child using a daily soil ingestion rate of 200 mg/day for a 11.4-kg child (age 1-2 years old).

For sites where the only receptors for soil ingestion are adults, an EMEG is calculated using an adult body weight of 80 kilograms and an assumed daily soil ingestion rate of 100 mg/day. There are very few data on soil ingestion by adults, but limited experimental studies suggest a soil ingestion rate in adults of up to 100 mg/day, with an average intake of 50 mg/kg. Concentrations of substances in soil are expressed as milligrams per kilogram (mg/kg) or ppm.

Cancer Risk Evaluation Guides (CREGs)

ATSDR's cancer risk evaluation guides (CREGs) are media-specific comparison values that are used to identify concentrations of cancer-causing substances that are unlikely to result in an increase of cancer rates in an exposed population. ATSDR develops CREGs using US EPA's cancer slope factor (CSF) or inhalation unit risk (IUR), a target risk level (10–6), and default exposure assumptions. The target risk level of 10^{-6} represents a possible risk of one excess cancer case in a population of one million.

To derive soil CREGs, ATSDR uses CSFs developed by US EPA and reported in the Integrated Risk Information System (IRIS). The IRIS summaries, available at http://www.epa.gov/iris/ , provide detailed information about the derivation and basis of the CSFs for individual substances. ATSDR derives CREGs for lifetime exposures, occurring from childhood through adulthood.

For this PHA, ATSDR derived exposure doses for community members exposed to arsenic and cadmium in soil (see Exhibit 1).

Exhibit 1: Exposure Dose Equation for Ingestion of Soil

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

where,

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

As part of its evaluation, ATSDR also calculated cancer risk estimates using the US EPA arsenic oral CSF of 1.5 $(mg/kg/day)^{-1}$. Under quantitative cancer risk assessment methodology, cancer risk estimates are expressed as a probability (see Exhibit 2).

Exhibit 2: Cancer Risk Equation

$$Age\ Specific\ Cancer\ Risk = D\ x\ CSF\ x\ (\frac{ED}{78})$$

where,

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

To determine cancer risk, ATSDR looked at two exposure populations: children exposed from birth to 21 years of age and adults exposed for 33 years. For children, exposure to surface soil with levels of arsenic ≥ 60 mg/kg may result in estimated cancer risks at and exceeding 1 x 10^{-4} (one extra cancer case in ten thousand persons exposed) which ATSDR considers a level of concern for lifetime cancer risk [ATSDR 2004]. For adults, arsenic surface soil levels ≥ 175 mg/kg indicate levels at and exceeding an overall cancer risk estimate of 1 x 10^{-4}.

Based on the data reviewed, cancer risk estimates for arsenic in soil were at and exceeding 1 in 10,000 people for about 128 of the 2,272 (5.6%) properties in the past and one property currently. The American Cancer Society estimates 1 in 3 Americans will get some form of cancer during their lifetime. That means that for every 10,000 people, on average 3,333 will get some kind of cancer. A cancer risk estimate of 1 in 10,000 people may make the lifetime risk of getting cancer higher by one case – from 3,333 to 3,334. The actual number of people getting cancer caused by exposure to arsenic in soil may be higher or lower, and could be none, because this is an estimation

Cancer risk estimates are expressed as the proportion of a population that may be affected by a carcinogen during a lifetime of exposure (24 hours/day, 365 days/year, for life). For example, an estimated cancer risk of 2 × 10^{-6} represents potentially two excess cancer cases in a population of one million over a lifetime of continuous exposure.

Arsenic

Arsenic, a naturally occurring element, is widely distributed in the Earth's crust, which contains about 3.4 ppm arsenic [Wedepohl 1991]. Most arsenic compounds have no smell or distinctive taste. Although elemental arsenic sometimes occurs naturally, arsenic is usually found in the environment in two forms—inorganic (arsenic combined with oxygen, chlorine, and sulfur) and organic (arsenic combined with carbon and hydrogen). Sometimes, the specific form of arsenic present in the environment is not determined. Therefore, what form of arsenic a person may be exposed to is not always known.

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

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

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

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

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

As noted above, water-soluble forms of inorganic arsenic are well absorbed. Ingesting less soluble forms of arsenic results in reduced absorption. Studies in laboratory animals show that arsenic in soil is only one-half to one-tenth as bioavailable as soluble arsenic forms [Casteel et al. 1997; Freeman et al. 1993; Freeman et al. 1995; Groen et al. 1994; Rodriguez et al. 1999]. In one study, approximately 80% of the arsenic from ingested soil was eliminated in the feces compared with 50% of the soluble oral dose [Freeman et al. 1993]. The bioavailability of arsenic in soil may be reduced due to low solubility and inaccessibility [Davis et al. 1992]. Most of the bioavailable arsenic in water and soil is expected to be present as inorganic arsenic (trivalent arsenic and pentavalent arsenic, specifically) [Health Canada 1993]. US EPA conducted an analysis and external independent peer review of arsenic's relative bioavailability (RBA) in soil, and concluded that [USEPA 2012a, 2012b]

- available research information suggests that an RBA of arsenic in soils can be expected to be less than 100%, EPA's current recommendation and ATSDR's approach is to use 60%.
- the upper percentile of US data results in a default RBA arsenic in soil value of 60%, and
- the default RBA for arsenic in soils should only be used if site-specific assessments for arsenic RBA are not feasible.

