Public Health Assessment

Final Release

WASHINGTON COUNTY LEAD DISTRICT – POTOSI AREA

WASHINGTON COUNTY, MISSOURI

EPA FACILITY ID: MON000705023

Prepared by the
Missouri Department of Health and Senior Services

JULY 8, 2010

Prepared under a Cooperative Agreement with the
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333

THE ATSDR PUBLIC HEALTH ASSESSMENT: A NOTE OF EXPLANATION

This Public Health Assessment was prepared by ATSDR's Cooperative Agreement Partner 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's Cooperative Agreement Partner 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.

In addition, this document has previously been provided to EPA and the affected states in an initial release, as required by CERCLA section 104 (i)(6)(H) for their information and review. The revised document was released for a 30-day public comment period. Subsequent to the public comment period, ATSDR's Cooperative Agreement Partner addressed all public comments and revised or appended the document as appropriate. The public health assessment has now been reissued. This concludes the public health assessment process for this site, unless additional information is obtained by ATSDR's Cooperative Agreement Partner which, in the agency's opinion, indicates a need to revise or append the conclusions previously issued.

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Prepared by:

Missouri Department of Health and Senior Services
Division of Community & Public Health
Section for Disease Control and Environmental Epidemiology
Bureau of Environmental Epidemiology
Under a Cooperative Agreement with the
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SUMMARY

INTRODUCTION

The top priority for the Missouri Department of Health and Senior Services (DHSS), in cooperation with the federal Agency for Toxic Substances and Disease Registry (ATSDR), in evaluating the public health impact of the Washington County Lead District - Potosi Area site is to provide the Potosi community with the best information possible to safeguard its health.

The Potosi Area is one of three US Environmental Protection Agency (EPA) National Priorities List (NPL) sites in Washington County that were listed primarily due to lead contamination of private drinking wells and residential yards from mining, milling, and smelter wastes. To a lesser extent, there is concern for cadmium and barium in drinking water, arsenic in soil, and physical hazards left behind like known and unknown diggings and shafts.

CONCLUSIONS

DHSS has reached five important conclusions in this health assessment:

Conclusion 1
Soil

DHSS concludes that ingesting (swallowing) and/or inhaling (breathing) lead contaminated soil or dust found in many of the residential yards within the Potosi Area for a year or longer may harm people's health. This conclusion applies to past, present and future exposure to lead at this site.

Basis for Decision
Soil

Residential yards throughout the mining areas of the Potosi Area contains lead and infrequently arsenic in soil at concentrations above a level of health concern. The primary concern from exposure to lead in Washington County is the effect lead has on the nervous system, especially on children less than 72 months of age.

EPA has removed soil from residential yards with lead concentrations above EPA's Time-Critical Removal Action level. These yards contained soil with lead contamination at a concentration of 1,200 parts per million (ppm) and greater or lead concentrations of 400 ppm and above for those that had a child less than 72 months of age with an elevated blood lead level. After EPA's Time-Critical Removal Actions, these yards are no longer expected to harm people's health due to lead contamination.

Residential yards with soil containing lead at concentrations between and including 400 ppm and 1,199 ppm still remain in the Potosi Area. Exposure to the soil in these yards for a year or longer may harm people's health. Individuals, especially children, can be exposed to this contaminated soil directly by accidentally ingesting the soil while working, playing, gardening, or spending time in the yard. This contaminated soil can be tracked indoors by shoes, pets and other routes and accumulate in the home. Individuals, especially children, can accidentally ingest this contaminated dust in the home. Although not as major of a route as ingestion, individuals can also be exposed by inhalation to contaminated dust in the yard and contaminated dust in the home. When this soil or dust is stirred up and becomes airborne, individuals, especially children, may breathe it in and absorb the lead through their lungs.

Conclusion 2
Groundwater

For past, present and future exposures to untreated lead and to a lesser extent cadmium contaminated well water, DHSS concludes for the Potosi Area that drinking this water for a year or longer may harm people's health. For present and future exposures of individuals who are using an EPA provided alternative source of drinking water, DHSS concludes that water from their contaminated private drinking water well is not expected to harm people's health through inhalation or skin contact.

Basis for Decision
Groundwater

A number of private drinking water wells in the Potosi Area were found to contain lead at concentrations greater than 15 parts per billion (ppb) and cadmium above 5 ppb. The primary exposure route to lead and cadmium contaminated water is through ingestion. The primary concern from exposure to lead in Washington County is the effect lead has on the nervous system, especially on children less than 72 months of age.

EPA is currently using 15 ppb of lead and 5 ppb for cadmium as the site-specific action level in Washington County as a guideline for providing alternative sources of water to private well users. For those individuals who are using EPA provided alternative sources of drinking water, they no longer need to drink water from their well; therefore, they are no longer being exposed to contaminated water through ingestion.

For individuals who have refused EPA alternative sources of water, they may still be drinking water from a contaminated private drinking water well. If these individuals are not drinking water from an alternative source or are not effectively filtering their well water, they may continue to be exposed to contaminated water that may harm people's health.

Conclusion 3 *Multi sources of lead*	For the past, present and future, residents and especially children can be exposed to lead from a number of sources that could harm their health.
Basis for Decision	The Potosi area was the site of lead mining, processing, and smeltering since the early 1700s, and remnants of those activities remain in the environment along with 74% of the homes in Potosi being built before 1979 when lead-based paint was used.
Conclusion 4	Construction of new residences on previously disturbed/mined land, that may contain elevated concentrations of lead, could harm the health of the occupants of these homes.
Basis for Decision	Residences are being established on previously disturbed/mined land that have not been evaluated for lead and other mining related contaminants or naturally occurring elements above health guidelines.
Conclusion 5	DHSS cannot currently conclude whether exposure to lead through air, sediment, surface water, fish, and edible plants in the Potosi Area could harm people's health. The information needed to make a decision is not available. DHSS is working with ATSDR, EPA, Missouri Department of Natural Resources (MDNR), Missouri Department of Conservation (MDC) and the Washington County Health Department to gather the needed information.
Basis for Decision	Lead has been found to have adverse effects on the nervous system, especially on children less than 72 months of age. In some former mining areas in Missouri, sampling has found lead in air, sediment, surface water, fish, and/or edible plants. However, the lead levels in these mediums vary greatly between mining areas. Water bodies (streams and lakes), sediment, and fish associated with the mining areas have not been sampled in the Potosi Area to determine if they contain elevated levels of contaminants. More testing is needed to determine if they may harm people's health.
Next Steps	To protect residents: 1. EPA has removed soils from residential yards containing lead concentrations that exceed Time-Critical Removal

Action levels. These yards contained soil with lead contamination at a concentration of 1,200 ppm and greater or lead concentrations of 400 ppm and above for those that had a child less than 72 months of age with an elevated blood lead level.

2. EPA has provided bottled water to residents who have elevated levels of lead, cadmium, arsenic, or barium in their private drinking water wells.

3. During the remedial phase, EPA will remove soil from residential yards that contain lower concentrations of lead that, if exposed to for a year or longer, may harm people's health.

4. EPA/MDNR should sample other media, such as air, sediment, surface water, fish, and edible plants, so it can be determined if exposure to these media may harm people's health.

5. EPA/MDNR should continue to cap diggings/shafts that are found to eliminate these physical hazards.

6. DHSS/ATSDR will coordinate with the Washington County Health Department, MDNR, and EPA to address community health concerns and questions as they arise by providing health professional and community education.

7. DHSS/ATSDR will coordinate with the Washington County Health Department, MDNR, and EPA to implement the recommendations in this public health assessment.

8. DHSS/ATSDR will continue to coordinate with the Washington County Health Department to provide health education to the residents of Washington County by informing them of the importance of having their residential yard soils and private drinking water tested for lead and remediated when elevated levels are found.

9. DHSS/ATSDR will assist the Washington County Health Department in continuing to encourage residents of Washington County to have their children blood-lead tested and have a yearly blood lead testing follow up conducted for children less than 72 months of age and expectant mothers.

10. DHSS/ATSDR will review and comment on any additional data from environmental samples collected by EPA, MDNR, or other agencies as it becomes available.

PURPOSE AND HEALTH ISSUES

The Missouri Department of Health and Senior Services (DHSS), in cooperation with the federal Agency for Toxic Substances and Disease Registry (ATSDR), are evaluating the public health impact of the Washington County Lead District - Potosi Area site. ATSDR is a federal agency within the U.S. Department of Health and Human Services and is mandated by the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) to conduct public health assessments at hazardous waste sites.

The primary contaminant of concern in the Potosi Area site is lead in soil and drinking water from mining, milling wastes, and former smelter areas. To a lesser extent, there is concern for arsenic and barium in soil as well as cadmium in drinking water. This public health assessment will determine if exposures to site-related contaminants have occurred in the past, present, or future at a level of health concern and recommend actions to reduce or prevent possible adverse health effects.

BACKGROUND

Site Description and History

The Washington County Lead District – Potosi Area site consists of approximately a 40 square mile region around the city of Potosi in which extensive lead and barite mining, milling, and smelting activities were conducted for over 200 years. Potosi is located approximately 60 miles southwest of St. Louis, Missouri. The Potosi Area site is located in the northeastern part of Washington County and is located in the Old Lead Belt of Missouri (See Figure 1 and 2). The U.S. Environmental Protection Agency (EPA) proposed the Washington County Lead District – Potosi Area site for the National Priorities List (NPL) on September 19, 2007 and finalized it on March 19, 2008. The NPL is EPA's national list of the most serious contaminated sites that are eligible for federal cleanup under the CERCLA.

Other sites in Washington County are also being investigated for mining-related contamination. The Washington County Lead District – Richwoods site and Old Mines site were investigated, proposed and listed on the NPL at the same time as the Potosi Area site. Other areas in Washington County outside of the NPL sites are also being investigated for possible lead contamination. This public health assessment will only discuss the Potosi Area site in east central Washington County (See Figure 3). The Richwoods and Old Mines sites are discussed in separate public health assessments.

Lead mining in the Potosi area has a long history dating back to the early 1700's. Lead was originally found on or near the surface. Later lead was mined from shafts less than 10 feet deep in the red clay residuum and fractured bedrock. The clay residuum is generally located several inches to three to four feet below barren soil overburden and its average thickness ranges from a few feet to more than 30 feet in depth. Continuous mining in the Potosi area began in 1721 at Mine Renault, located just north of Potosi, with the use of slave labor to mine the surface and near surface lead ores. Numerous small mines rapidly opened and closed with some producing as much as 1,500 pounds of ore per day. Activity tapered off after 20 years with only intermittent production through the rest of the century. In 1799, mining began to be developed on a larger scale when Moses Austin sank a mineshaft to a depth of 80 feet and built a reverberatory furnace in the Potosi area. Until the construction of the reverberatory furnace in the Potosi area, lead smelting was done by over 20 less efficient log and kiln furnaces. By 1802 the reverberatory furnace was smelting lead ore for the entire Potosi region. By the late 1800's, a greater number of mines penetrated the bedrock at depths of 100 feet or greater (1,2,3).

Early lead miners tossed barite aside into waste piles, because it originally had few uses. It became valuable after the civil war (1861-1865) as a long-lasting white pigment. Barite mining boomed in 1926, when the mineral was discovered to be a useful weighting agent in oil drilling mud. Although mechanical mining of the residuum for lead and barite began in 1904 with the use of an early steam shovel, hand mining was the mainstay until 1942. After 1942, many of the large mining operations used mechanized mining methods that utilized shovels and front-end loaders to mine the residuum. The residuum was then hauled to the washer where high pressure water was used to remove the clay. This was followed by passing the remaining material through log washers to remove more clay and onto a jig system to separate the barite and lead from any remaining waste rock. Washington County was the world leader in barite production for a number of years but production started to decline in 1985 due to competition in other states (1,3).

These past mining activities have left large areas of disturbed land along with associated water retention ponds. These disturbed mining areas are distributed throughout eastern Washington County and the Potosi Area site. In some instances, individuals have built homes on these disturbed areas or removed materials to use as fill materials around their homes, driveways, and playgrounds. Construction of homes in certain areas has shown higher levels of lead contamination in soils after completion, than before the property was disturbed (personal conversation with Jeff Weatherford, EPA Remedial Project Manager), allowing for higher levels of lead contamination at the new residences.

Site Investigation

The initial effort to identify if contaminants from the historical mining in the Potosi Area could be having potential adverse health and environmental impacts began in the spring and summer of 2004 by the Missouri Department of Natural Resources (MDNR). This was part of a statewide project to identify all lead and zinc mining, milling, smelting, and processing sites in Missouri. The purpose of this project was to evaluate and categorize sites based on their potential risk to human health and the environment from contaminated soil and groundwater. These initial efforts focused on sampling 20 public properties because of the ease of access. This investigation identified elevated lead concentrations above 400 parts per million (ppm) on seven public properties. Lead levels ranged from not detected up to a maximum of 4,067-ppm lead when analyzed using an X-Ray Fluorescence (XRF) instrument (1).

Because of the elevated levels of lead, MDNR and EPA began an investigation of the Washington County Lead District by sampling residential yards and private drinking water wells. Sampling and analysis was conducted from June 2005 through December 2005. To investigate the Potosi Area site for contamination, the site was divided up into 10 different Study Areas (SAs), SAs 1 thru 9 and Mineral Point (this document will just refer to them as the 10 Study Areas) (See Figure 3). Except for Potosi, Mineral Point, and Springtown, the Potosi Area site is primarily rural residential and large tailings areas associated with past mining activities (1). On June 16, 2007, MDNR released an Integrated Site Inspection/Removal Assessment Report for the Potosi Area site detailing their investigation.

MDNR sampled soil at 359 residences located on or near mining or mine waste disposal areas as well as publicly owned properties during this investigation. Of the properties sampled, approximately 65% had soil lead levels that exceeded 400 ppm and 18% that exceeded 1,200 ppm. Arsenic levels ranged from less than 3 ppm to 61 ppm with elevated levels of arsenic usually associated with elevated levels of lead (1). Barium was detected at a maximum of 10,500 ppm in a residential yard, but the majority of the samples were lower for an average of 2,730 ppm (1,4).

Sampling also included approximately 172 private drinking water wells of which 36 wells exceeded EPA's action level for lead of 15 parts per billion (ppb). Four private wells exceeded EPA's Maximum Contaminant Level (MCL) of 5 ppb for cadmium at a maximum of 5.73 ppb, with two also having elevated levels of lead (1). Barium was detected at a maximum of 2,230 ppb with an average concentration of 589 ppb. Only three wells tested above the MCL of 2,000 ppb (1,4).

Summary Table of 2005 MDNR Residential Soil Sampling

Total Residences Sampled	359
Number of Yards Exceeding 400 ppm of lead	233
Number of Yards Exceeding 1,200 ppm of lead	65

ppm = parts per million

Summary Table of 2005 MDNR Residential Private Well Sampling

Total Private Wells Sampled	172
Number of Private Wells Exceeding EPA's Action Level for Lead of 15 ppb	36
Number of Private Wells Exceeding EPA's MCL for Cadmium of 5 ppb	4

ppb = parts per billion

In October 2005, EPA began sampling in the Potosi area to support a removal action. Of the 534 properties sampled, lead was present in soil at levels between 400 and 1,199 ppm in 150 yards and 52 yards had lead contamination above 1,200 ppm (5). EPA is currently using lead levels above 1,200 ppm in residential yards as the level requiring a Time-Critical Removal Action and residential soil lead levels between 400 to 1,199 ppm as areas that will be part of a later Remedial Action. If an area between 400 to 1,199 ppm is frequently used by children under 72 months of age or a residence where a child with elevated blood-lead has been identified, this is also included in the Time-Critical Removal Action (5,6). Samples of private drinking water wells also found 55 residential wells that exceeded the EPA's Action Level for lead (5). See the Time-Critical Removal Action section for details on the removal.

Summary Table of 2005 EPA Residential Soil and Private Well Sampling

Total Residences Sampled	534
Number of Yards Between 400 and 1,199 ppm Lead	150
Number of Yards Exceeding 1,200 ppm of Lead	52
Number of Private Wells Exceeding EPA's Action Level for Lead of 15 ppb	55

ppm = parts per million   ppb = parts per billion

As part of the project, soil samples were also taken at 241 source areas and analyzed for lead, cadmium, barium, and arsenic with an XRF. Source areas were areas of mine and/or mill waste that serve as a source of contamination to other properties. Of those samples, 198 were taken from source areas near a residence. Thirty-one of the source area samples were submitted to MDNR's laboratory for confirmation analysis for arsenic, barium, and lead. Lead and arsenic were found to be the major contaminants, with results for lead ranging from 267 to 5,300 ppm, with an average of 1,978 ppm. Results for arsenic ranged from 4.1 to 138 ppm with an average of 30.4 ppm (1).

Five of the above samples were submitted to the University of Colorado's Laboratory of Environmental and Geological Sciences for lead speciation and bioaccessibility analyses. Two of the samples were from source areas and three from residential yards. Of the total lead measured in the five samples an average of 53% of the lead was readily bioaccessible (1). This means that on average, 53% of the lead in the soil, if ingested by a person, would be released during digestion and available for absorption in the digestive system (7). Forms of lead indicative of lead paint or leaded gasoline exhaust deposition were not observed in these five soil samples (1).

Other Sources of Exposure to Contaminants

Besides many private wells being contaminated with lead, the City of Potosi public well #4 has shown lead contamination. Public water well #4 has shown dissolved lead concentrations between 4.8 and 12.6 ppb between 1994 and 2004. A sample collected in

December 2003 contained a total lead concentration of 73.5 ppb (1,3). Samples taken before and after this date did not contain lead above EPA's Action level of 15 ppb (1). Considering that the Potosi water system is a blended system and regularly monitored for lead at the tap, the likelihood of tap water from the Potosi water system exceeding the EPA action level is minimal. Other contaminants found in the public wells included samples of the Mineral Point well #1, Potosi wells #5 and #6 that have exceeded EPA's MCL for Radium and Gross Alpha radiation. Potosi East Well #7 has exceeded MCL for Gross Alpha radiation. Being a blended system, the city is able to maintain radionuclide levels below the MCL (1).

Another potential source of lead exposure, especially for children under 72 months of age, is that a large percentage of homes in Washington County were built before 1979. These homes may have lead-based paint because its use in residential paint was not restricted until 1978. In Washington County as a whole, 61% of the homes were built before 1979 and in the City of Potosi that number is even higher at 74% (8,9). Deteriorating and cracking lead paint and areas of friction where the lead paint is ground to dust are areas where children can easily be exposed to lead contamination through their high hand-to-mouth activity (10). Therefore, lead-based paint may be an additional source of lead exposure.

So far the environmental evaluation of the Potosi Area site has focused on groundwater and soil contamination. Surface water (streams and confined waters), sediments, and fish present in those water bodies have not been evaluated to determine if contamination is present in these media (1). The Potosi area is part of the Big River drainage area. The Big River is contaminated with lead from source area tailings piles in St. Francois County and the Potosi Area site source areas could be contributing to that contamination. If the water bodies and fish in the Potosi Area site are contaminated with lead, this could be another exposure pathway through the ingestion of lead contaminated water and fish.

Air sampling for lead has not been done and is not considered a major pathway of exposure unless the material is disturbed. Considering that the tailings areas are mostly located in rural areas with some vegetation and are not like the large tailings pile areas of St. Francois and Madison Counties, wind doesn't seem to affect and move the lead contaminated materials like it does at the large tailings piles. The air pathway could potentially be a problem for residents who live on or near unpaved roads where the lead contaminated materials were used as surface materials and the roads have heavy vehicle traffic.