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

The chronic oral MRL (0.0003 mg/kg/day) is based on a study in which a large number of farmers (both male and female) were exposed to high levels of arsenic in well water in Taiwan. US EPA's oral reference dose (RfD) is also 0.0003 mg/kg/day [USEPA 2008]. A clear dose-response relationship was observed for characteristic skin lesions. A control group consisting of 17,000 people was exposed to 0.0008 mg/kg/day and did not experience adverse health effects. This is considered to be the NOAEL. Hyperpigmentation and keratosis of the skin were reported in farmers exposed to 0.014

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

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

Cadmium

Cadmium is a natural element in the earth's crust. It does not corrode easily and is used in a variety of commercial products, including batteries, pigments, metal coatings, and plastics. All soil and rocks, including coal and mineral fertilizers, contain some cadmium. Most cadmium used in the United States is extracted during the production of other metals like zinc, lead, and copper. Cadmium enters soil, water, and air from mining, industry, and burning coal and household wastes. Fish, plants, and animals take up cadmium from the environment (ATSDR 2008).

In 2012, ATSDR released its Toxicological Profile for Cadmium along with a chronic oral Minimal Risk Level (MRL) of 0.0001 mg/kg/day (ATSDR 2012). A chronic MRL is defined as an estimate of daily human exposure to a substance for a year or more that is likely to be without an appreciable risk of non-carcinogenic, adverse effects. The chronic oral MRL for cadmium is based on a meta-analysis of more recent studies published after 2000 that shows kidney damage as the most sensitive effect from long-term exposure to cadmium. ATSDR's chronic MRL has an uncertainty factor of three. In addition, persons with diabetes may be especially sensitive to the renal toxicity of cadmium (ATSDR 1012, Akesson et al. 20015; Buchet et al. 1990). The chronic oral MRL for cadmium is ten times lower than the 1989 RfD (0.0001 mg/kg/day vs. 0.001 mg/kg/day). Thus cadmium may be more harmful than previously thought in 1989.

Also in 2012, ATSDR released an intermediate, oral MRL of 0.0005 mg/kg/day. Intermediate MRLs are based on studies with exposure durations of 2 weeks to less than one year. Studies by Brzoska et al. (2005a, 2005b, ATSDR 2012) showed decreased bone mineral density in female rats after 3 months of exposure and peaking at 9 months of exposure. A benchmark dose analysis predicted an effect level at 0.05 mg/kg/day, which was divided by an uncertainty factor of 100 to arrive at the intermediate, oral MRL of 0.0005 mg/kg/day. At 74 ppm cadmium in soil, the estimated cadmium doses in children birth to <6 years (0.0009 to 0.0013 mg/kg/day) exceeds the intermediate oral MRL of 0.0005 mg/kg/day. Children, particularly female children, could be at risk of mild bone damage.

The levels of cadmium increase with age for all people naturally due to the low levels of cadmium found in all foods (highest levels are found in shellfish, liver and kidney meats) and the tendency to accumulate in the body (ATSDR 2008). Smokers' body burdens of cadmium can be approximately twice that of nonsmokers due to cadmium uptake by tobacco (CDC 2009). Exposure to high levels of cadmium severely damages the lungs and can cause death. Eating food or drinking water with very high levels severely irritates the stomach, leading to vomiting and diarrhea. Long-term exposure to lower levels of cadmium in air, food, or water leads to a buildup of cadmium in the kidneys and possible kidney disease. Other long-term effects are lung damage and fragile bones. Facilities like Blackwell Zinc have been known to release cadmium particles into the air, which later deposit in the surrounding community (ATSDR 2008).

Lead

Lead is a naturally occurring bluish-gray metal found in the earth's crust and it has many different uses. It is used in the production of batteries, ammunition, metal products (solder and pipes), and devices to shield X-rays. Because of health concerns, lead from paints and ceramic products, caulking, and pipe solder has been dramatically reduced in recent years. Prior to 1955, there were no limits on lead in paint, but it is estimated that it was between 2.5% and 5%. After 1978, there is less than 0.06% lead in paint. Using lead as an additive to gasoline was banned in 1996 in the United States.

Today, lead can be found in all parts of the environment because of human activities including burning fossil fuels, mining, manufacturing, and past uses [ATSDR 2007b, 2007c]. Because of this, lead is often found in the body in low levels. In the past three decades, however, blood lead levels (BLLs) in the general public have decreased by 78% as a result of the regulation of lead in gasoline, paint, and plumbing materials [ACCLPP 2007].