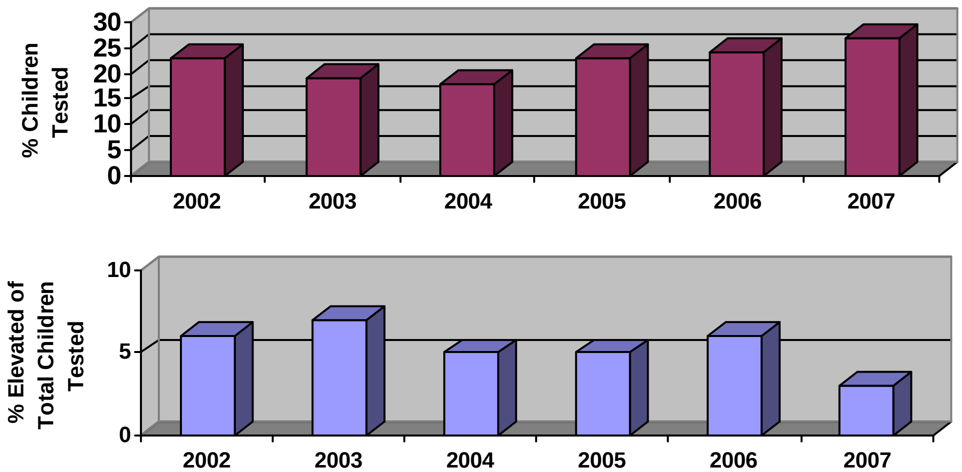
Washington Co. Health Department Activities

Prior to the Washington County Lead District – Potosi Area site being listed as a National Priority List site, elevated blood-lead levels were known to be a problem in Washington County. DHSS data show that in Washington County, 9% (162 children of an estimated population of 1,875) of the children less than 72 months of age had their blood-lead tested in 1996. Of those tested, 14% (22 children) were found to have blood-lead levels above 10 microgram per deciliter (µg/dL). From 1996 to 2001 only those children with blood-lead levels above 10 µg/dL were required to be reported to DHSS. This means that the number of children tested was probably higher because of not being reported to DHSS, so the actual percentage of children with elevated blood-lead levels was likely less than 14%. The Center for Disease Control and Prevention (CDC) has set 10 µg/dL as the blood-lead level of concern and above 10 µg/dL, follow up and intervention should take place to lower the child's blood-lead level (10).

Beginning on January 1, 2002, Missouri state law required that DHSS implement a childhood lead-testing program in which children less than six years (72 months) of age be tested for lead poisoning based upon blood-lead testing protocols. The law also required the reporting of all child blood-lead sample results be reported to DHSS, where prior to 2002, only the elevated blood-lead sample results were required to be reported. Other factors that increased the blood-lead testing numbers and lowered the percentage of children over 10 µg/dL were: increased provider (doctors, nurses, etc.) education, patient and community education about lead poisoning, increased effort by Washington County Health Department (WCHD) to sample more children, and increased Medicaid funding and outreach for testing of children in low income families. Also contributing to the additional blood-lead testing was the heightened news media coverage on the health hazards of lead poisoning and the national recognition of the environmental and health issues that were occurring in the city of Herculaneum. Herculaneum is the location of the Doe Run Company historical lead smelter that continues to operate.

The percentage of children under 72 months of age that were tested and the percentage of those children found to be above 10 µg/dL are illustrated in the following graph. Only the data from 2002 through 2007 is presented in the graph because reporting for all blood lead test results was not required until after 2002. This provides a better representation of the number of children who had elevated blood lead levels (above 10 µg/dL).

Percentage of Children Less than 72 Months of Age Tested and the Percentage with Elevated Blood Lead Levels Washington County Superfund Site



Source: Missouri Department of Health and Senior Services Systematic Tracking of Elevated Lead Levels and Remediation (STELLAR), now the Missouri Health Strategic Architectures & Information Cooperative (MOHSAIC).

In 2007, the percentage of children with an elevated blood-lead level was 3% for Washington County as a whole, and 4 % for the area covered by the Potosi Zip code (63664). The area covered under the Potosi Zip code does not match the area covered by the Potosi Area site being investigated. Because of elevated blood lead levels in children in Washington County and elevated soil and groundwater lead levels found by MDNR and EPA investigations, EPA began a Time-Critical Removal Action in December 2005. To inform the public of what was occurring, EPA conducted public meetings at the three separate sites of Potosi, Richwoods, and Old Mines. As part of the public meetings, DHSS provided educational materials, and in cooperation with ATSDR and WCHD, provided free blood-lead testing to anyone attending the meetings. Further testing is needed to determine if remediation efforts and health education provided to the community has lowered children's blood lead levels.

Elevated Blood Lead Risk Assessment

When WCHD or a health care provider identifies a child with a blood lead level above 10 µg/dL, the child is said to have an elevated blood lead level. When a child is found to have an elevated blood lead level, their health care provider, local county health department, and/or managed health care agency typically provides health education to the family to reduce the child's blood lead level. For every child with a blood lead level at 15 µg/dL or greater, an Elevated Blood Level Risk Assessment is completed to find what is causing the child to have elevated levels of lead in his/her blood. In Washington

County and the Potosi Area, the DHSS Bureau of Environmental Epidemiology's Childhood Lead Program conducts these Risk Assessments. The Risk Assessments typically include testing for lead in drinking water, yard soil, dust from soil, lead-based paint, or other interior sources such as doorways, windowsills, window troughs, walls, along with other areas the child may come into contact with lead. WCHD offers free blood lead testing for citizens of Washington County to determine if they have an elevated blood lead level.

Washington County Time-Critical Removal Action

Based on the findings of elevated lead in soil and groundwater, EPA began a Time-Critical Removal Action to excavate soils in residential yards contaminated with lead over 1,200 ppm or yards with over 400 ppm if a child with an elevated blood-lead level was present. As of August 2009, EPA has screened 1,685 properties, of which 205 had a soil lead level of 1,200 ppm or above (5).

Those soils exceeding 1,200 ppm of lead will be excavated up to a depth of 12 inches. If the soil at a depth of 12 inches exceeds 1,200 ppm, excavation may continue until concentrations fall below 1,200 ppm. If excavation below 24 inches does not achieve a concentration below 1,200 ppm, EPA may choose to place a warning barrier and backfill the area with clean soil. The replacement clean soil will have lead levels below 240 ppm with all other hazardous substances, pollutants, or contaminants below EPA residential soil screening levels (5).

Two hundred and two of these properties have had the contaminated soil excavated and clean soil brought in and the area seeded. Contaminated soil is being taken to the Indian Creek Mine tailings pile that is being used as a repository (5). The Time-Critical Removal Action in the Potosi Area is nearing completion for those properties with soil lead contamination above 1,200 ppm or yards with over 400 ppm if a child with an elevated blood-lead level is present or if drinking water levels are above 15 ppb. Other contaminated yards between 400 ppm and 1,199 ppm are expected to be addressed by a future EPA Remedial Action.

EPA has also sampled 882 drinking water wells, of which 136 exceeded EPA's Action Level for lead of 15 ppb. Of those private wells found contaminated with lead, 127 have been provided with bottled water, while the remainder of the homeowners have refused (5). In place of the bottled water, an in-house under-sink filtration system is being considered as an alternative under a trial program.

After the Time-Critical Removal Action is complete, EPA will start a Remedial Action that consists of four Operable Units (OUs). As reported in a draft EPA proposed plan, OU-1 will consist of cleaning up surface soils identified at residential and child high use properties over 400 ppm that weren't cleaned up under the Time-Critical Removal Action. OU-2 consists of working on the contaminated groundwater and in particular the private drinking water wells. OU-3 consists of remediating the mine waste areas contaminated by historical mining activity and OU-4 consists of the surface water and sediments impacted by historical mining activity.

Land Use, Natural Resources, and Geology

Except for the cities of Potosi, Mineral Point, and Springtown, the Potosi Area site is primarily rural residential with large disturbed and reworked areas that remain from past lead and barite mining activities. Some of the disturbed and reworked areas contain ponds. See Figure 3 for a view of the disturbed and reworked areas (1). The remaining areas are diversified with forest, pasture, farmland and single-family housing on large-sized lots or farmsteads.

In the past, the natural resources of the Potosi Area site included the lead and barite deposits that were mined but are now depleted or not economically profitable to mine. Presently, the natural resources consist of forestland, wildlife, and water bodies, including, tailings ponds that are sometimes used for fishing.

Geology of the area consists of surface soils that vary from 10% to 80% clay over a residuum that is gravelly clay. The soil and residuum range in thickness from 10 to 35 feet in depth. The strip mining for lead and barite has disturbed much of the Potosi Area site. The area is underlain by the unconfined Ozark Aquifer, which is highly fractured and ranges from 235 to 370 feet thick. Karst areas with sinkholes, solution-widened cavities, caves, springs, and losing streams are present (1). Over 75 caves and 100 springs have been documented in Washington County and surface recharge areas such as numerous sinkholes, losing streams, mine shafts and exploratory borings can easily allow surface water into the aquifer (1,3). The Ozark aquifer is the major source of drinking water for private wells in the areas and approximately 22% of the private wells sampled during MDNR's SI/RA showed contamination above an Action Level for lead or MCL for cadmium. Below the Ozark Aquifer is the St. Francois Confining Unit that is an effective barrier to downward groundwater movement to the St. Francois Aquifer. Interconnections between the two aquifers have probably occurred because of faulting, unplugged drill holes, and improperly completed wells allowing some contamination into the St. Francois Aquifer (1,3).

Physical hazards

Physical hazards in the Washington County Lead District – Potosi Area site consist of known and unknown deserted diggings and mine shafts. These hazards vary from a shallow depression of a few feet to mine shafts that originally were around 100 feet deep. Over 1,400 of these diggings/shafts sites related to the mineral industry may be present in all of Washington County (1). Some may have become grown over by vegetation and unrecognizable until they are stumbled on to. A limited number of smelter remains are still present with dilapidated facilities and/or stone chimneys that could present a falling stone hazard if disturbed as well as elevated levels of lead in surrounding soils.

Demographics

Except for the city of Potosi (with a population of 2,662), Mineral Point, and Springtown, the Potosi Area site of the Washington County Lead Mine District is primarily rural residential. The Potosi Area site consists of approximately 40 square miles that have been broken up into ten Study Areas. Because these study areas are irregularly shaped polygons and the majority of the area is rural, an accurate number of residents in the study areas was difficult to determine. MDNR did estimate the population within the Potosi study areas as 7,280 (1).

Because the Washington County Lead District – Potosi Area Public Health Assessment covers the city of Potosi and much of the surrounding rural area, DHSS averaged the relevant demographics in Washington County and the city of Potosi to determine demographics for the site. From 2000 U.S. Census data, the average percentages for the different races were, 95.5% white, 2.3% black, 0.6% American Indian and Alaska Native, 0.35% other races and 1.25% being two or more races. The average percentage of children under 5 years of age is 7.0% and the average percentage of adults over the age of 65 was 14.8%. The average percentage of families below the poverty level for 1999 in Washington County was 17.1% with the city of Potosi having a larger percentage at 28.1%. According to the 2000 Census, the percentage of homes that were built before 1979 in Washington County was 67.7% with the city of Potosi having a higher percentage at 74 % (8,9).