Lead has no physiological value, and if it gets into the body, lead can affect various organ systems and be stored in the bones. Lead that is not stored in bones leaves the body as waste. About 99% of the amount of lead taken into the body of an adult will be excreted in the waste within a couple of weeks, while about 30% of the lead taken into the body of a child will leave in the waste [ATSDR 2007b]. Most of the remaining lead moves into bones and teeth. Lead can stay in bones for decades; however, some lead can leave bones and reenter the blood and organs under certain circumstances; for example, during pregnancy, after a bone is broken, and during advancing age.

Lead can be found in many products and locations. Lead-based paint and contaminated dust are the most widespread and dangerous high-dose source of lead exposure for young children [CDC 2009]. However, lead exposure can occur from many indoor, outdoor, and other sources [CDC 2009; NYDOH 2010]. Table 11, Appendix C, provides additional information about these sources.

Lead uptake, especially from the gastrointestinal tract, is influenced by nutrients such as calcium and iron as they occur in meals or with intermittent eating. Lead uptake generally increases as dietary levels of these nutrients decrease. Appendix D provides ways people can reduce lead uptake, such as eating healthy foods. In addition, lead uptake is a function of age, administered dose, the chemical species, and the particle size of the lead-containing media [USEPA 1994].

Lead-contaminated dust can be inhaled or ingested. Once airborne lead deposits onto soil, it does not dissipate, biodegrade, or decay easily. Lead usually binds to soil and indoor dust and can become a long-term source of lead exposure. Exposure to lead-contaminated soil can be affected by particle size, ground cover, soil conditions, seasonal variation, behavior patterns, a person's age, outdoor activity, and a variety of other risk factors. Many factors can influence uptake, such as lead bioavailability and individual nutritional status, and therefore the BLLs.

Blood Lead Levels and Health Effects

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

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

- *Blood Lead Reference Level now 5 µg/dL* – Until recently, children were identified as having a blood lead level of concern if the test result was 10 or more micrograms per deciliter (µg/dL) of lead in blood. Experts now use a reference level of 5 µg/dL. This reference level is based on the highest 2.5% of the U.S. population of children 1 to 5 years of age from the 2009-2010 National Health and Nutrition Examination Survey (NHANES) [ACCLPP 2012; CDC 2012a, 2012b]. The current (2011–2012) geometric mean BLL for that age group is 0.97 µg/dL [CDC 2015].

- *No Change in Blood Lead Levels Requiring Medical Treatment* – What has not changed is the recommendation for when to use medical treatment for children. Experts recommend chelation therapy when a child is found with a test result equal to and greater than 45 µg/dL [CDC 2014], however chelation is not without risks.

- *Health Effects in Children with Measurable Blood Lead Levels less than 5 µg/dL and 10 µg/dL* – There is no clear threshold for some of the more sensitive health effects associated with lead exposures. In children, the National Toxicology Program reports conclusions on health effect studies of low-level lead exposure for both <5 µg/dL and <10 µg/dL where there is sufficient evidence of [NTP 2012]
  - Decreased academic achievement (<5 µg/dL),
  - Decreased intelligence quotient (IQ) (<5 µg/dL and <10 µg/dL),
  - Decreased specific cognitive measures (<5 µg/dL),
  - Increased incidence of attention-related and problem behavior (<5 µg/dL),
  - Decreased hearing (<10 µg/dL),
  - Reduced postnatal growth (<10 µg/dL), and
  - Delays in puberty (<10 µg/dL).

- *Health Effects of Lead on Developing Fetuses* – Lead crosses the placenta; consequently, it can pass from a pregnant woman to her developing fetus. Follow-up testing, increased patient education, and environmental, nutritional and behavioral interventions are indicated for all pregnant women with BLLs greater than or equal to 5 µg/dL to prevent undue exposure to the developing fetus and newborn [CDC 2013c]. Too much lead in a pregnant women's body can [CDC 2013C]
  - Put her at risk for miscarriage,
  - Cause the baby to be born too early or too small,
  - Hurt the baby's brain, kidneys, and nervous system, and
  - Cause the child to have learning or behavior problems.

- *Health Effects for Adults* – Adults who are exposed to lead over many years could develop kidney problems, high blood pressure, cardiovascular disease, and cognitive dysfunction [Kosnett et al. 2007].

Neither ATSDR nor US EPA has developed a MRL or RfD for exposure to lead. Therefore, ATSDR cannot use the usual approach of estimating human exposure to an environmental contaminant and then comparing that dose to a health based comparison value (such as an MRL of RfD). Instead, lead is evaluated using a biological model that predicts blood lead concentrations that could result from human exposure to environmental lead contamination. Specifically for this PHA, ATSDR evaluated exposure to lead by using US EPA's Integrated Exposure Uptake Biokinetic (IEUBK) model for lead in children.