Quality Assurance and Quality Control

Various people, organizations, and contractors have been involved in the sampling, research, and analyses at this site, resulting in Quality Assurance and Quality Control (QA/QC) information of varying degrees of accuracy and precision.

In preparing this public health assessment, DHSS and ATSDR have relied on the information provided in the referenced documents and have assumed that adequate quality assurance and quality control measures were followed with regard to chain-of-custody, laboratory procedures, and data reporting. The validity of the analysis and, therefore, the conclusions in this public health assessment, are valid only if the referenced information is complete and reliable.

DISCUSSION

Pathways Analysis

This section addresses the pathways by which residents of the area may have been exposed to lead, and to a lesser degree arsenic and cadmium, from the contaminated tailings, soil, and/or groundwater. When a chemical is released into the environment, the release does not always result in exposure. Exposure only occurs when a chemical comes into contact with and enters the body. To determine whether the residents of Washington County, particularly those living in the vicinity of tailings and mining areas or areas and media affected by the past mining, DHSS conducted an analysis of exposure pathways. For a chemical to pose a health risk, a completed exposure pathway must exist. ATSDR has determined that an exposure pathway consists of five elements including: a source of contamination, transport through an environmental medium such as soil or water, a point of exposure, a route of human exposure, and a receptor population. Completed exposure pathways require that all five of the elements of exposure exist. An exposure pathway can be eliminated if at least one of the five elements is missing and will never be present. Potential exposure pathways, however, have at least one of the five elements missing or uncertain, but could exist. Completed and potential exposure pathways could have occurred in the past, could be occurring presently, or could occur in the future. Because the physical and chemical composition of contaminants is similar in all of the Study Areas, pathways of human exposure in each of the Study Areas are similar. Exposure is through the ingestion or inhalation of lead-contaminated tailings that have been placed on the land surface or moved where human can come into contact with them or ingestion of contaminated groundwater. Dermal contact is not considered a pathway of exposure because lead is not readily absorbed through the skin.

Completed Exposure Pathways

Lead has been found to be the main contaminant at the Washington County Lead District – Potosi Area site and has contributed to elevated blood-lead levels in children less than 72 months of age. The five elements of a completed exposure pathway at the Washington County Lead District – Potosi Area are:

1. **Contaminant source –** lead contaminated tailings, soils, and groundwater.
2. **Environmental medium and transport** – soil, groundwater, dust, surface water, sediment, fish, air, and garden vegetables.
3. **Point of exposure –** areas where exposure to lead contamination is taking place.
4. **Route of exposure –** ingestion and inhalation.
5. **Receptor population –** those that ingest and/or inhale lead contamination.

Table 1 in Appendix B illustrates the different exposure pathways present at the Washington County Mines Site – Potosi Area.

Completed Exposure Pathways

Completed exposure pathways at the Washington County Lead District – Potosi Area have existed in the past, are presently occurring, and will continue in the future, until the pathways to contaminated soil and groundwater are lessened or eliminated. Lead is the primary contaminant and to a lesser extent arsenic and cadmium. The major exposure pathways are ingestion and inhalation of lead and other contaminants.

Exposure to soil contaminants can occur by directly or accidentally ingesting the soil while working, playing, gardening, or spending time in the yard. This contaminated soil can be tracked indoors by shoes, pets, and other methods and accumulate in the home. Individuals, especially children, can accidentally ingest this contaminated dirt in the home. Children are more likely to be exposed to household dust and other forms of contaminated media because of their high hand-to-mouth activity. Although not as major of an exposure route as ingestion, individuals can also be exposed to this contaminated soil in the yard and contaminated dirt in the home by inhalation. When this soil or dust is stirred up and becomes airborne, individuals may breathe it in and absorb the lead through their lungs.

Individuals can be exposed to the lead in their water supply through ingestion while drinking and cooking with contaminated water. Individuals may accidentally ingest lead contaminated water while bathing, playing, or swimming.

In addition to exposure to soil and groundwater, the DHSS Childhood Lead Program along with the Washington County Health Department have identified children in the area with elevated blood lead levels whose homes had elevated levels of lead in indoor dust. The high levels of lead in the indoor dust may have come from elevated levels of lead in outdoor soil, dust from lead based paint in the home, or other sources. This completes an exposure pathway through ingestion and inhalation of lead contaminated indoor dust. In 2007, 4% of the children tested in the Potosi Area zip code still had elevated blood-lead levels above 10 µg/dL compared to the statewide average of 1.5%.

EPA has greatly reduced exposure to lead-contaminated soil and groundwater by their Time-Critical Removal Action. The intent of an EPA Time-Critical Removal Action is to identify and eliminate critical exposure pathways in an expedient manner. For this Time-Critical Removal Action, EPA has removed soil from residential yards with lead concentrations of 1,200 ppm and above and residential yards with lead concentrations greater than 400 ppm that had a child less than 72 months of age with an elevated blood lead level. In addition, EPA has identified private drinking wells with levels of lead greater than 15 ppb. EPA has offered all of these residents bottled water to eliminate or reduce exposure.

Potential Exposure Pathways

Potential exposure pathways consist mostly of those areas where the environment has not been tested for lead contamination. These include the water bodies associated with past-disturbed mining areas and the streams that cross the site. It is not known what levels of lead or other contaminants are present in the water and sediment. Also, the fish in these water bodies have not been tested to see if they contain lead at a level that if consumed in large enough quantities would cause a health effect. Edible plants could be anything from garden produce grown in lead contaminated soil to wild edible plants in mining disturbed soils. These potential pathways may or may not be present at an exposure level that would be of a health concern. Contaminated garden areas are being addressed as part of EPA's Time-Critical Removal Action, but they may not gain access to sample and remove contaminated soil for all residences.

TOXICOLOGICAL EVALUATION

Introduction

This section will discuss the health effects of exposure to specific contaminants found at the site. A discussion of non-cancerous health effects and the possibility of the contaminants causing cancer are evaluated in this section. ATSDR has developed Comparison Values (CVs) that are media-specific concentrations used by health assessors to select environmental contaminants of concern. Contaminant concentrations that are less than the CV are unlikely to pose a health threat. Contamination levels above the CV do not necessarily indicate that a health threat is present, but that further evaluation of the chemical and pathways is needed. CVs are usually developed for chronic (more than 365 days) exposure, intermediate (14 day to 365 days) exposure and acute (less than 14 days) exposure. Environmental Media Evaluation Guides (EMEGs) are CVs that have been derived for a variety of chemicals in various media. ATSDR has not developed a CV for lead, but one is available for arsenic, cadmium, and barium.

Instead, exposure to lead is evaluated by using a biological model that predicts a blood lead concentration that would result from exposure to environmental lead contamination. The modeled blood lead concentration is then compared to the level of concern for blood lead concentrations in children as recommended by the CDC (11). Using this model, EPA has established a standard clean up value of 400 ppm for lead in soil using the default parameters in this model (12). The default parameters in the model include estimated soil ingestion and time spent outdoors. If the default parameters are found to be inaccurate in an area being investigated, the clean up value used at that site may be different than what is listed above.

Lead, and to a lesser extent arsenic, barium, and cadmium have been found in tailings piles, soils, and groundwater in and around the city of Potosi and in the 10 Study Areas of the Washington County Lead District – Potosi Area. The tailings areas and residential yards vary as to the amount of exposure that occurs in each area. Although lead is naturally occurring, the practice of depositing mine tailings above ground has made a large volume of lead more accessible to people. From natural processes and human intervention, the contaminated tailings have moved throughout the community in different media where exposure has occurred.

Lead

Lead is a naturally occurring metal found in the earth's crust. It has no characteristic taste or smell. It is mined and processed for use in various industries. It is used in some types of batteries, ammunition, ceramic glazes, medical equipment, scientific equipment, and military equipment. At one time, lead was used as an additive in gasoline and paint (11). Paint containing lead may still be present in older homes and becomes more available for uptake into the body if it is deteriorated or flaking. Tailings contaminated with lead have been deposited on the ground surface in tailings piles and also moved by nature and man into areas where exposure can easily occur.

The pathways of concern for lead exposure are inhalation and ingestion. Lead is not readily absorbed through the skin, so dermal contact is not an important route of exposure**.** The correlation between lead-contaminated soil and blood lead level are influenced by many factors, including access to soil, levels of lead in soil, behavior patterns (especially of children), presence of ground cover, seasonal variation of exposure conditions, particle size and composition of lead compounds found at various sites, and the route of exposure. These complex factors explain in some instances discrepant findings that are reported in the literature (13).

Children are more sensitive to the effects of lead than adults. The Centers for Disease Control and Prevention (CDC) considers lead poisoning the number one preventable health problem facing children (10). No safe blood lead level (BLL) in children has been determined, but CDC has set the current level of concern at greater than or equal to (≥) 10 microgram of lead per deciliter of blood (10 µg/dL)(10,11). Children identified with BLLs ≥ 10 µg/dL should prompt public health actions and receive follow-up services as recommended in CDC's Managing Elevated Blood Lead Levels among Young Children (10). Health effects of lead poisoning at these BLLs include decreased attention span, hyperactivity, and lower IQ scores. Recent studies have shown that adverse health effects can also occur in children with blood-lead levels below 10 µg/dL (10,11). Needleman and Gatsonis report that children's IQ scores are inversely related to blood lead levels. Several studies provide sufficient evidence that children's mental process or the faculty by which knowledge is acquired was adversely affected by lead (13).

Lead has no nutritional benefits for humans and has its greatest effect on the nervous system, especially in children. An unborn child can also be exposed to lead if their mothers have lead in their bodies. This exposure can cause problems such as premature births, low birth weight, decreased mental ability, learning difficulties, and reduced growth as young children. Young children can also be exposed to lead in their mother's breast milk if she has elevated lead in her system (11).

The biologic fate of inorganic lead in the human body is well known. Inorganic lead is not metabolized but is directly absorbed, distributed, and excreted. Once in the blood, lead is disturbed primarily among three compartments -- blood, soft tissue (kidney, bone marrow, liver, and brain), and mineralizing tissue (bones and teeth). Mineralizing tissue contains about 95% of the total body burden of lead in adults (11).