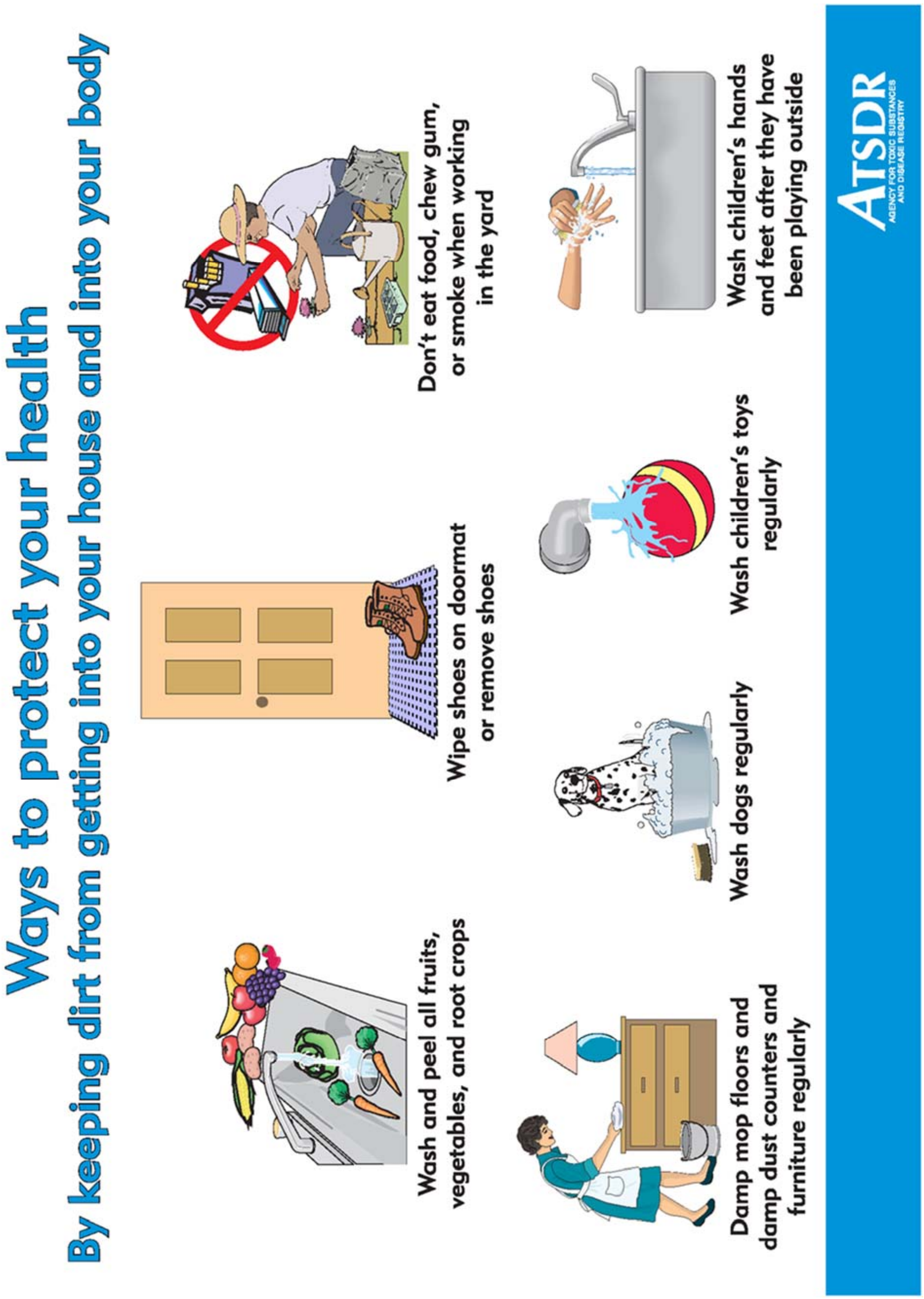
Note also that the US EPA developed the Adult Lead Methodology (ALM) to predict the risk of elevated BLLs in nonresidential settings, such as the workplace, for adult women's exposures to soil; however, the ultimate receptor is the fetus. More information about US EPA's adult lead methodology can be found at *http://www.epa.gov/superfund/lead/products.htm*.

The IEUBK Model The IEUBK model calculates exposure from lead in air, water, soil, dust, diet, paint, and other sources and predicts the risk of elevated BLLs in children 6 months to 7 years of age. The model can also be used to predict risk for specific age groups up to age 7. There is currently no generally accepted model for predicting blood lead concentrations for children 7 years of age and older.

The IEUBK model is designed to integrate exposure with pharmacokinetic modeling to predict blood lead concentrations. The four main components of the current IEUBK model are: 1) an exposure model that relates environmental lead concentrations to age-dependent intake of lead into the gastrointestinal tract; 2) an absorption model that relates lead intake into the gastrointestinal tract and lead uptake into the blood; 3) a biokinetic model that relates lead uptake in the blood to the concentrations of lead in several organ and tissue compartments; and 4) a model for uncertainty in exposure and for population variability in absorption and biokinetics [USEPA 1994].

The IEUBK model results can be viewed as a predictive tool for estimating changes in blood concentrations as exposures are modified [USEPA 1994]. The IEUBK model provides choices a user may make in estimating a child's blood lead concentration. These are referred to "user-specified" parameters or decisions. The reliability of the results obtained using the model is very dependent on the selection of the various coefficients and default values that were used. The Uncertainties subsection within the Public Health Implications section of this report discusses some of the limitations of the model.

Appendix D — Attachments


Ways to protect your health
By keeping dirt from getting into your house and into your body
Wash and peel all fruits, vegetables, and root crops
Wipe shoes on doormat or remove shoes
Don't eat food, chew gum, or smoke when working in the yard
Damp mop floors and damp dust counters and furniture regularly
Wash dogs regularly
Wash children's toys regularly
Wash children's hands and feet after they have been playing outside
ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

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

Ways to prevent high levels of lead in blood include

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

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

✔ **Eating a balanced diet.**

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

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

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

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

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

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

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

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

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

How to Prevent Lead Exposure at Home

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

- Talk to your local health department about testing paint and dust in your home for lead if you live in a home built before 1978.
- Common home renovation activities like sanding, cutting, and demolition can create hazardous lead dust and chips by disturbing lead-based paint. These can be harmful to adults and children.
- Renovation activities should be performed by certified renovators who are trained by EPA-approved training providers to follow lead-safe work practices.
- Learn more at EPA's Renovation, Repair, and Painting rule Web page:

  http://www.epa.gov/lead/pubs/renovation.htm.

Lead can be found in a variety of sources.
These include:

- paint in homes built before 1978
- water pumped through leaded pipes
- imported items including clay pots.
- certain consumer products such as candies, make -up and jewelry
- certain imported home remedies

- If you see paint chips or dust in windowsills or on floors because of peeling paint, clean these areas regularly with a wet mop.
- Wipe your feet on mats before entering the home, especially if you work in occupations where lead is used. Removing your shoes when you are entering the home is a good practice to control lead.
- Use only cold water from the tap for drinking, cooking, and for making baby formula. Hot water is more likely to contain lead. Run cold water 30 to 60 seconds before using it.

Remove recalled toys and toy jewelry from children's access. Stay up-to-date on current recalls by visiting the Consumer Product Safety Commission's Web site: http://www.cpsc.gov/.

LEAD poisoning Know the Facts

Lead poisoning is caused by swallowing or breathing lead. Children under 6 years old are most at risk. If you are pregnant, lead can harm your baby.

FACT Lead can cause learning and behavior problems.

Lead poisoning hurts the brain and nervous system. Some of the effects of lead poisoning may never go away.

Lead in a child's body can:

- Slow down growth and development
- Damage hearing and speech
- Make it hard to pay attention and learn

FACT Most children get lead poisoning from paint in homes built before 1978.

When old paint cracks and peels, it makes dangerous dust. The dust is so small you cannot see it. Most children get lead poisoning when they breathe or swallow the dust on their hands and toys.

FACT A lead test is the only way to know if your child has lead poisoning.

Most children who have lead poisoning do not look or act sick. Ask your doctor to test your child for lead.

Protect Your Family

1. Test your home for lead.

- If you live in a home built before 1978, have your home inspected by a licensed lead inspector.
- Contact your local health department for more information.

Sometimes lead comes from things other than paint in your home, such as:

- Candy, toys, glazed pottery, and folk medicine made in other countries
- Work like auto refinishing, construction, and plumbing
- Soil and tap water

2. Keep children away from lead paint and dust.

- Use wet paper towels to clean up lead dust. Be sure to clean around windows, play areas, and floors.
- Wash hands and toys often, especially before eating and sleeping. Use soap and water.
- Use contact paper or duct tape to cover chipping or peeling paint.

3. Renovate safely.

Home repairs like sanding or scraping paint can make dangerous dust.

- Keep children and pregnant women away from the work area.
- Make sure you and/or any workers are trained in lead-safe work practices.
- Home repairs like sanding or scraping paint can make dangerous dust.

Contact us for more information:

CDC
CENTERS FOR DISEASE CONTROL AND PREVENTION

5 Things you can do

to help lower your child's lead level.

If your child has a high lead level, there are things you can do at home to help.

1 Make a plan with your doctor.

Work together with your doctor to find the best treatment for your child. Ask questions if you don't understand something.

You may need to:

- Go back for a second lead test.
- Test your child for learning and development problems. This test is called a "developmental assessment."

2 Find the lead in your home.

Most children get lead poisoning from lead paint in homes built before 1978. It is important to find and fix lead in your home as soon as possible. Have your home inspected by a licensed lead inspector.

Don't remodel or renovate until your home has been inspected for lead. Home repairs like sanding or scraping paint can make dangerous lead dust.

3 Clean up lead dust.

When old paint cracks and peels, it makes lead dust. Lead dust is so small you cannot see it. Children get lead poisoning from swallowing dust on their hands and toys.

- Use wet paper towels to clean up lead dust.
- Clean around windows, play areas, and floors.
- Wash hands and toys often with soap and water. Alwayswash hands before eating and sleeping.
- Use contact paper or duct tape to cover chipping or peeling paint.

4 Give your child healthy foods.

Feed your child healthy foods with calcium, iron, and vitamin C. These foods may help keep lead out of the body.

- Calcium is in milk, yogurt, cheese, and green leafy vegetables like spinach.
- Iron is in lean red meats, beans, peanut butter, and cereals.
- Vitamin C is in oranges, green and red peppers, and juice.