Arsenic

Arsenic is an element that is widely distributed in the earth's crust. Inorganic arsenic occurs naturally in soils and many kinds of rock, especially in minerals and ores that contain copper and lead. Inorganic arsenic is expected to be the form present at the site. Arsenic cannot be destroyed in the environment; however, it can change its form or become attached or separated from particles. It can change its form by reacting with oxygen or other molecules present in air, water, or soil, or by the action of bacteria that live in soil or sediment (14).

The pathways of uptake for arsenic at the site are ingestion and inhalation. Arsenic contaminated soil or water on the skin is a minor pathway; however, direct skin contact with high concentrations of inorganic arsenic compounds may cause the skin to become irritated, with some redness and swelling. However, it does not appear that skin contact is likely to lead to any serious internal effects. Skin exposure to the low levels of arsenic in the soil at the site is not usually a concern. After ingestion or inhalation exposure to arsenic, the liver changes some of the arsenic to a less harmful organic form, which is excreted in the urine. Most of the arsenic will be gone within several days, but some will remain in the body for several months or longer. Inorganic arsenic has been recognized as a human poison since ancient times, and large oral doses (above 60 ppm in food or water) can produce death. Smaller doses of inorganic arsenic (0.3 to 30 ppm in food or water) may cause irritation of your stomach and intestines, with symptoms such as stomachache, nausea, vomiting, and diarrhea. Other effects from ingestion of inorganic arsenic include decreased production of red and white blood cells which may cause fatigue, abnormal heart rhythm, blood-vessel damage resulting in bruising, and impaired nerve function causing a "pins and needle" sensation in the hands and feet (14).

At the Potosi site, arsenic was detected in residential yards from less than 3 ppm to a maximum of 61 ppm, with an average of 17.26 ppm and 72% of the yards being equal to or below 20 ppm. Arsenic was found up to a maximum of 138 ppm in source areas. The average soil background level of arsenic taken from areas where no historical mining, milling, smelting, or mine waste disposal is believed to have occurred was 2.24 ppm (1).

ATSDR has developed an EMEG for arsenic in soil of 20 ppm for children and 200 ppm for adults for chronic exposure (greater than 365 days). ATSDR has also developed an acute value (less than 14 days) of 10 ppm for the pica child. A pica child has a craving to put non-food items in their mouths or eat non-food items, such as dirt, paint chips, etc. (14). Since the maximum level of arsenic in residential soils (61 ppm) is above the EMEG for a child (20 ppm), dose calculations were made and compared to an ATSDR derived Minimal Risk Level (MRL). MRLs are an estimate of daily human exposures to a substance that is likely to be without an appreciable risk of non-carcinogenic adverse health effects over a specified duration of exposure (14). Using the maximum level of arsenic detected in private yards (61 ppm), DHSS calculated the exposure dose of arsenic from soil ingestion for a child at 0.00078 milligrams/kilograms/day (mg/Kg/day) for non-cancer health effects. Dose calculations were also made for the average arsenic level detected (17.26 ppm) of the 219 yards sampled for a result of 0.00022 mg/Kg/day (See Table 2 for calculations). The non-carcinogenic doses (0.00078 and 0.00022 mg/Kg/day) was compared to the MRL from oral exposure to arsenic of 0.0003 mg/Kg/day. The calculated exposure dose was also compared to a no-observed-adverse-effect-level (NOAEL) of 0.0008 mg/Kg/day (14). NOAELs are the highest dose of a chemical in a study or a group of studies that did not cause harmful health effects in people or animals. Using the maximum level of arsenic, the calculated dose is above the MRL, but equal to the NOAEL. However, when using the average level of arsenic, the calculated dose is below the MRL and NOAEL. Considering that the dose calculations used conservative numbers to be extra protective, no adverse non-carcinogenic health effects are expected.

Calculations were also made for the inhalation exposure pathway, but the calculated dose was 10,000 times lower so exposure through this pathway is not a health concern (See Table 2 for calculations). These calculations used the maximum value detected in private yards and were below levels of health concern, so average arsenic soil levels were not calculated.

Children, and especially those with pica behavior, could be exposed to elevated levels of arsenic in residential soil. Although health effects are not expected, exposure to elevated levels of arsenic could still be occurring in the residential yards. EPA's removal of the lead contaminated soil will address much of the arsenic contamination and the possibility of exposure.

Source areas contain higher levels of arsenic that would allow for greater exposure. However, the time spent in the source areas is expected to be limited with only short-term exposure that is not expected to cause adverse health effects.

Barium

Barium is a silvery-white metal that is found in ores containing mixtures of elements. When combined with other chemicals such as sulfur or oxygen, it forms barium compounds. These compounds are used to make paint, bricks, ceramics, glass, rubber, and other products. Barium compounds are also used by the oil and gas industries to make drilling mud that makes it easier to drill through rock by keeping the drill bit lubricated (15).

The health effects of the different barium compounds vary depending on how well the compound dissolves in water or in the stomach. Barium compounds that do not dissolve well, such as barium sulfate, are generally not harmful. In fact, doctors sometimes use barium sulfate when performing some medical tests and taking x-rays of the gastrointestinal tract (15).

Barium has not been shown to cause cancer in humans. The EPA has determined that barium is not likely to be carcinogenic to humans following ingestion and that there is insufficient information to determine whether it will be carcinogenic to humans following inhalation exposure (15).

Barium is sometimes found naturally in drinking water and food. The barium compounds that are usually found naturally do not dissolve or mix well with water, so the amount of barium found occurring in drinking water naturally is usually small. Certain foods, such as Brazil nuts, seaweed, fish, and some plants, may contain high concentrations of barium, but the concentration is not usually enough to be a health concern (15).

Because the concentration of barium detected in three private drinking water wells exceeded its MCL of 2,000 ppb with a maximum of 2,230 ppb, EPA has provided these residents with bottled water. Barium was detected at a maximum level in residential yards at 10,500 ppm, slightly above the ATSDR's chronic EMEG for a child of 10,000 ppm**.** Considering that barium was detected slightly above health guidelines in only a few instances, it is not likely to cause harmful health effects.

Cadmium

Cadmium is a soft, silver-white metal that occurs naturally in the earth's crust. Cadmium is not usually present in the environment as a pure metal, but as a mineral combined with other elements. It is most often present in nature as complex oxides, sulfides, and carbonates in zinc, lead, and copper ores. Cadmium has many industrial uses and is used in consumer products including batteries, pigments, metal coatings, plastics, and some metal alloys (16).

The exposure route of concern for cadmium in Washington County is ingestion of contaminated drinking water. Cadmium can also be ingested from food, since low levels are present in most foods with the highest levels present in shellfish, liver, and kidney meats. Cigarette smoke also contains cadmium and can double the daily intake. Ingestion of high levels of cadmium in contaminated food or water can severely irritate the stomach, leading to vomiting and diarrhea, and sometimes death. Cadmium is a cumulative toxicant and ingestion of lower levels for a long period of time can lead to a buildup of cadmium in the kidneys and, possibly, kidney damage. The kidney is the main target organ for cadmium toxicity following chronic-duration exposure by oral routes.

The EPA has classified cadmium as a probable human carcinogen by inhalation based on limited evidence of an increase in lung cancer in humans and evidence of lung cancer in rats. Studies on humans and animals ingesting cadmium have not found increases in cancer, although additional research is needed (16).

Four private wells were found to have cadmium levels slightly above the MCL for cadmium (maximum of 5.73 vs. MCL of 5 ppb). Considering that cadmium was detected only slightly above its MCL in a few private wells, no adverse health effects are expected, especially since EPA has offered bottled water to these households to eliminate exposure.

Cancer

The American Cancer Society estimates that in the United States, slightly less than half of all men and slightly more than one-third of all women will develop some form of cancer in their lifetime (17).

While the EPA considers lead to be a probable human carcinogen and the National Toxicology Program (NTP) has determined that lead and lead compounds are reasonably anticipated to be human carcinogens based on limited studies (12,18), there has been no studies linking residential ingestion or inhalation of lead contaminated soil or drinking water to increased cancer risks. The primary health concern for lead at the Washington County Lead District – Potosi site is not cancer, but lead's effect on the nervous system, especially for children less than 72 months of age.

Arsenic is considered by EPA, the International Agency for Research on Cancer, and the National Toxicology Program to be a human carcinogen by the inhalation and ingestion exposure routes. Exposure by the inhalation route in workers has shown the predominant carcinogenic effect is increased risk of lung cancer. In general, most researchers observe that risk increases as a function of exposure and duration. Most of the research on arsenic causing lung cancer comes from studies involving workers at copper smelters and arsenical chemical plants. When exposure occurs by the ingestion route, the main carcinogenic effect is increased risk of skin cancer. This is based on epidemiological studies of populations exposed to levels of arsenic in drinking water. Other studies have shown that inorganic arsenic can also increase the risk of bladder, liver, kidney, and prostate cancer (14). ATSDR has developed a Cancer Risk Evaluation Guide (CREG) for arsenic. Levels below the CREG value are not expected to cause a cancer rate above an additional cancer per 1,000,000 persons. The CREG value for arsenic in soil is 0.5 ppm and arsenic in air of 0.0002 micro grams per cubic meter ($\mu g/m^3$).

Since soil arsenic levels are above the CREG value, we calculated the ingestion dose using the maximum soil level detected in private yards at 0.0000668 mg/Kg/day and the average soil level in private yards at 0.0000189 mg/Kg/day for carcinogenic health effects. Calculations were also made for the inhalation exposure pathway but levels were well below the CREG value and are not a health concern (See Table 2 for calculations).

ATSDR reported no studies on low level exposure to arsenic that induced cancers or a threshold level that leads to a cancer endpoint. The studies that were found indicated levels above 0.001 mg/Kg/day with exposure coming mostly from drinking water and not soil (14). Although it is not known if prolonged ingestion exposure at the detected soil levels can induce cancer, it is not expected. Most arsenic induced cancers have occurred from much higher dose levels, usually in occupational setting than those present in residential yards. Considering the variation of arsenic levels in residential soil/source areas, the actual exposure to the soil, and that air concentrations for arsenic are not known, but are not expected to be elevated, it cannot be determined if arsenic in the soil poses a health concern for cancer. Since soils with elevated arsenic levels also have elevated lead levels, clean up of the lead contamination should also remove the elevated levels of arsenic.

Barium has not been shown to cause cancer in humans. The EPA has determined that barium is not likely to be carcinogenic to humans following ingestion and that there is insufficient information to determine whether it will be carcinogenic to humans following inhalation exposure (15).

Cadmium is considered a probable human carcinogen (limited human, sufficient animal studies) from inhalation by EPA and a known human carcinogen by NTP. An association has been found between occupational inhalation exposure to cadmium and lung cancer (17). Although no air sampling has been done in Washington County, concentrations of cadmium are not expected to be anywhere near occupational levels, and no carcinogenic health effects are expected.

Children's Health

In general, children are more likely than adults to be exposed to contaminants in soil and water. In their daily activities, children have a tendency for frequent hand-to-mouth contact and often introduce non-food items into their mouths. Because children are smaller, their bodies/organ systems are still developing, and they typically absorb more of the contaminants, so it usually takes less of a contaminant to cause adverse health effects in children than adults (11).

Children are more susceptible to lead poisoning than adults, and children are also more likely to be exposed to lead contaminated materials. Infants and young children can swallow and breathe lead in dirt, dust, or sand while they play on the floor or ground. They can also be exposed to lead through breast milk if the mother has elevated levels of lead in her system. Also, compared to adults, a larger proportion of the amount of lead swallowed will enter the blood in children (11). While about 99% of the amount of lead taken into the body of an adult will leave as waste within a few weeks, only about 32% of lead taken into the body of a child will leave as waste (11). All of these factors result in children being more affected by lead than adults when they have similar lead concentrations in their environment.

When children are exposed to lead contaminated materials, a variety of adverse health effects can occur depending on the level of lead to which they are exposed and the duration of exposure. These effects include learning disabilities, slowed growth, hyperactivity, impaired hearing, and at very high exposure levels, even brain damage. Unborn children can also be exposed to lead through their mothers if their bodies contain lead and are at risk of premature birth, low birth weight, decreased mental ability, learning difficulties, and reduced growth as young children (11).

Children who exhibit pica behavior may be at an even greater risk of exposure to lead and arsenic in soil than other children. Individuals who exhibit pica behaviors have a craving to put non-food items in their mouths or eat non-food items, such as dirt, paint chips, etc. (11).

CDC's current level of concern is 10 microgram of lead per deciliter of blood (10 µg/dL) in children. Recent studies have shown that adverse health effects can also occur in children with blood-lead levels below 10 µg/dL (10,12). Yearly blood-lead testing before a child is 72 months of age is key to determining if the child has been exposed. Eliminating exposure pathways by controlling contamination sources, practicing good personal hygiene, and eating a proper diet high in calcium can lessen the risk of lead poisoning in children (10).

The effects of exposure to arsenic on children are expected to be similar to the effects on adults. Children are exposed to arsenic in many of the same ways adults are and exhibit similar symptoms. In addition to symptoms that occur in adults, exposure to arsenic may result in children having lower IQ scores or exposure to arsenic may injure pregnant women or their unborn babies. Because children tend to eat and drink less of a variety of foods and drinks than adults, ingestion of a food, juice, or baby formula containing arsenic may have a larger impact on them (14).

Since lead and arsenic both target the nervous system, exposure to soil that contains elevated levels of the two minerals may have an additive effects on the severity of health effects.

It is not known whether children are more or less sensitive to the health effects caused by barium exposure. People who ingest elevated levels of barium may experience gastrointestinal disturbances, such as vomiting, abdominal cramps, or diarrhea. Exposure can also cause difficulties in breathing, increased or decreased blood pressure, numbness around the face, and muscle weakness (15).

The effects of exposure to elevated cadmium levels on children are expected to be similar to the effects on adults. Ingestion of high levels of cadmium in contaminated food or water can severely irritate the stomach, leading to vomiting and diarrhea, and sometimes death. Ingestion of lower levels of cadmium over an extended period of time can lead to buildup in the kidneys, and possibly, kidney damage. (16)

COMMUNITY HEALTH CONCERNS

During 2005, EPA and MDNR completed an investigation of Washington County lead and barite mining areas. To inform the community of their findings and the follow-up that was expected to take place, EPA and MDNR held public meetings/public availability sessions on October 17, 2005, in Cadet, Missouri and on October 18, 2005, in Potosi, Missouri. In cooperation with the Washington County Health Department and ATSDR, DHSS provided free blood-lead screenings for those interested at the meetings. Few public health concerns were expressed at the meetings, but some residents did express a desire to get the lead-contaminated soils replaced so that they no longer posed any danger to the children (19). Some health concerns were expressed during the 2005 sampling event by several citizens concerning the health effects of consuming fish from area lakes that were once associated with mining activities (1).

Conversations in early 2008 with personnel of the Washington County Health Department that deal with the public on a daily basis and do the blood-lead testing for the county indicated that their really aren't any health concerns about the lead contamination. Even though the residents aren't concerned about the lead, they are usually willing to let EPA test their yards and private wells and perform remediation if necessary.

DHSS, along with ATSDR, released a version of this document for public comment on December 18, 2009. Comments were accepted until February 5, 2010. In addition, two public meetings were hosted by DHSS during this comment period in Washington County. The meetings were held on January 21, 2010, at the Washington County Health Department in Potosi, Missouri, and at the Richwoods School in Richwoods, Missouri. The purpose of these meetings was to provide citizens with a chance to discuss the content of this health assessment on a one-to-one basis with DHSS and ATSDR health officials. An EPA official was also present to address environmental questions. In addition, it was an opportunity for health officials to address any comments or questions citizens may have had. No additional questions or comments were received about this health assessment during the comment period.

CONCLUSIONS

CONCLUSIONS	DHSS has reached five important conclusions in this health assessment:
Conclusion 1 *Soil*	DHSS concludes that ingesting (swallowing) and/or inhaling (breathing) lead contaminated soil or dust found in many of the residential yards within the Potosi Area for a year or longer may harm people's health. This conclusion applies to past, present and future exposure to lead at this site.
Basis for Decision *Soil*	Residential yards throughout the mining areas of the Potosi Area contains lead and infrequently arsenic in soil at concentrations above a level of health concern. The primary concern from exposure to lead in Washington County is the effect lead has on the nervous system, especially on children less than 72 months of age. EPA has removed soil from residential yards with lead concentrations above EPA's Time-Critical Removal Action level. These yards contained soil with lead contamination at a concentration of 1,200 parts per million (ppm) and greater or lead concentrations of 400 ppm and above for those that had a child less than 72 months of age with an elevated blood lead level. After EPA's Time-Critical Removal Actions, these yards are no longer expected to harm people's health due to lead contamination. Residential yards with soil containing lead at concentrations between and including 400 ppm and 1,199 ppm still remain in the Potosi Area. Exposure to the soil in these yards for a year or longer may harm people's health. Individuals, especially children, can be exposed to this contaminated soil directly by accidentally ingesting the soil while working, playing, gardening, or spending time in the yard. This contaminated soil can be tracked indoors by shoes, pets and other routes and accumulate in the home. Individuals, especially children, can accidentally ingest this contaminated dust in the home. Although not as major of a route as ingestion, individuals can also be exposed by inhalation to contaminated dust in the yard and contaminated dust in the home. When this soil or dust is stirred up and becomes airborne, individuals, especially children, may breathe it in and absorb the lead through their lungs.

Conclusion 2 *Groundwater*	For past, present and future exposures to untreated lead and to a lesser extent cadmium contaminated well water, DHSS concludes for the Potosi Area that drinking this water for a year or longer may harm people's health. For present and future exposures of individuals who are using an EPA provided alternative source of drinking water, DHSS concludes that water from their contaminated private drinking water well is not expected to harm people's health through inhalation or skin contact.
Basis for Decision *Groundwater*	A number of private drinking water wells in the Potosi Area were found to contain lead at concentrations greater than 15 parts per billion (ppb) and cadmium above 5 ppb. The primary exposure route to lead and cadmium contaminated water is through ingestion. The primary concern from exposure to lead in Washington County is the effects lead has on the nervous system, especially on children less than 72 months of age. EPA is currently using 15 ppb of lead and 5 ppb for cadmium as the site-specific action level in Washington County as a guideline for providing alternative sources of water to private well users. For those individuals who are using EPA provided alternative sources of water, they no longer need to drink water from their well; therefore, they are no longer being exposed to contaminated water through ingestion. For individuals who have refused EPA alternative sources of water, they may still be drinking water from a contaminated private drinking water well. If these individuals are not drinking water from an alternative source or are not effectively filtering their well water, they may continue to be exposed to contaminated water that may harm people's health.
Conclusion 3 *Multi sources of lead*	For the past, present and future, residents and especially children can be exposed to lead from a number of sources that could harm their health.
Basis for Decision	The Potosi area was the site of lead mining, processing, and smeltering since the early 1700's, and remnants of those activities remain in the environment along with 74% of the homes in Potosi built before 1979 when lead-based paint was used.
Conclusion 4	Construction of new residences on previously disturbed/mined land, that may contain elevated concentrations of lead, could harm the health of the occupants of those homes.

Basis for Decision	Residences are being established on previously disturbed/mined land, that have not been evaluated for lead and other mining related contaminants or naturally occurring elements above health concern levels.
Conclusion 5	DHSS cannot currently conclude whether exposure to lead through air, sediment, surface water, fish, and edible plants in the Potosi Area could harm people's health. The information needed to make a decision is not available. DHSS is working with ATSDR, EPA, Missouri Department of Natural Resources (MDNR), Missouri Department of Conservation (MDC) and the Washington County Health Department to gather the needed information.
Basis for Decision	Lead has been found to have adverse effects on the nervous system, especially on children less than 72 months of age. In some former mining areas in Missouri, sampling has found lead in air, sediment, surface water, fish, and/or edible plants. However, the lead levels in these mediums vary greatly between mining areas. Water bodies (streams and lakes), sediment, and fish associated with the mining areas have not been sampled in the Potosi Area to determine if they contain elevated levels of contaminants. More testing is needed to determine if they may harm people's health.

RECOMMENDATIONS

1. EPA should continue to investigate residential yards, including newly developed residential properties, and other areas where individuals, especially children, might be exposed to elevated lead or other contaminants like arsenic and cadmium, and remediate appropriately.

2. EPA should continue to identify and sample private wells in the area to determine if elevated levels of lead or other contaminants, like arsenic and cadmium, are present and take action to prevent exposure to drinking water with elevated levels of contaminants.

3. EPA/MDNR should extend/continue their sampling outside the Potosi, Richwoods, and Old Mines Areas in Washington County.

4. Washington County Health Department/DHSS should continue their efforts to test the blood of children in the community and follow-up on elevated blood leads as necessary.

5. Washington County Health Department/DHSS should continue their efforts in reaching out to the community to educate them on the adverse health effects of lead exposure.

6. Indoor dust within a home may contain lead from a variety of sources including lead based paint. Therefore, all agencies involved in remediation efforts in Washington County should work toward educating the public on how to reduce or eliminate their exposure to all sources of lead including lead-based paint.

7. EPA/MDNR should sample other media, such as air, sediment, surface water, fish, and edible plants, so it can be determined if exposure to these media can harm people's health.

8. Before developing property previously disturbed by mining, people should make sure that the property has been properly evaluated for lead and other mining-related contaminants.

PUBLIC HEALTH ACTION PLAN

This Public Health Action Plan (PHAP) for the Washington County Lead District – Potosi Area site contains a description of actions by the Missouri Department of Health and Senior Services (DHSS), the Agency for Toxic Substances and Disease Registry (ATSDR), and other stakeholders. The purpose of the PHAP is to ensure that this public health assessment not only identifies public health hazards, but provides an action plan to mitigate and prevent adverse human health effects resulting from past, present, and future exposures to hazardous substances at or near the site. Below is a list of commitments of public health actions to be implemented by DHSS, ATSDR, or other stakeholders at the site:

1. DHSS/ATSDR will work with the Washington County Health Department and EPA to provide health education for the residents of the Potosi Area site so they can help reduce or eliminate their exposure to all sources of lead.

2. DHSS/ATSDR will continue to coordinate with the Washington County Health Department, MDNR, and EPA to address community health concerns and questions as they arise by providing health professionals and community health education.

3. DHSS/ATSDR will work with the Washington County Health Department to encourage residents of Washington County to have yearly blood lead testing of children less than 72 months of age and expectant mothers.

4. DHSS/ATSDR will work with the Washington County Health Department to encourage residents of Washington County to have their yards soils and private drinking water wells tested for lead and remediated when elevated levels are found.

5. DHSS/ATSDR will coordinate with the Washington County Health Department, MDNR, and EPA to implement the recommendations in this public health assessment.

6. DHSS/ATSDR will review additional sampling data from further investigations of the different Study Areas and provide guidance regarding possible health risk.

7. DHSS/ATSDR will update this public health assessment as needed.

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CERTIFICATION

This Washington County Lead District – Potosi Area Public Health Assessment was prepared by the Missouri Department of Health and Senior Services, Bureau of Environmental Epidemiology, under a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry (ATSDR). It was completed in accordance with the approved methodologies and procedures existing at the time the public health consultation was initiated. Editorial review was completed by the Cooperative Agreement partner.

Technical Project Officer, CAT, CAPEB, DHAC

The Division of Health Assessment and Consultation (DHAC), has reviewed this public health assessment and concurs with its findings.

Team Lead, CAT, CAPEB, DHAC, ATSDR

APPENDIXES

Appendix A:

Figure 1: Washington County Lead District Site Location Map
Figure 2: Washington County Lead District Sites
Figure 3: Washington County Lead District – Potosi Site

Appendix B:

Table 1: Washington County Lead District – Potosi Site Exposure Pathways
Table 2: Calculations for Arsenic Exposure Dose

Appendix A

Figures: **Figure 1: Washington County Lead District Site Location Map**
Figure 2: Washington County Lead District Sites
Figure 3: Washington County Lead District – Potosi Site

Figure 1

Washington County Lead District Site Location Map

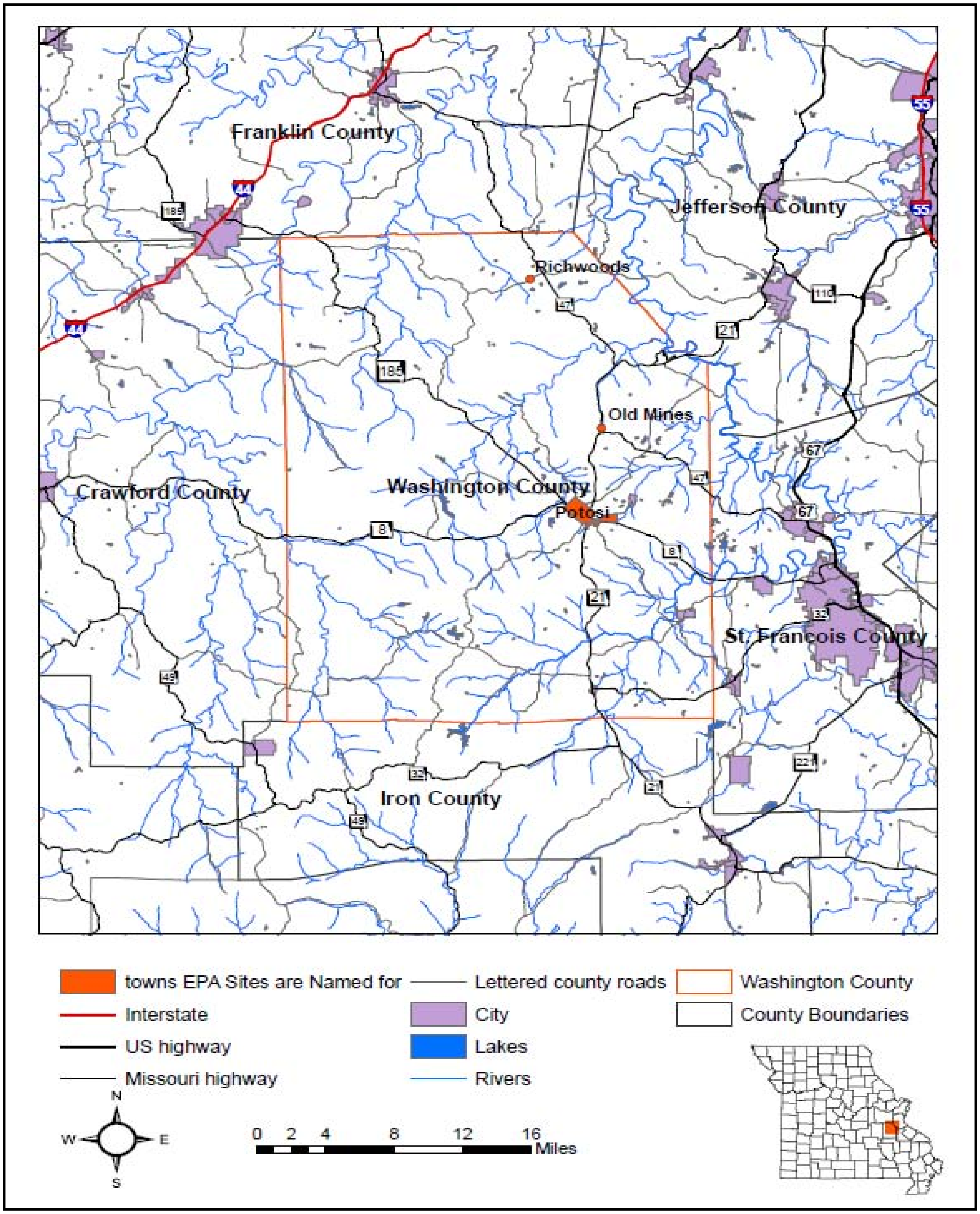
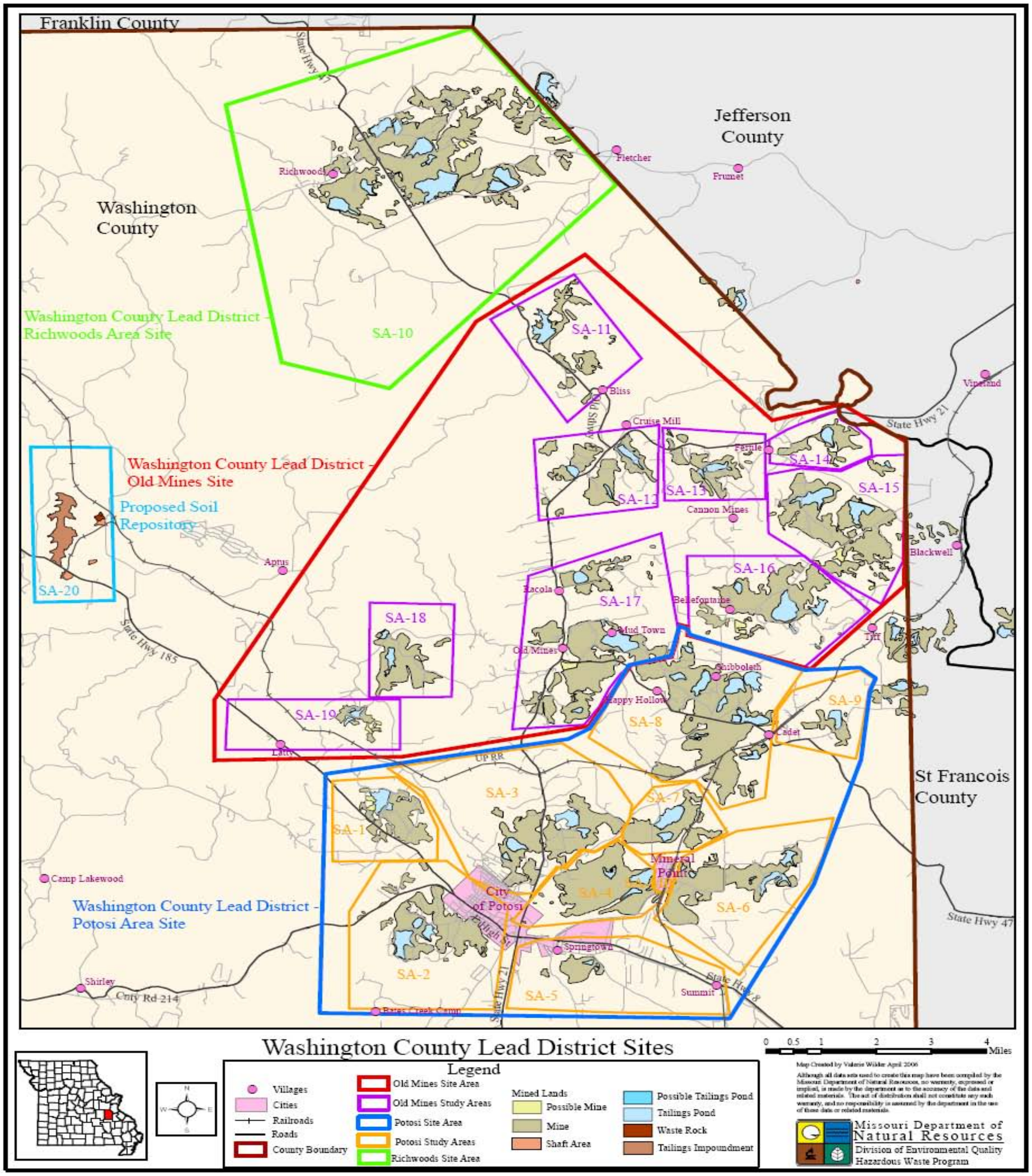


Figure 2

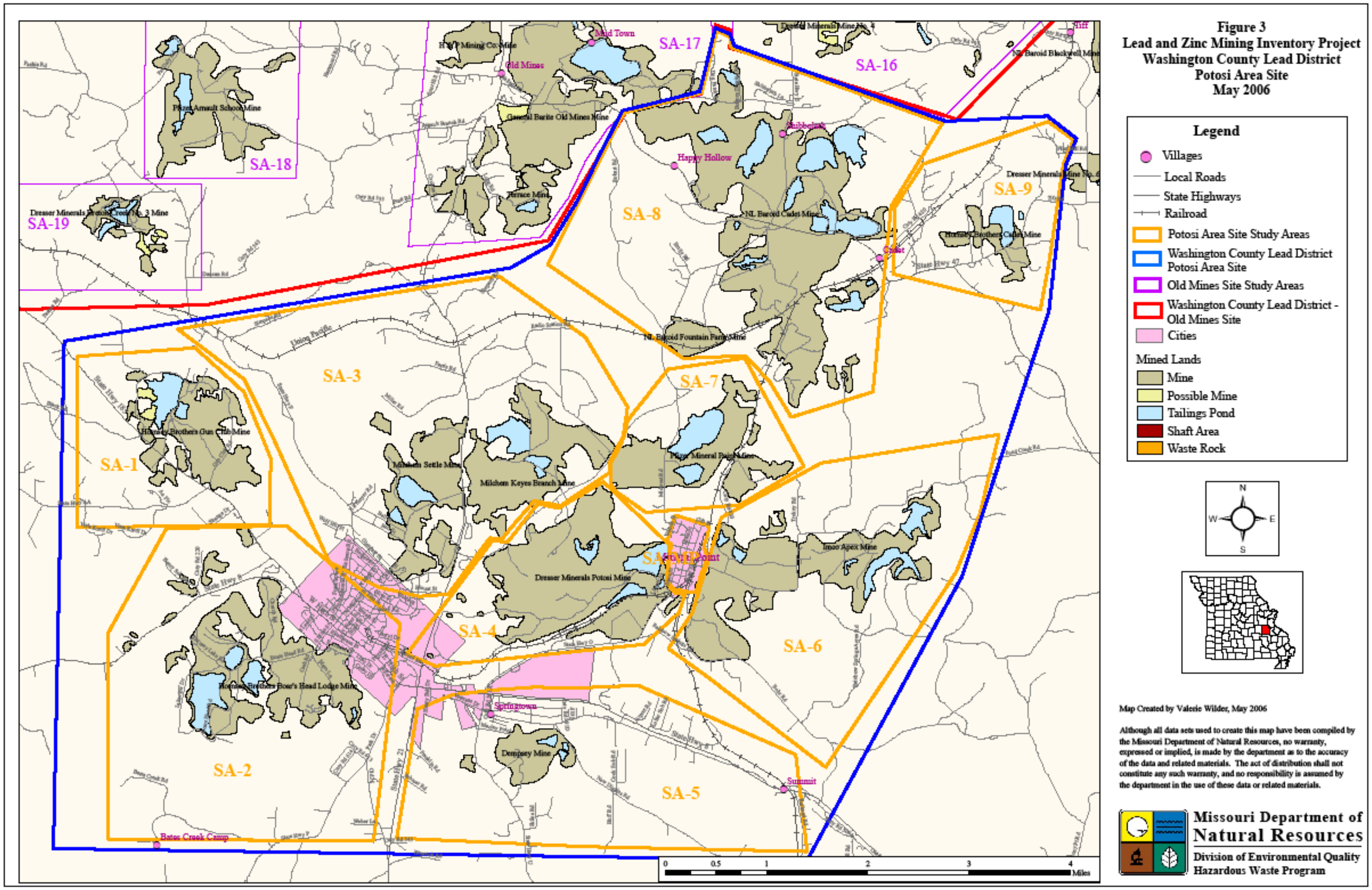
Washington County Lead District Sites



Source: Missouri Department of Natural Resources

Figure 3

Washington County Lead District –Potosi Area Site



Appendix B

Table 1

Washington County Lead District – Potosi Area Site Exposure Pathways

Table 2

**Calculations for Arsenic Exposure Dose at
Washington County Lead District – Potosi Area Site**

Table 1

Washington County Lead District – Potosi Area Site Exposure Pathways

Pathway Name	Exposure Pathways Elements					Time	Type of Pathway
	Source	**Environmental Medium**	**Point of Exposure**	**Route of Exposure**	**Receptor Population**		
Soil	Mining and Smelting Waste	Soil	Smelting and Tailings Areas, Private Yards, and Driveways	Ingestion and Inhalation	Residents, Visitors, and Transient Populations	Past, Present, and Future	Completed
Indoor Dust	Mining and Smelting Waste	Soil Dust	Inside Homes	Ingestion and Inhalation	Residents, Visitors, and Transient Populations	Past, Present, and Future	Completed
Groundwater	Mining and Smelting Waste	Groundwater	Private Drinking Wells	Ingestion	Residents, Visitors, and Transient Populations	Past, Present, and Future	Completed
Sediment	Mining and Smelting Waste	Sediment	Tailings Areas, Streams, and Ponds or Lakes	Ingestion	Residents, Visitors, and Transient Populations	Past, Present, and Future	Potential
Surface Water	Mining and Smelting Waste	Surface Water	Area Streams and Lakes	Ingestion	Stream and Lake Users	Past, Present, and Future	Potential
Fish	Mining and Smelting Waste	Fish	Locally Caught Fish	Ingestion	Individuals Eating Locally Caught Fish	Past, Present, and Future	Potential
Edible Plants	Mining and Smelting Waste	Edible Plants	Locally Grown or Gathered Plants	Ingestion	Gardeners and Individuals Eating Plants Gathered in the Area	Past, Present, and Future	Potential

Table 2

Calculations for Arsenic Exposure Dose at Washington County Lead District – Potosi Area Site

Pathway Soil Ingestion Intake Equation:

Intake $_{(Ingestion)}$ (mg/Kg/day) = Chemical concentration in soil X Conversion factor for soil X Soil ingestion Rate for child X Exposure frequency X Exposure duration for child / Body weight for child X Averaging time $_{(non\text{-}carcinogenic\ or\ carcinogenic)}$

Non-Carcinogenic:

Maximum level detected in private yards:
Intake $_{(Ingestion)}$ mg/Kg/day = 61 mg/Kg X 1.00E-6 Kg/mg X 200 mg/day X 350 day/year X 6 years / 15 Kg X 2190 =

Intake $_{(Ingestion)}$ = 0.00078 mg/Kg/day or 7.8E-04 mg/Kg/day

Average of levels detected in private yards:
Intake $_{(Ingestion)}$ mg/Kg/day = 17.26 mg/Kg X 1.00E-6 Kg/mg X 200 mg/day X 350 day/year X 6 years / 15 Kg X 2190 =

Intake $_{(Ingestion)}$ = 0.000221 mg/Kg/day or 2.21E-04 mg/Kg/day

Carcinogenic:

Maximum level detected in private yards:
Intake $_{Ingestion)}$ mg/Kg/day = 61 mg/kg X 1.00E-6 Kg/mg X 200 mg/day X 350 day/year X 6 years / 15 Kg X 25550 =

Intake $_{(Ingestion)}$ = 0.0000668 mg/Kg/day or 6.68E-05 mg/Kg/day

Average of levels detected in private yards:
Intake $_{Ingestion)}$ mg/Kg/day = 17.26 mg/kg X 1.00E-6 Kg/mg X 200 mg/day X 350 day/year X 6 years / 15 Kg X 25550 =

Intake $_{(Ingestion)}$ = 0.0000189 mg/Kg/day or 1.89E-05 mg/Kg/day

Pathway Inhalation Intake Equation:

Intake $_{\text{(inhalation)}}$ (mg/m^3/day) = Chemical Concentration in soil X (1/Particulate Emission Factor) X (Exposure Time in hours/day/24 hours/day) X Exposure Frequency X Exposure Duration for child/Averaging Time $_{\text{(non-carcinogenic or carcinogenic)}}$

Non-Carcinogenic:

Maximum level detected in private yards:
Intake $_{\text{(inhalation)}}$ mg/m^3/day = 61 mg/Kg X (1/1.36E+09 m^3/Kg) X (24 hours/day/24 hours/day) X 350 days/year X 6 years / 2190 =

Intake $_{\text{(inhalation)}}$ mg/m^3 = 0.000000043 mg/m^3/day or 4.3E-08 mg/m^3/day

Carcinogenic:

Maximum level detected in private yards:
Intake $_{\text{(inhalation)}}$ mg/m^3/day = 61 mg/Kg X (1/1.36E+09 m^3/Kg) X (24 hours/day/24 hours/day) X 350 days/year X 6 years / 25550 =

Intake $_{\text{(inhalation)}}$ mg/m^3 = 0.00000000369 mg/m^3/day or 3.69E-9 mg/m^3/day