5 Learn more. Get support.

Contact your local health department. Trained staff will answer your questions and connect you to other resources in your community.

Dealing with lead poisoning can be stressful. Be sure to ask for support. You may want to talk to other parents who have children with lead poisoning.

Contact us for more information:

CDC
CENTERS FOR DISEASE CONTROL AND PREVENTION

Blood Lead Levels in Children

What Do Parents Need to Know to Protect Their Children?

Protecting children from exposure to lead is important to lifelong good health. Even low levels of lead in blood have been shown to affect IQ, ability to pay attention, and academic achievement. And effects of lead exposure cannot be corrected.

The most important step parents, doctors, and others can take is to **prevent lead exposure before it occurs**.

Update on Blood Lead Levels in Children

- Children can be given a blood test to measure the level of lead in their blood.
- Until recently, children were identified as having a blood lead level of *concern* if the test result is 10 or more micrograms per deciliter of lead in blood. Experts now use a new level based on the U.S. population of children ages 1-5 years who are in the top 2.5% of children when tested for lead in their blood (when compared to children who are exposed to more lead than most children).
- In the past, blood lead level tests below 10 micrograms per deciliter of lead in blood may, or may not, have been reported to parents. The new, lower value means that more children likely will be identified as having lead exposure allowing parents, doctors, public health officials, and communities to take action *earlier* to reduce the child's future exposure to lead.
- What has *not* changed is the recommendation for when to use medical treatment for children. These new recommendations do not change the recommendation that chelation therapy be considered when a child is found with a test result of greater than or equal to 45 micrograms per deciliter of lead in blood.

Actions for Parents

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

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

Lead can be found in a variety of sources. These include:

- **paint in homes built before 1978.**
- **water pumped through leaded pipes.**
- **imported items including clay pots.**
- **certain consumer products such as candies, make up and jewelry.**
- **certain imported home remedies.**

National Center for Environmental Health
Division of Emergency and Environmental Health Services

CDC

Background

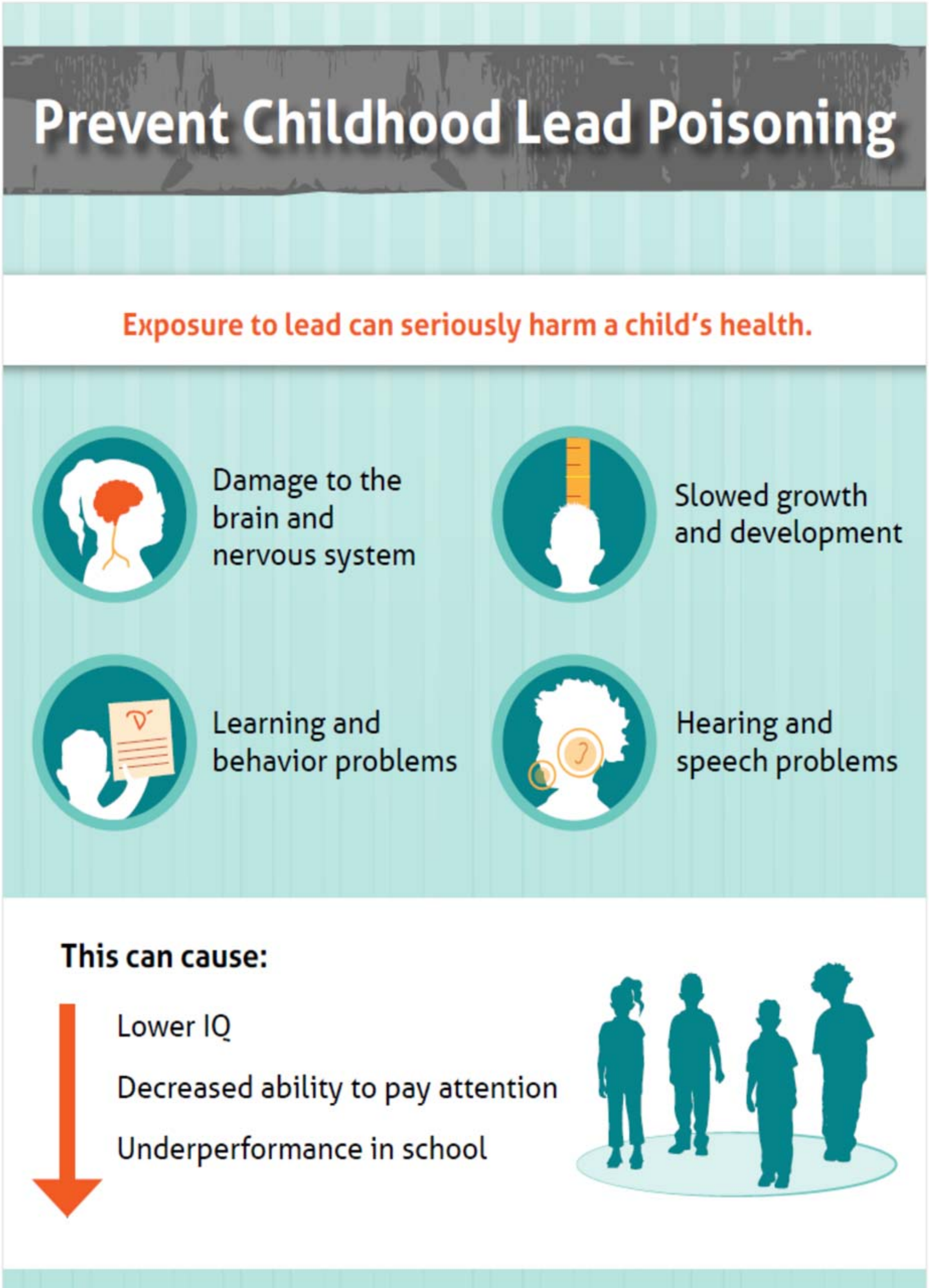
Effect of a Different Blood Lead Level

- In the past, blood lead level tests below10 micrograms per deciliter may, or may not, have been reported to parents. Identifying a child's blood lead equal to or above 5 micrograms per deciliter means more parents should learn that their child has an elevated blood lead level.
- Even though no medical treatment is recommended for children with blood lead levels lower than 45 micrograms per deciliter, parents will know they need to learn about sources of lead exposure and find out if one or more unrecognized sources of lead are present in their home. Parents then can follow the Centers for Disease Control and Prevention (CDC)'s recommendations to control exposure to lead.
- No changes are recommended to the existing CDC guidelines for the evaluation and treatment of children requiring chelation (those with BLLs ≥ 45 micrograms per deciliter).

New Recommendations to Define Elevated Blood Lead Levels

- In January 2012, a committee of experts recommended that the CDC change its "blood lead level of concern." The recommendation was based on a growing number of scientific studies that show that even low blood lead levels can cause lifelong health effects.
- The committee recommended that CDC link lead levels to data from the National Health and Nutritional Examination Survey (NHANES) to identify children living or staying for long periods in environments that expose them to lead hazards. This new level is based on the population of children aged 1-5 years in the U.S. who are in the top 2.5% of children when tested for lead in their blood. Currently, that is 5 micrograms per deciliter of lead in blood. CDC's "blood lead level of concern" has been 10 micrograms per deciliter.
- The new value means that more children will be identified as having lead exposure earlier and parents, doctors, public health officials, and communities can take action earlier.
- The committee also said, as CDC has long said, that the best way to protect children is to prevent lead exposure in the first place.

To learn more about preventing lead exposure, visit CDC's Web site at http://www.cdc.gov/nceh/lead/


Prevent Childhood Lead Poisoning
Exposure to lead can seriously harm a child's health.
Damage to the brain and nervous system
Slowed growth and development
Learning and behavior problems
Hearing and speech problems
This can cause:
Lower IQ
Decreased ability to pay attention
Underperformance in school

Lead can be found throughout a child's environment.

1. Homes built before 1978 (when lead-based paints were banned) probably contain lead-based paint.

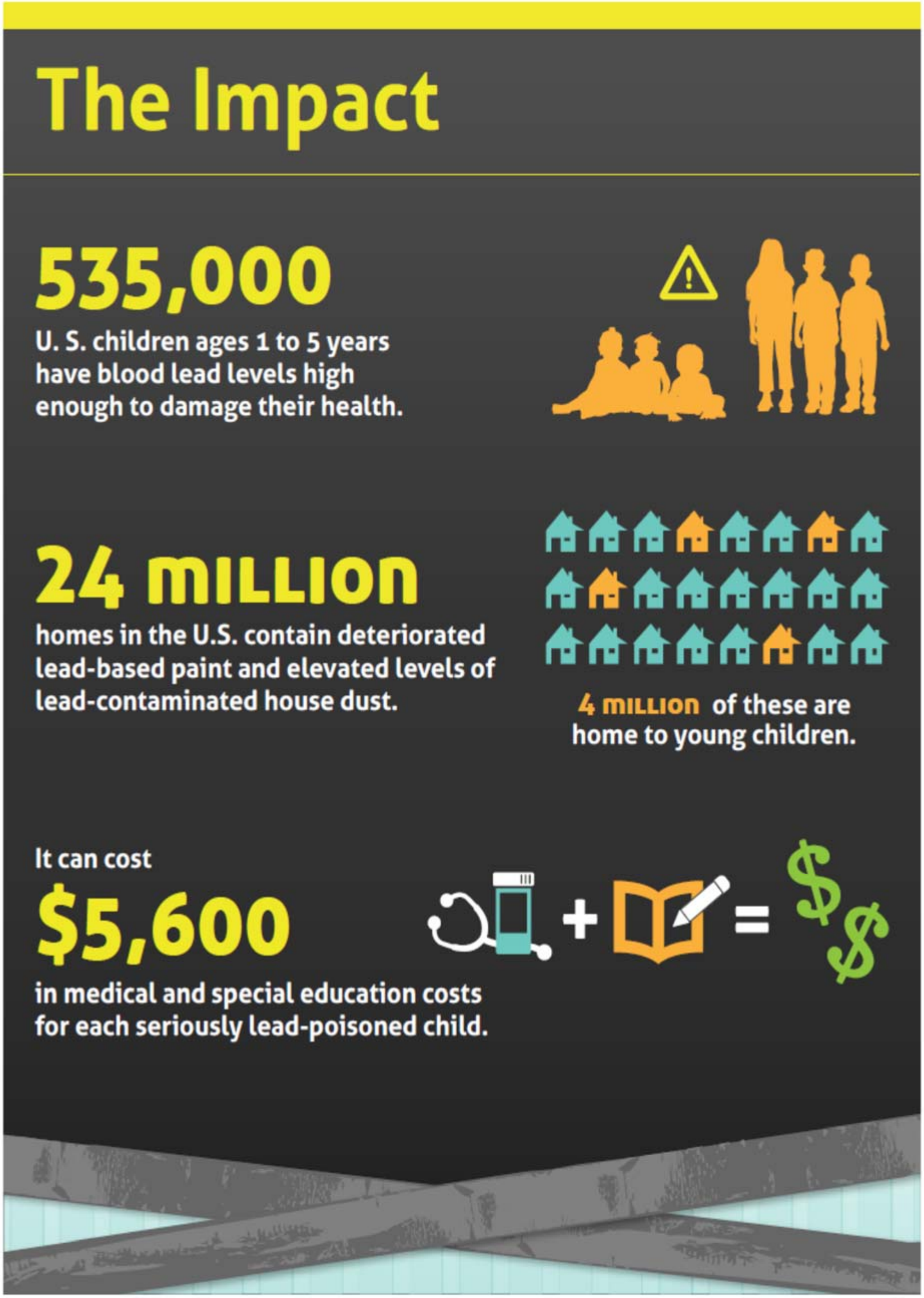
   When the paint peels and cracks, it makes lead dust. Children can be poisoned when they swallow or breathe in lead dust.

2. Certain water pipes may contain lead.

3. Lead can be found in some products such as toys and toy jewelry.

4. Lead is sometimes in candies imported from other countries or traditional home remedies.

5. Certain jobs and hobbies involve working with lead-based products, like stain glass work, and may cause parents to bring lead into the home.


The Impact
535,000
U. S. children ages 1 to 5 years have blood lead levels high enough to damage their health.
24 MILLION
homes in the U.S. contain deteriorated lead-based paint and elevated levels of lead-contaminated house dust.
4 MILLION of these are home to young children.
It can cost
$5,600
in medical and special education costs for each seriously lead-poisoned child.

The good news:
Lead poisoning is 100% preventable.

Take these steps to make your home lead-safe.

Talk with your child's doctor about a simple blood lead test. If you are pregnant or nursing, talk with your doctor about exposure to sources of lead.

Talk with your local health department about **testing paint and dust in your home for lead** if you live in a home built before 1978.

Renovate safely. Common renovation activities (like sanding, cutting, replacing windows, and more) can create hazardous lead dust. If you're planning renovations, use contractors certified by the Environmental Protection Agency (visit www.epa.gov/lead for information).

Remove recalled toys and toy jewelry from children and discard as appropriate. Stay up-to-date on current recalls by visiting the Consumer Product Safety Commission's website: www.cpsc.gov.

Visit www.cdc.gov/nceh/lead to learn more.

LEAD poisoning

Are You Pregnant?

Prevent Lead Poisoning. Start Now.

Lead poisoning is caused by breathing or swallowing lead. Lead can pass from a mother to her unborn baby.

Too much lead in your body can:

- Put you at risk of miscarriage
- Cause your baby to be born too early or too small
- Hurt your baby's brain, kidneys, and nervous system
- Cause your child to have learning or behavior problems

Lead can be found in:

- Paint and dust in older homes, especially dust from renovation or repairs
- Candy, make up, glazed pots, and folk medicine made in other countries
- Work like auto refinishing, construction, and plumbing
- Soil and tap water

Contact your local health department to learn more.

Now is the time to keep your baby safe from lead poisoning. Here's what you can do:

1 Watch out for lead in your home.

Most lead comes from paint in older homes. When old paint cracks and peels, it makes dangerous dust. The dust is so small you cannot see it. You can breathe in lead dust and not even know it.

Home repairs like sanding or scraping paint can make dangerous lead dust. Pregnant women should not be in the house during cleaning, painting, or remodeling a room with lead paint.

Tip: If you live in an older home, have your home inspected by a licensed lead inspector.

2 Eat foods with calcium, iron and vitamin C.

These foods may help protect you and your unborn baby.

- **Calcium** is in milk, yogurt, cheese, and green leafy vegetables like spinach.
- **Iron** is in lean red meat, beans, cereals, and spinach.
- **Vitamin C** is in oranges, green and red peppers, broccoli, tomatoes, and juices.

3 Talk to your doctor.

Talk to your doctor about any medicines or vitamins you are taking. Some home remedies and dietary supplements have lead in them. It is important that you tell your doctor about any cravings you are having such as eating dirt or clay.

Contact us for more information: