Health Consultation

ARSENIC IN SOIL IN EAST OMAHA, NEBRASKA

MARCH 20, 2007

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333

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

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

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HEALTH CONSULTATION

ARSENIC IN SOIL IN EAST OMAHA, NEBRASKA

Prepared By:

Site and Radiological Assessment Branch
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry

Health Consultation

Arsenic in Soil in East Omaha, Nebraska

Overview of Arsenic in Soil in East Omaha, Nebraska

Introduction

This health consultation describes the public health significance of arsenic in soil in east Omaha, Nebraska. The report is being released by the Agency for Toxic Substances and Disease Registry, a federal health agency.

ATSDR works with the U. S. Environmental Protection Agency (EPA) to investigate hazardous waste sites throughout the United States. While reviewing soil data for the Omaha Lead Site, ATSDR discovered elevated arsenic levels at some properties.

Table of Contents

This health consultation contains the following sections:

Statement of Issues

ATSDR

The Agency for Toxic Substances and Disease Registry (ATSDR) is a federal health agency in Atlanta, Georgia, with 10 regional offices. ATSDR's regional office in Kansas City, Kansas, includes Nebraska.

Issues addressed

The purpose of this health consultation is to decide whether arsenic levels in soil in east Omaha are a public health hazard for adults and children.

Background

Overview of Background

Introduction

The Background section of this health consultation provides information about the site, including background arsenic levels in soil and the source of arsenic. The section also provides demographic information about people who live in eastern Omaha.

Contents

The background section contains the following topics:

The Site Investigation Area

Site boundaries

The area investigated includes residences, childcare facilities, schools, and other noncommercial/nonindustrial properties in the eastern portion of the City of Omaha, Douglas County, Nebraska. Some properties in this area were contaminated with lead from multiple sources, including air emissions from a lead refining operation.

The area investigated extends roughly from State Street to the north, Harrison Street to the south, 52nd Street to the west, and the Missouri River to the east. The area does not, however, include the central business district. A few properties outside the area also have been sampled.

This health consultation refers to the area as the State Street, Harrison Street, and 52nd Street Site (SH52 Site). Figure A-1 (Appendix A) identifies the area investigated.

Soil sampling history

In March 1999, the EPA began collecting soil samples from residential properties in Omaha to characterize the extent of contamination and to prioritize clean-up activities for the Omaha Lead Site. Soil sampling before 1999 also was conducted by the Douglas County Health Department, the EPA, and other interested parties.

Initially, the EPA tested soil samples for lead because lead was associated with emissions from ASARCO, a nearby smelter. Lead levels in soil were determined using a portable instrument called an x-ray fluorescence (XRF) detector. Because the XRF instrument also could measure other metals in soil at the same time it measured for lead, the concentration of arsenic and other metals was also determined.

From 1999 to the summer of 2005, the EPA tested about 26,800 properties for lead. Of these, almost 25,900 properties were also tested for arsenic. A review of the validity of the arsenic data is contained in Appendix B.

Continued on next page

The Site Investigation Area, Continued

Clean-up activities at the Omaha Lead Site

As part of EPA's Superfund activities for the Omaha Lead Site, EPA has removed contaminated soil from properties in the area since 1999. The first cleanups were conducted at daycare centers and certain residences meeting these criteria:

1. Daycare centers with lead levels in soil exceeding 400 parts of lead per million parts of soil (or 400 ppm), or
2. Residential properties with average lead levels in soil exceeding 400 ppm, if a child 6 years and younger lives at the residence, and if that child's blood lead levels exceed 15 micrograms lead per deciliter of blood.

EPA continues to remediate soils from residential properties and in 2006 was removing soils where soil lead levels exceeded 800 ppm. EPA will determine a final action level for lead when the agency releases a final Record of Decision for the Omaha Lead Site.

Arsenic Background Levels

Background arsenic levels in soil

EPA determined the background level of arsenic in soil by collecting 27 soil samples from neighborhoods 8 miles north of the ASARCO lead refining facility. Arsenic levels in these samples ranged from 3.1 to 10.8 ppm, and the average arsenic level was 7.2 ppm (EPA 2000).

A statistical analysis of the data shows that:

- 95% of arsenic levels from uncontaminated areas should be less than 11.5 ppm arsenic,
- 99% of arsenic levels from uncontaminated areas should be less than 13.7 ppm.

Stated another way, the average arsenic level in uncontaminated soil is about 7 ppm, with the highest arsenic levels from uncontaminated soil rarely exceeding 11 to 14 ppm.

Arsenic Levels in Soil Measured by XRF

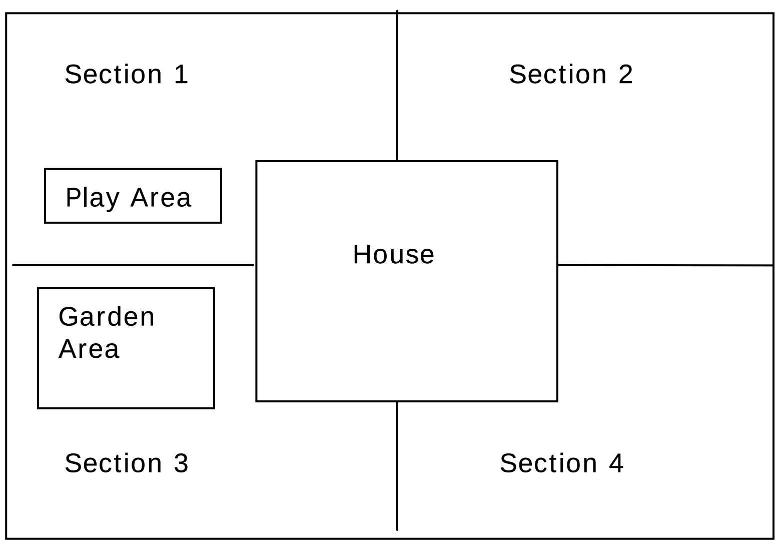
Sample design for individual property testing

In Omaha, EPA tested almost 25,900 properties for arsenic.

From most properties, up to four composite soil samples were collected by dividing the property into four sections or quadrants. The composite soil sample for each section was created by collecting five different soil samples from the section and mixing them together. Therefore, each property could have several composite soil samples, depending upon the number of sections into which the property was divided. Most properties had four composite samples, two from the front yard and two from the back yard. EPA also collected discrete soil samples from gardens, from near the home's drip line, and from play areas.

Diagram 1 shows a typical sample design for a residential property.

Diagram 1



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Arsenic Levels in Soil Measured by XRF, Continued

Number of properties with elevated arsenic

In east Omaha, 777 properties currently have average arsenic levels in soil above 70 ppm. The property with the highest average arsenic level contained 1,184 ppm arsenic. At this property, arsenic levels in various sections were 735 ppm (front yard, section 1), 560 ppm (front yard, section 2), 110 ppm (back yard, section 3), and 3,330 ppm (back yard, section 4).

Table 1 shows the current number of properties for various arsenic levels in soil. For example, 319 properties have yard-wide average arsenic levels in soil between 100 to 199 ppm. In east Omaha, about 3% of the properties (or 3 in every 100 properties) have average arsenic levels above 70 ppm.

Figure A-2 in Appendix A shows the distribution of properties in the study area that have average arsenic levels above 70 ppm. No obvious pattern is present, which indicates that properties with high levels of arsenic in soil are randomly distributed throughout east Omaha neighborhoods.

As part of their clean-up activities for the Omaha Lead Site, the EPA has removed contaminated soil from over 1,355 properties in east Omaha. Of those lead-remediated properties, 39 had average soil arsenic levels above 70 ppm, leaving 777 properties currently with average soil arsenic levels above 70 ppm.

In addition to residential properties, 10 daycare centers currently have average arsenic levels above 70 ppm. The highest average soil arsenic level at a daycare center is 251 ppm.

Maximum Arsenic Levels in Soil

Because EPA collected composite soil samples, the maximum concentration of arsenic in soil is not known with certainty. However, studies at a similar site in Denver, Colorado (i.e., the Vasquez Blvd and I-70 Site), showed that maximum arsenic levels are five to six times greater than average levels (ATSDR 2005a).

This means that for a yard with an average arsenic level of 1,000 ppm arsenic, certain parts of the yard may have as much as 5,000 to 6,000 ppm arsenic in soil. A child with soil pica behavior who eats soil from a highly contaminated part of the yard will have a much higher exposure to arsenic and be at greater risk of harmful effects.

The source of arsenic in highly contaminated yards probably resulted from the application of an arsenic-containing weed killer. The areas of the yard with higher arsenic levels in soil probably resulted higher application of the weed killer in these areas.

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Arsenic Levels in Soil Measured by XRF, Continued

Table 1. Number of Current Properties at Different Arsenic Concentrations

Average Arsenic Concentration in ppm	*Number of Properties Currently with Elevated Arsenic in Soil*
greater than 2,000	0
1000 to 1,999	1
900 to 999	1
800 to 899	1
700 to 799	1
600 to 699	1
500 to 599	1
400 to 499	9
300 to 399	22
200 to 299	64
100 to 199	319
70 to 99	357
Total	777

Arsenic Source

EPA's report regarding the arsenic source

In the Remedial Investigation for the Omaha Lead Site (in Appendix D), EPA states the following :

- The source of high arsenic levels in residential yards is not fallout from an industrial source.
- Most soil samples have small amounts of arsenic that resulted from atmospheric fallout, probably from the ASARCO refinery.

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Arsenic Source, Continued

EPA's report regarding the arsenic source (continued)

EPA states that arsenic contamination from the refinery does not raise total arsenic levels above 20 ppm in residential soils (EPA 2004). EPA considers properties with high levels of arsenic in soil to be unrelated to the Omaha Lead Site.

Three soil samples were analyzed by the University of Colorado Laboratory for Environmental and Geological Studies. Their report concludes that arsenic from these three soil samples most likely originated from an arsenic-containing pesticide (EPA 2004). EPA's investigations into the source of arsenic and the type of arsenic present in eastern Omaha can be found at this EPA Web site:
http://www.epa.gov/Region7/cleanup/superfund/sites/omaha_ne_lead_RI.pdf

Demographic Information

East Omaha: demographic information

Eastern Omaha is a racially diverse community made up of whites (62%), African-Americans (25%), Asians (1%), American Indians (1%), and other or multiple races (11%).

In this community, 17% of the residents in the various racial groups identify as Hispanic.[1] Table 2 shows detailed demographic information.

Number of children per household

Demographic information shows that about one of every 4 households in east Omaha includes a preschool child. This information is used to estimate the number of preschool children who eat dirt, which is also known as soil pica behavior. The Discussion section of this health consultation has more information about soil pica behavior.

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1 The designation "Hispanic" in the census is a cultural and not a racial category; therefore, the percentage of Hispanic residents cannot be compared to other racial percentages.

Demographic Information, Continued

Table 2. Demographic information for the SH52 Site in Eastern Omaha

Population Parameter	***# People***
Total	158,360
Whites	98,594
African-American	38,819
Asian	2,140
American Indian/Alaskan Native	1,739
Native Hawaiian/Other Pacific Islander	121
Other Races	12,734
Multiple Races	4,213
Children 6 Years and Younger	17,515
Hispanic Origin	22,817
Total Housing Units	66,538

Discussion

Overview of Discussion

Introduction

The Discussion section of the report describes

- How people become exposed to arsenic in soil,
- How to estimate people's exposure, and
- The possible health effects from exposure to arsenic in soil.

Contents

This section contains the following topics:

Exposure to Arsenic in Soil

How exposure occurs to arsenic in soil

Children and adults can be exposed to arsenic in soil by accidentally swallowing small amounts of soil that cling to their hands when they put their hands in their mouths. This exposure is greatest for preschool children because of their frequent hand-to-mouth activity. When arsenic-contaminated soil is tracked indoors, people can also be exposed to arsenic by ingesting arsenic-contaminated dust that clings to their hands.

Preschool children, on average, swallow more soil and dust than people in any other age group. This is because some preschoolers often have close contact with soil and dust when they play, and because they tend to engage frequently in hand-to-mouth activity.

The amount of soil that people ingest daily is somewhere between 30 milligrams to 200 milligrams (ATSDR 2005a; EPA 1997; Calabrese 1997). To put this amount in perspective, it is approximately equal to a pinch (or less than $^{1}/32$ teaspoon) to $^{1}/8$ teaspoon of soil

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Exposure to Arsenic in Soil, Continued

An overview of arsenic absorption

As described previously, one way exposure to arsenic in soil occurs is from ingesting contaminated soil that clings to people's hands. Not all the arsenic that is swallowed, however, actually gets into the body—some arsenic will pass through the digestive system without being absorbed. For example, some arsenic is bound so tightly to soil particles it is less likely to be absorbed by the lining of the intestinal tract (the gut) than is arsenic bound loosely to soil particles. This process of how much arsenic actually crosses the gut and gets into the body is known as bioavailability.

For example, if only half of the arsenic in soil is capable of passing from the gut and into someone's body, the soil arsenic is referred to as being 50 percent bioavailable.

The bioavailability of arsenic in soil varies depending upon the source of arsenic (e.g., smelters, mines, pesticide application). Studies have shown soil arsenic bioavailability to range from nonbioavailable to 78% (Roberts 2002; Casteel 1997; Casteel 2001; Freeman 1993; Freeman 1995; Lorenzana 1996).

Several of these studies investigated soil contaminated with an arsenic-based herbicide or pesticide. One group of scientists tested a soil sample from two locations in Florida. Using groups of five monkeys as test subjects to determine arsenic absorption, the arsenic in one soil sample had an average relative bioavailability of 10.7% and a standard deviation of 4.9% while the other soil sample had an average relative bioavailability of 17% and a standard deviation of 10% (Roberts 2002). Because only one soil sample was tested from each location and because the standard deviation is large, some uncertainty exists in the reported relative bioavailability of 10.7% and 17% for these two locations.

EPA studied arsenic bioavailability in residential soil from the Vasquez Boulevard and I-70 (VBI70) Site in Denver, Colorado. Arsenic levels in soil at the VBI70 site are very similar to arsenic levels in soil at the SH52 Site. Properties with high levels of arsenic are randomly distributed in residential neighborhoods, and the predominant form of arsenic is arsenic trioxide, a form typically found in arsenic-based pesticides. Using weanling pigs, EPA tested five composite soil samples from several residential neighborhoods in the VBI70 study area and reported the following relative bioavailability for arsenic: 18%, 18%, 23%, 37%, 37%, and 43%. Using a statistical method, EPA estimated the 95^{th} upper confidence limit of the average relative bioavailability to be 42% (Casteel 2001; EPA 2001). In other words, the average relative bioavailability for soils from the VBI70 site is not likely to exceed 42%.

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Exposure to Arsenic in Soil, Continued

Uncertainty in arsenic absorption

Some uncertainty exists in estimating relative bioavailability for arsenic from the VBI70 site for several reasons. First, only six soil samples were tested in pigs and second not all of the arsenic that was administered to the pigs was accounted for in their urine and feces.

Arsenic bioavialability in East Omaha

Because the types of arsenic at the VBI70 Site and at the SH52 Site are similar, ATSDR chose a relative bioavailability ranging from 40% to 60% for arsenic in soil.

Other factors affecting arsenic exposure

Other factors are also important in estimating the dose of arsenic, including

- the concentration of arsenic in soil,
- how much soil is ingested,
- how frequently someone ingests soil, and
- a person's weight.

How to estimate arsenic exposure

The following equation estimates the amount of arsenic a person absorbs from ingesting arsenic-contaminated soil

Arsenic Dose =

$$\frac{\text{(arsenic concentration in soil)(milligrams soil ingested)(\% absorption)(0.000001 kg/mg)}}{\text{Body weight in kg}}$$

Variation in arsenic dose

A range of doses is possible because different values can be used for various parameters in the equation. For example, the amount of soil ingested varies from 30 mg for most children, to 200 mg for a small percentage of children, and to 5,000 mg for children with soil pica behavior (ATSDR 2005a; ATSDR 2001; Calabrese 1997). Weight can also vary from 10 kg for a 1-year-old child, to 35 kg for elementary age children, and to 70 kg for an adult. In addition, arsenic bioavailability is probably somewhere between 40% and 60%.

Therefore, because of differences in weight, soil intake, and bioavailability, the estimated dose of arsenic can vary for each age group.

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Exposure to Arsenic in Soil, Continued

Comparison of dose to health guidelines

To determine whether harmful effects might be possible from ingesting arsenic-contaminated soil, ATSDR compares the estimated amount of arsenic exposure (or dose) to the Agency's "health guidelines" dose for arsenic.

For arsenic, ATSDR's oral Minimal Risk Levels (MRLs) are available for acute exposures (exposures less than 2 weeks) and for chronic exposures (exposures greater than 1 year).

Health guideline for brief exposures

A Minimal Risk Level is a dose below which noncancerous harmful effects are not expected.[2] In the case of arsenic, ATSDR has developed a provisional acute oral MRL of 0.005 mg/kg/day.[3] The acute dose of 0.005 mg/kg/day means 0.005 milligrams of arsenic per kilogram body weight per day. When someone's estimated dose is below 0.005 mg/kg/day for short periods (e.g., one to two weeks), then non-cancerous harmful effects are unlikely.

The provisional acute oral MRL was derived from a human poisoning episode that showed several transient (i.e., temporary) effects at an estimated dose of 0.05 mg/kg/day. The transient effects observed included nausea, vomiting, abdominal pain, and diarrhea (Mizuta 1956). The acute effect level of 0.05 mg/kg/day identified in the Mizuta investigation is supported by another study (Franzblau 1989).

It is important to note about the acute oral MRL that

- The acute oral MRL is 10 times below the levels thought to cause harmful effects in humans.
- The acute oral MRL is based on people being exposed to arsenic dissolved in water instead of arsenic in soil, a fact that might influence how toxic arsenic in soil is.
- The acute oral MRL applies to exposures less than 2 weeks.

The acute oral MRL applies to non-cancerous effects only; it is not used to determine whether people could develop cancer (ATSDR 2000).

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2 It is important to remember that MRLs cannot be used to determine the risk of cancer.

3 The acute oral MRL is provisional because the harmful effect is based on a serious health effect instead of the customary less serious health effect. ATSDR developed the provisional MRL for arsenic specifically to give health professionals guidance in evaluating acute exposures of less than 14 days.

Exposure to Arsenic in Soil, Continued

Health guideline for long-term exposures

A similar comparison is made to evaluate whether long-term exposure to arsenic might cause non-cancerous harmful effects. In this case, the estimated dose of arsenic over long periods is compared with ATSDR's chronic oral MRL of 0.0003 mg/kg/day.

Estimating Exposure and Determining Possible Health Effects in Children

How soil pica behavior affects arsenic exposure

Children with soil pica behavior have the highest amount of exposure to arsenic in soil because they ingest the largest amounts of soil. Table 3 shows a representative sample of average arsenic levels in residential properties in eastern Omaha along with the estimated absorbed dose of arsenic in children with soil pica behavior.

The estimated absorbed dose of arsenic in children with soil pica behavior can be compared with ATSDR's health guideline for acute (short-term) exposures of 0.005 mg/kg/day. When this guideline is exceeded, a concern might exist for harmful effects and further evaluation is needed.

A representative soil pica example

For example, if preschool children with soil pica behavior live at the property with the highest average arsenic concentration, their estimated absorbed dose of 0.1 mg/kg/day not only exceeds ATSDR's provisional acute oral MRL for arsenic of 0.005 mg/kg/day but also exceeds the estimated level of 0.05 mg/kg/day—a level that causes harmful effects in humans. These children are at risk of harmful effects from arsenic in soil.

Soil arsenic levels and child health concerns

If preschool children with soil-pica behavior live at a property where the average arsenic level is 70 ppm, their estimated dose is 0.005 mg/kg/day if they practice soil-pica behavior three times during the week. Of the properties tested, 777 have average arsenic levels above 70 ppm (see Table 1).

Children with soil pica behavior who live at properties with average arsenic levels greater than 70 ppm are also at risk of harmful effects from arsenic, and this risk increases as the average arsenic level increases. The property with the highest average arsenic level was 1,184 ppm.

Estimating Exposure and Determining Possible Health Effects in Children, Continued

Table 3. Estimated Absorbed Doses in Preschool Children with Soil Pica Behavior

Average Arsenic Concentration in Soil in ppm	***Estimated Absorbed Dose in Children with Soil pica Behavior Ingesting 5,000 mg soil Dose in mg/kg/day***	***Provisional Acute Oral MRL in mg/kg/day***	***Exceeds Health Guideline***
1,184	0.1 to 0.14	0.005	yes
1,000	0.08 to 0.12	0.005	yes
900	0.073 to 0.1	0.005	yes
800	0.065 to 0.09	0.005	yes
700	0.057 to 0.08	0.005	yes
600	0.05 to 0.07	0.005	yes
500	0.044 to 0.058	0.005	yes
450	0.036 to 0.047	0.005	yes
350	0.028 to 0.04	0.005	yes
300	0.025 to 0.035	0.005	yes
250	0.02 to 0.029	0.005	yes
200	0.016 to 0.023	0.005	yes
150	0.01 to 0.017	0.005	yes
100	0.008 to 0.01	0.005	yes
70	0.006 to 0.008	0.005	yes
50	0.004 to 0.005	0.005	no

Possible harmful effects for children with soil pica

The most likely health effects that might occur from eating arsenic-contaminated soils include

- nausea
- stomach cramps
- vomiting
- diarrhea
- headaches
- facial swelling, especially around the eyes

The symptoms are temporary and should subside when exposure to arsenic ceases.

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Estimating Exposure and Determining Possible Health Effects in Children, Continued

Assumptions for children with soil pica

The estimated doses in children with soil pica behavior were derived using the following assumptions:

- 5,000 mg of soil ingested (about 1 teaspoon),
- a one-time soil pica event,
- a soil pica frequency of 3 days per week,
- 40 to 60% arsenic bioavailability, and
- an 11-kg (24-pound) child.

Variations in soil pica dose estimations

It is important to remember that the estimated dose in children can vary depending upon how much soil they eat, how much arsenic crosses the gut, how much they weigh, and how frequently they eat dirt.

Uncertainty about health effects from soil pica

Some uncertainty exists in deciding whether adverse health effects might occur in children. This uncertainty exists in two areas: estimating how much arsenic children are exposed to (i.e., the dose) and determining the possible health effects. The uncertainty that exists in estimating the dose for soil-pica children comes from

- estimating the amount of dirt that children with soil pica behavior eat,
- variations in how often children exhibit soil-pica behavior, and
- whether children eat dirt from areas of the yard with low or high levels of arsenic in soil.

Therefore, a child with soil-pica behavior who lives at a property with arsenic-contaminated soil might not get sick if that child eats soil from an area in the yard with low arsenic levels, or if that child eats only a small amount of soil, and the amount of arsenic exposure is below ATSDR's acute oral MRL for arsenic.

Conversely, children with soil-pica behavior might be at greater risk if they eat dirt from a part of the yard that is more heavily contaminated.

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Estimating Exposure and Determining Possible Health Effects in Children, Continued

Clean up of lead-contaminated properties in East Omaha

It should be pointed out that some arsenic-contaminated yards in Omaha also contain unsafe levels of lead, and that these yards were or will be remediated as part of the Omaha Lead Site. About 36 properties cleaned up because of high levels of lead in soil also had average arsenic levels that exceeded 70 ppm.

Nevertheless, some yards contain elevated levels of arsenic but have low levels of lead in soil. These yards will not be cleaned up as part of EPA's activities for the Omaha Lead Site.

Number of children at risk in East Omaha

As stated, using 2000 census data for eastern Omaha, a preschool child lives in 1 out every 4 households.[4] Therefore, of the 777 properties where average arsenic levels in soil are above 70 ppm, about 200 preschool children are present. Because somewhere between 4% and 20% of preschool children will have soil pica behavior during their preschool years, about 10 to 40 preschool children with soil pica behavior live at properties with average arsenic levels exceeding 70 ppm Barltrop 1966, Robischon 1971, Sheelshear 1975, Vermeer and Frate 1979). As mentioned previously, soil pica behavior is most likely to occur in 1- and 2-year-old children and occurs less frequently in older preschool children.

Possible harmful effects in children with typical soil intake

It is also possible to estimate the absorbed dose of arsenic in children with typical soil ingestion (e.g., 30 mg/day to 200 mg/day or a pinch to $^{1}/_{8}$ teaspoon) (ATSDR 2005a; EPA 1997; Calabrese 1997). These estimated doses are shown in Table 4.

Children who typically ingest 30 mg of soil daily have estimated absorbed doses below ATSDR's provisional acute oral MRL of 0.005 mg/kg/day. Those children with average soil intake are not at risk of harmful effects from exposure to arsenic in soil, even at the most contaminated properties.

Continued on next page

4 The precise number is 0.263 preschool children per household based on an estimated 17,515 preschool children and 66,538 households in the area investigated shown in Figure A-1.

Estimating Exposure and Determining Possible Health Effects in Children, Continued

Possible harmful effects in children with typical soil intake (continued)

Children who ingest 200 mg soil daily and who live at the most contaminated properties (e.g., the property with average arsenic levels above 800 ppm) have an estimated absorbed dose slightly above ATSDR's provisional acute oral MRL of 0.005 mg/kg/day. These children have a small risk of experiencing nausea, stomach cramps, vomiting, diarrhea, facial swelling, and headaches.

Children with typical soil ingestion who live at properties where average arsenic levels in soil are below 1,000 ppm are not likely to experience harmful effects from arsenic.

Variations in exposure

Like the estimated doses in children with soil pica behavior, the estimated doses in children with typical soil intake will vary depending upon the bioavailability of arsenic in soil, their weight, and how much soil they ingest.

Table 4. Estimated Absorbed Doses in Preschool Children with Typical Soil Ingestion

Average Arsenic Concentration in Soil in ppm	*Estimated Absorbed Dose in Preschool Children Ingesting 30 mg Soil Daily in mg/kg/day*[5]	*Exceeds ATSDR's Provisional Acute Oral MRL of 0.005 mg/kg/day*	*Estimated Absorbed Dose in Preschool Children Ingesting 200 mg Soil Daily in mg/kg/day*[6]	*Exceeds ATSDR's Provisional Acute Oral MRL of 0.005 mg/kg/day*
1,184	0.0009 to 0.0013	no	0.006 to 0.009	yes
900	0.0007 to 0.001	no	0.0046 to 0.0065	yes
800	0.00061 to 0.00087	no	0.0004 to 0.0058	yes
700	0.0005 to 0.0008	no	0.0035 to 0.004	no
70	0.00008 to 0.00012	no	0.0004 to	no

5 To estimate the absorbed dose of arsenic, ATSDR used 30 mg or 200 mg of soil ingested, a daily exposure, a body weight of 16 kg, and either 40 or 60% bioavailability.

6 To estimate the absorbed dose of arsenic, ATSDR used 30 mg or 200 mg of soil ingested, daily exposure, a body weight of 16 kg, and either 40 or 60% bioavailability.

Estimating Arsenic Exposure and Determining Possible Health Effects in Adults

Assumptions for estimating absorbed arsenic dose in adults

As previously mentioned, adults also swallow small amounts of soil that cling to their hands while outdoors working, playing, and gardening. To estimate the absorbed arsenic dose in adults, ATSDR assumes that 40 to 60% of ingested arsenic crosses the gut, that adults ingest 50 mg of soil each day, and weigh 70 kg (about 155 pounds).

The estimated absorbed dose of arsenic for adults at various arsenic concentrations in soil is shown in Table 5.

Comparison of absorbed dose to health guidelines

The estimated absorbed dose of arsenic in adults from soil ingestion at all properties in east Omaha is below ATSDR's provisional acute oral MRL of 0.005 mg/kg/day.

The estimated absorbed dose of arsenic in adults also is below ATSDR's chronic oral MRL of 0.0003 mg/kg/day for all properties except for the few properties where the average arsenic level exceeds 800 ppm. At these properties, the estimated absorbed dose of arsenic ranges from 0.00037 mg/kg/day to 0.0005 mg/kg/day, thus slightly exceeding ATSDR's chronic oral MRL of 0.0003 mg/kg/day.

A long-term human study on a large population has shown that a dose of 0.014 mg/kg/day will damage the skin, causing conditions known as hyperkeratosis and hyperpigmentation.[7] The same study showed that a dose of 0.0008 mg/kg/day will not damage the skin (Tseng et al. 1968).

Because the estimated doses for adults who live at the most contaminated properties is significantly below the no-effect level in humans of 0.0008 mg/kg/day, harmful skin effects in adults who live at these properties are not likely.

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7 Arsenic-induced hyperkeratosis is a skin condition found most often on the feet and palms. Many small depressions occur in the skin with small, hard outgrowths of skin in the center of each depression. Hyperkeratosis can also appear as scaling skin. Hyperpigmentation of the skin occurs as small brown areas or blotches on the skin around the eyelids, temples, neck, nipples, and groin. In severe cases, pigmentation may cover the chest, back, and stomach. It sometimes appears as mottling on the skin and has been described as looking like raindrops. If mottling occurs, it is more frequent on the chest, back, and stomach.

Estimating Arsenic Exposure and Determining Possible Health Effects in Adults, Continued

Table 5. Estimated Absorbed Doses in Adults

Average Arsenic Concentration in Soil in ppm	***Estimated Absorbed Dose in Adults in mg/kg/day[8]***	***Chronic Oral MRL in mg/kg/day***	***Exceeds Health Guideline***
1,184	0.0004 to 0.0005	0.0003	yes
900	0.00026 to 0.0004	0.0003	yes
800	0.00023 to 0.00037	0.0003	yes
700	0.0002 to 0.0003	0.0003	no
600	0.00019 to 0.00028	0.0003	no
70	0.00002 to 0.00003	0.0003	no

Background information on arsenic and cancer

According to EPA and the U.S. Department of Health and Human Services, arsenic is known to cause cancer in people. This conclusion is based on convincing evidence from many studies of people who were exposed to either arsenic-contaminated drinking water, to arsenical medications, or to arsenic-contaminated air in the workplace (ATSDR 2000).

Of the different types of cancer from oral exposure, skin cancer—namely, squamous cell carcinoma and basal cell carcinoma—and other types of cancer, including cancer of the lungs, bladder, kidney, and liver, are a concern.

EPA's method for estimating the risk of cancer from arsenic

One way to evaluate the cancer-causing potential from arsenic in soil is to estimate the average amount of arsenic-contaminated soil that people ingest over many years and use mathematical equations to estimate a theoretical increase in cancer risk. EPA typically uses this approach to estimate a potential increased risk of cancer from estimated exposure doses.

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8 To estimate the absorbed dose of arsenic in adults, ATSDR assumed 50 mg of soil ingested daily, 40 to 60% bioavailability, and 70-kg body weight.

Estimating Arsenic Exposure and Determining Possible Health Effects in Adults, Continued

Cancer risk from arsenic in soil

A key parameter in estimating cancer risk is the cancer slope factor, which, for arsenic, was derived from arsenic exposures via drinking water and skin cancer cases reported in a Taiwanese study (Tseng et al. 1968; ATSDR 2000.)

Using the estimated dose from soil ingestion for adults over 30 years, the mathematical model suggests that an increased risk of cancer might exist for long-time residents at some of the properties in Omaha.

For example, for adults who live at a property with an average soil arsenic concentration of 100 ppm, the model predicts an increased risk of zero to two extra cases of cancer for every 100,000 adults who ingest soil over a 30-year period. For the property with the highest average arsenic levels (i.e., 1,184 ppm), an increased risk of zero to three extra cases of cancer for every 10,000 people is predicted.

Uncertainty in assessing arsenic's cancer risk

ATSDR notes also that for several reasons, some uncertainty surrounds the mathematical estimate of cancer risk:

The mathematical model is based on cancers observed at certain exposure levels to arsenic. The model then assumes that cancers will occur at lower levels of exposure, even though this has not been supported or rejected by actual studies. It is possible, but again not proven, that the human body can eliminate arsenic at low exposure levels before arsenic has a cancer causing effect. If this is true, the mathematical model would overestimate the theoretical risk of cancer.

- The mathematical model, at least for arsenic, is based on key information from the Taiwan study. Some of this information is somewhat uncertain because the exposure doses for this population were estimated rather than measured. In addition, the people in the Taiwan study might have been exposed to arsenic via pathways other than drinking contaminated water. If true, this would bias the key input to the mathematical model and would overestimate cancer risk.
- Some researchers have suggested that the cancer incidence observed in the Taiwan study does not apply to U.S. residents due to nutritional differences between these populations (ATSDR 2000).

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Estimating Arsenic Exposure and Determining Possible Health Effects in Adults, Continued

Uncertainty in assessing arsenic's cancer risk (continued)

- Soil ingestion might be less in winter when people spend more time indoors compared to summer when people tend to spend more time outdoors.

In addition to the uncertainties listed above, some scientists believe that the mathematical model is inherently flawed. Specifically, they believe that exposures to small amounts of arsenic are safe if they are lower than a "threshold dose" for cancer. These scientists suggest that exposure to small amounts of arsenic might not cause cancer (Stöhrer 1991; Abernathy et al. 1996).

National Research Council review of arsenic and cancer

In support of the cancer-causing potential for arsenic in the environment, the National Research Council recently concluded that little evidence supports a threshold for arsenic carcinogenesis. The Council also stated that nutritional status and arsenic exposure from other sources in the Taiwanese studies would have only modest impact on cancer risk estimates derived from using the Taiwanese data. In that regard, it should also be noted that cancer studies from other countries, such as Chile, India, and Bangladesh, support the cancer estimates derived from the Taiwanese studies. Still, EPA's science advisory board is reevaluating several scientific issues concerning arsenic's carcinogenicity in humans.

Health Outcome Data

Health Outcome Data for East Omaha

Introduction

As mentioned previously, human studies consistently have shown increased rates of skin cancer from exposure to arsenic. The specific skin cancers include squamous cell carcinoma and basal cell carcinoma of the skin. Other cancers of concern include lung, bladder, kidney, and liver.

ATSDR report on cancer rates in East Omaha

In July 2005, ATSDR released a public health consultation comparing certain cancer rates in east Omaha to cancer rates in Douglas County and the state of Nebraska. Compared with the residents of Douglas County or with Nebraska as a whole, residents of east Omaha had a modestly increased rate of lung, kidney, and stomach cancer, but did not show an increase in bladder cancer. The Nebraska cancer registry does not collect information about squamous cell carcinoma and basal cell carcinoma of the skin, so rates of these cancers cannot be examined.

Conclusion

Even though certain cancers consistent with arsenic exposure are increased, such as lung and kidney cancers, it is not possible to conclude that arsenic exposure caused these malignancies. Information about other factors that are also related to cancer, such as smoking, nutrition, and occupation, are not available on those individuals in east Omaha who were diagnosed with cancers and who were included in the analysis. Smoking, nutrition, and occupational exposure may explain the differences in cancer rates between east Omaha, Douglas County, and Nebraska as a whole. In particular, the modest increase in lung cancers might be due to smoking and tobacco use, which account for 85% of all lung cancers. Therefore, it is not possible to determine whether these other factors increased the rate of certain cancers or whether exposure to arsenic increased the rate (ATSDR 2005b).

Limitations of this health consultation

Other factors that could not be evaluated included the length of time individuals diagnosed with cancer lived in east Omaha. If someone developed cancer shortly after moving to east Omaha, his or her cancer probably did not result from exposure to arsenic in soil. Similarly, if someone moved away from east Omaha and developed cancer, his or her contribution to cancer rates in east Omaha would be omitted. The full report can be found at this ATSDR Web site: http://www.atsdr.cdc.gov/HAC/PHA/OmahaCancer/OmahaCancerHC070805.pdf.

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Health Outcome Data for East Omaha, Continued

Limitations of this health consultation (continued)

It is also important to realize that relatively few properties in east Omaha have high levels of arsenic in soil, and these properties are scattered randomly over seven zip codes. Only 3% of the properties tested had significantly elevated levels of arsenic in soil. Thus the number of people possibly exposed to high levels of arsenic in soil is too few to affect east Omaha cancer rates.

Child Health Considerations

Child Health Considerations for East Omaha

The concern for children

ATSDR recognizes the unique vulnerabilities of children from exposure to contaminants in their environment. Children are at greater risk than are adults from certain kinds of exposures to hazardous substances because they often have greater exposure than do adults. For instance, children frequently play outdoors and are more likely to come in contact with soil than are adults. Children are more likely to get contaminated dirt on their hands, and are more likely to swallow some of that dirt if they do not wash their hands properly before eating. Children are also smaller than adults, resulting in higher doses of chemical exposure per body weight. Most important, children depend completely on adults for risk identification and management decisions, housing decisions, and access to medical care.

Children and soil

Consequently, whenever soil is a pathway of concern—as it is in Omaha—children will have greater exposure to contaminants in soil than will adults. Thus a major focus of ATSDR's evaluation was children's exposure to arsenic in soil and the potential health effects associated with their exposure. Children with soil pica behavior are a particular concern because should they eat arsenic-contaminated soil, they could have significant exposure to arsenic.

Response to Comments

Comments on Public Release Health Consultation

Comments on Health Consultation

In November 2005, when ATSDR released the Health Consultation for Arsenic in Soil in East Omaha, Nebraska, the Agency requested that people submit comments about the consultation. ATSDR received no written comments from residents or agencies.

Response to questions from residents

However, the Agency did receive numerous phone calls from residents asking questions about arsenic contamination in their yard. Many of the questions were similar to questions we received from residents during the public meetings that the Agency held in Omaha. Those questions and ATSDR's response are summarized here.

Question 1

How did arsenic get in my soil?

EPA has conducted studies that show that the arsenic in yards with high levels of arsenic probably came from an arsenic-containing herbicide (e.g., a weed killer). In the 1950s and 1960s, commercial weed killers that contained high levels of arsenic could be purchased at garden centers. When people applied these weed killers to their lawn, the product raised arsenic levels in surface.

More information about the source of arsenic can be found at this EPA website: http://www.epa.gov/Region7/cleanup/superfund/sites/omaha_ne_lead_RI.pdf

Question 2

Who will clean up my yard?

The yards with high levels of arsenic will not be remediated by the US EPA. EPA explained at the public meetings in Omaha that the arsenic probably came from some type of herbicide (i.e., weed killer) that residents used on their grass. Therefore, EPA cannot use Superfund monies to clean up those yards.

ATSDR reviewed the options that people could take to reduce exposure. Residents could cover their yard with clean fill or they could rotor-till their yard to mix the top few inches of soil (where most of the arsenic is found) with relatively clean soil 6 to 12 inches below the surface. Rotor-tilling the soil will thus reduce the concentration of arsenic at the surface significantly.

Question 3 **Can I have a vegetable garden?**

Yes, residents can have a vegetable garden in yards with elevated arsenic. Garden vegetables take up only very small amounts of arsenic and the resulting arsenic levels in plants are not harmful. Residents should be sure to wash vegetables, particularly root vegetables and low-growing vegetables, to remove dirt that clings to the produce. Gardeners can reduce their exposure also by washing their hands after gardening.

Gardens also are likely to have lower levels of arsenic than other parts of the yard because residents usually till the soil to prepare it for planting and often add soil amendments (e.g., compost, sand). Both of these activities will reduce the arsenic concentration in the top six inches of soil where roots grow.

Question 4 **What parts of my yard are contaminated with arsenic?**

ATSDR staff reviewed EPA's sampling plan with residents explaining that in most cases EPA collected four (composite) samples from each property. In general, the front yard was divided into two sections and the back yard was divided into two sections. Therefore, residents could be told the arsenic concentration in the right and left sections of the front and back yard.

For some properties, some sections were not contaminated with arsenic. Knowing which sections had high levels of arsenic and which sections had low levels of arsenic allowed residents to decide what parts of their yard needed attention. For example, in some yards, only the back yard needed to be rotor-tilled to reduce arsenic levels in surface soil while in other yards only the front yard needed to be rotor-tilled.

Conclusions

Conclusions about Arsenic in Soil in East Omaha

Arsenic and children

Arsenic in soil at some properties in Omaha may pose a public health hazard. ATSDR has made this determination because preschool children with soil pica behavior could be exposed to arsenic at levels that might cause harmful effects. If preschool children with soil pica behavior eat large amounts of arsenic-contaminated soil, they could experience harmful effects such as, nausea, stomach cramps, vomiting, diarrhea, facial swelling, and headaches. Still, these symptoms are temporary and should subside once exposure to arsenic ceases.

Soil pica behavior, that is, the eating of large amounts of soil, may occur in up to 20% of preschool children. The highest percentage occurs in children 1 to 2 years old and diminishes in older preschool children.

Arsenic and adults

Like children, adults also can be exposed to chemicals in soil by inadvertently putting their hands in or near their mouth. If adults live in properties with elevated levels of arsenic, this behavior can result in exposure to very small amounts of arsenic over long periods. Such long-term exposure to low amounts of arsenic over many decades might increase their risk of developing skin cancer. For example, for adults who live at the property with the highest arsenic level in soil (i.e., 1,184 parts per million), their estimated risk of cancer ranges from zero to three extra cases of cancer if 10,000 people were exposed to that level of arsenic in soil.

Non-cancerous effects from exposure to low levels of arsenic in soil are not likely in adults.

Recommendations

Recommendations for the SH52 Site in East Omaha

Health education and promotion

ATSDR's Division of Health Assessment and Consultation will conduct health education and health promotion activities in Omaha to inform residents about arsenic contamination in some properties. These efforts will also include information for residents about ways to reduce exposure to arsenic in soil.

Reduce exposure to arsenic

To protect the health of children, especially children with soil pica behavior, and to protect adults, reduce exposure to arsenic at properties with elevated levels of arsenic in soil. In reducing such exposure, priority should be given to properties with the highest arsenic levels where preschool children reside or where they are likely to play.

For More Information

For More Information

Contact these ATSDR staff members for more information about arsenic in soil in east Omaha:

David Mellard, Ph.D.
Toxicologist, Division of Health Assessment and Consultation
ATSDR, Atlanta, Georgia
404-498-0443 or toll free 1-800-CDC-INFO

Sue Casteel, M.S.
Regional Representative, Division of Regional Operations
ATSDR, Kansas City, Kansas
913-551-1312.

When calling ATSDR's toll free number, please ask for David Mellard with ATSDR.

Public Health Action Plan

Public Health Action Plan for the SH52 Site in East Omaha

Health educational programs	ATSDR developed educational programs for community members and health care providers to educate people about arsenic health effects and about actions residents can take to protect themselves and their families from further arsenic exposure. ATSDR conducted these health education activities in November 2005 when the agency held public meetings to inform residents of its findings. Appendix C contains a pictorial showing ways to protect family members from contaminants in soil.
Participation in community meetings	During public meetings held in November 2005, ATSDR talked with residents about potential health issues associated with arsenic contamination at the site. ATSDR also worked with numerous community groups, school officials, and others to inform them about arsenic issues in east Omaha.
Evaluation of additional environmental data	If ATDR receives additional environmental data about arsenic in soil in east Omaha or the SH52 Site, the agency will evaluate the data and will determine the appropriate public health response.

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References

References

Abernathy CO, Chappell WR, Meek ME, Bigg H, Guo HR. 1996. Roundtable summary: Is ingested inorganic arsenic a “Threshold” Carcinogen. Fundam Appl Toxicol;29:168–75.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2005a. Soil pica, soil-ingestion, and health outcome investigation: site-specific health activities, Vasquez Boulevard Interstate-70, Denver, Colorado. Atlanta: US Department of Health and Human Services; March.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2005b. Health consultation concerning cancer incidence rates in East Omaha, Omaha, Douglas County, Nebraska, 1990–2001. Atlanta: US Department of Health and Human Services; July.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2001. Summary report for the ATSDR soil pica workshop. Atlanta: US Department of Health and Human Services; March. [ATSDR] Agency for Toxic Substances and Disease Registry. 2005. Public health assessment guidance manual (update). Atlanta: US Department of Health and Human Services; January.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2000. Toxicological profile for arsenic (update). Atlanta: US Department of Health and Human Services; September.

Barltop D. 1966. The prevalence of pica. Am J Dis Child;112:116–23.

Calabrese EJ, Stanek EJ. 1998. Soil ingestion estimation in children and adults: a dominant influence in site-specific risk assessment. Environ Law Rep, News and Anal;28:10660–71.

Calabrese EJ, Stanek EJ, Pekow P, Barnes RM. 1997. Soil ingestion estimates for children residing on a Superfund Site. Ecotoxicol Environ Safety;36:258–68.

Calabrese EJ, Stanek EJ. 1993. Soil pica: not a rare event. J Environ Sci Health; A28(2):373–84.

Calabrese EJ, Barnes RB, Stanek ES, Pastides H, Gilbert C, Veneman P, et al. 1989. How much soil do young children ingest: an epidemiologic study,. Regul Toxicol Pharmacol;10:123-37.

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References, Continued

References (continued)

Casteel SW, Brown LD, Dunsmore ME, et al. 1997. Relative bioavailability of arsenic in mining wastes. Denver, CO: US Environmental Protection Agency, Region 8.

Casteel SW, Evans T, Dunsmore ME, et al. 2001. Relative bioavailability of arsenic in soils from the VBI70 Site. Final report. Denver, CO: US Environmental Protection Agency, Region 8.

[EPA] Environmental Protection Agency. 2004. Remedial Investiongation Residential Yard Soil, Omaha Lead Site. Kansas City, MO: Region VII; June 9.

[EPA] Environmental Protection Agency. 2001. Baseline human health risk assessment, Vasquez Boulevard and I-70 Superfund Site, Denver, CO. Denver: US Environmental Protection Agency; August.

[EPA] Environmental Protection Agency. 2000. Omaha Lead site investigation background summary report. Kansas City, MO: Region VII; January 27.

[EPA] Environmental Protection Agency. 1998. Environmental technology verification report, Field Portable X-ray Fluorescence Analyzer Niton XL Spectrum Analyzer. Washington DC; March.

[EPA] Environmental Protection Agency. 1997. Exposure factors handbook. Chapter 4: Soil ingestion and pica. Washington DC: Office of Research and Development, National Center for Environmental Assessment. EPA/600/P-95/002FA; August.

Franzblau A, Lilis R. 1989. Acute arsenic intoxication from environmental arsenic exposure. Arch Environ Health;219:589–96.

Freeman GB, Johnson JD, Killinger JM, et al. 1993. Bioavailability of arsenic in soil impacted by smelter activities following oral administration in rabbits. Fundam Appl Toxicol;21:83–8.

Freeman GB, Schoof, RA, Ruby MV, et al. 1995. Bioavailability of arsenic in soil and house dust impacted by smelter activities following oral administration in cynomolgus monkeys. Fundam Appl Toxicol;28:215–22.

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References, Continued

References
(continued)

Lorenzana RM, Duncan B, Ketterer M, et al. 1996. Bioavailability of arsenic and lead in environmental substrates. I. Results of an oral dosing study of immature swine. Seattle, WA: US Environmental Protection Agency, Region 10: EPA 910/R-96-002.

Mizuta N, Mizuta M, Ito F, et al. 1956. An outbreak of acute arsenic poisoning caused by arsenic-contaminated soy-sauce (shoyu): a clinical report of 220 cases. Bull Yamaguchi Med Sch;4(2-3):131–49.

Roberts SM, Weimer WR, Vinson JRT, Munson JW. 2002. Measurement of arsenic biavailability in soil using a primate model. Toxicol Sci;67:303–10.

Robischon P. 1971. Pica practice and other hand-mouth behavior and children's developmental level. Nurs Res;20:4–16.

Shellshear ID. 1975. Environmental lead exposure in Christchurch children: soil lead a potential hazard. N Z Med J;81:382–86.

Stanek EJ, Calabrese EJ. 2000. Daily soil ingestion estimates for children at a Superfund site. Risk Anal;20(5):627–35.

Stohrer G. 1991 Arsenic: opportunity for risk assessment. Arch Toxicol;65:525-31.

Tseng WP, Chu HM, How SW, Fong JM, Lin CS, Yeh S. 1968. Prevalence of skin cancer in an endemic area of chronic arsenicism in Taiwan. J Natl Cancer Inst;40:453–63.

Vemeer DE, Frate Da. 1979. Geophagia in rural Mississippi: environmental and cultural contexts and nutritional implications. Am J Clin Nutr;32:2129–35.

Wong MS. 1988. The role of environmental and host behavioral factors in determining exposure to infection with *Ascaris lumbriocoides* and *Trichuris trichlura*. St. Augustine, Trinidad: Faculty of Natural Sciences, University of the West Indies (Ph.D. Dissertation).

Appendix A

Figures

Figure A-1. Site investigation area

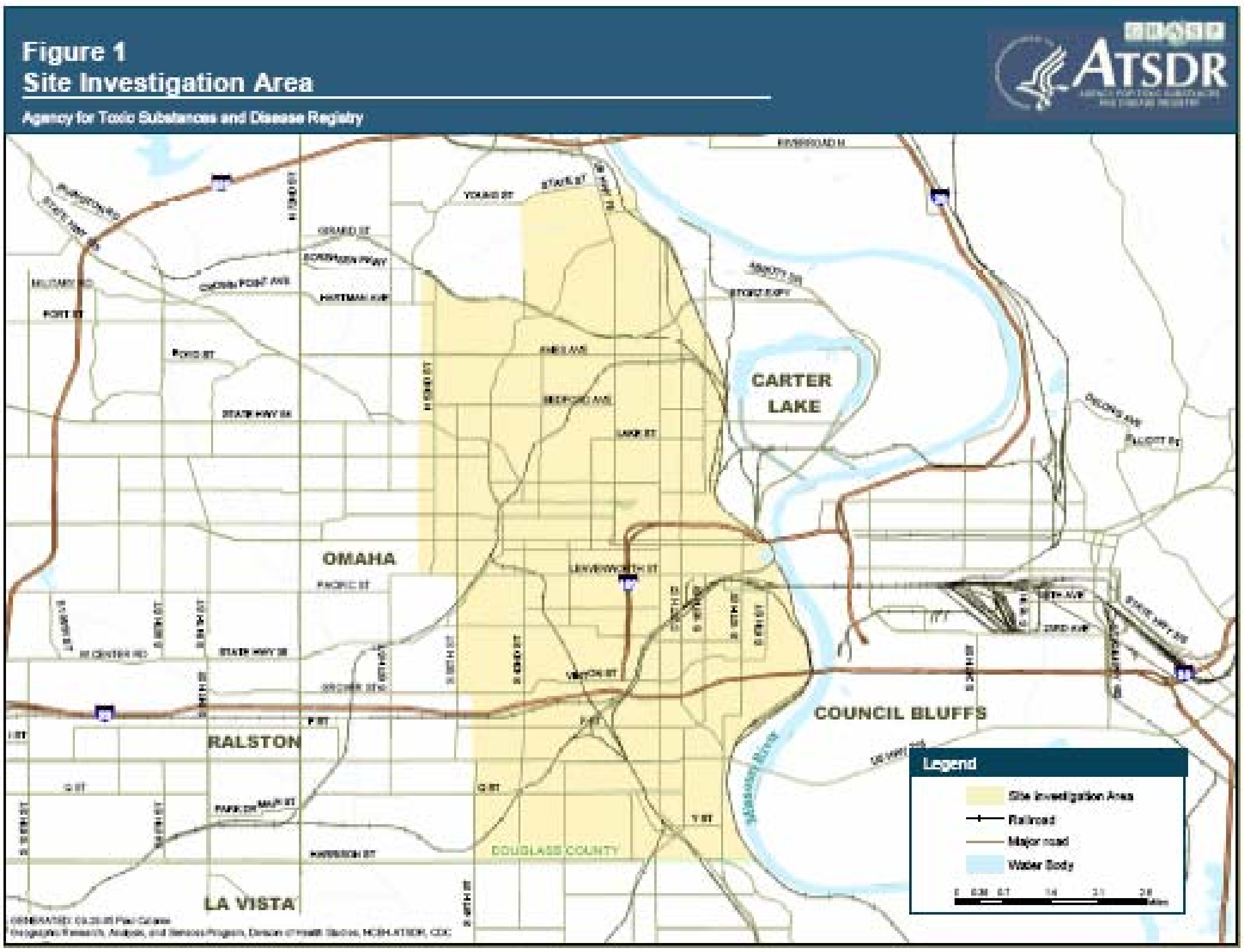
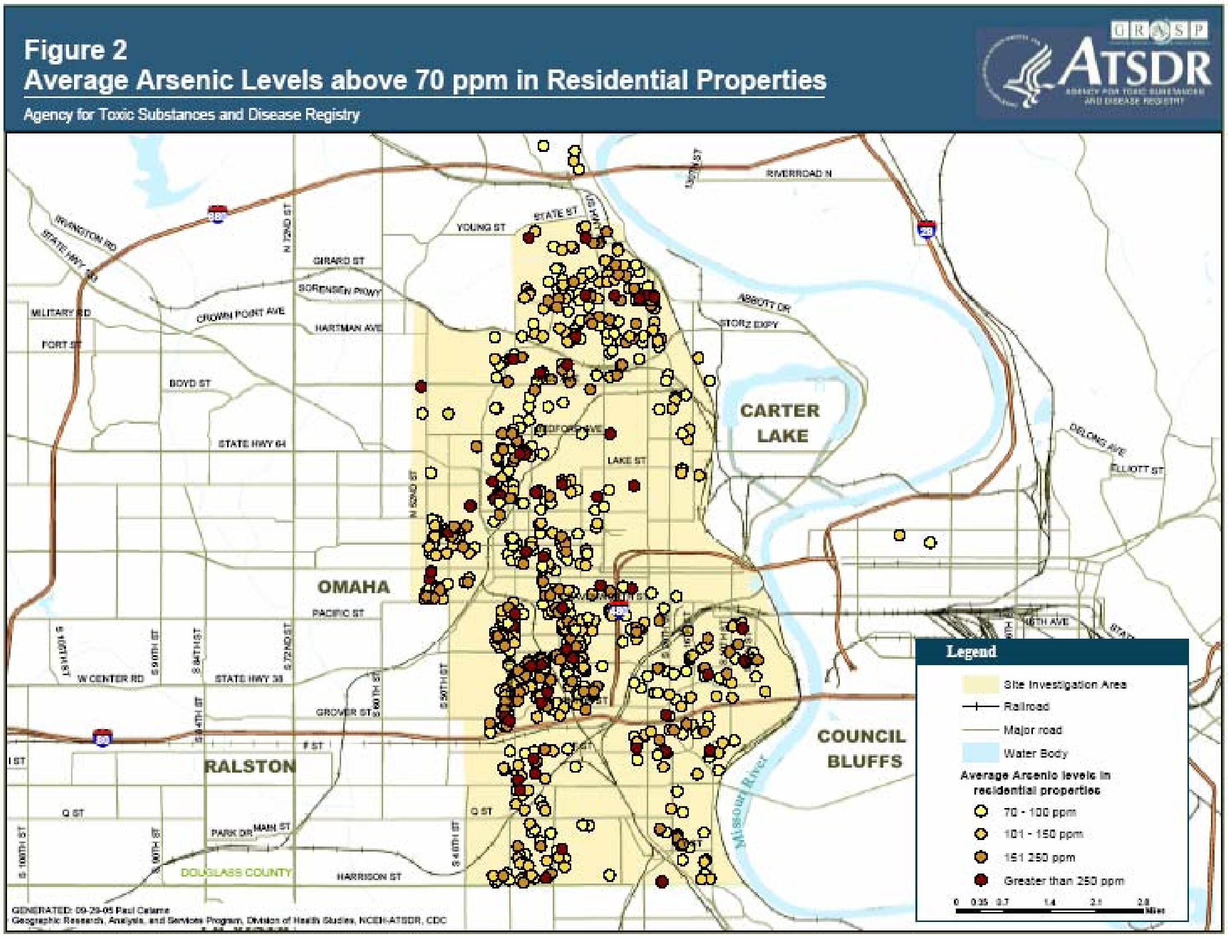


Figure A-2. Properties with average arsenic levels above 70ppm.



Appendix B

Validity of Arsenic Data

Sample design

Up to four soil samples were collected from most properties by dividing the property into four sections. From each section, 5 different soil samples were collected and mixed together to form one composite soil sample for each section. In addition to these samples, a fifth soil sample was collected in the drip zone (i.e., within 3 feet of the house) to determine the contribution of lead-based paint.

XRF instruments

Over the 15 years that arsenic measurements were made using the XRF method, two instruments were used: the Niton XRF and the Innov-X. The EPA used the Niton XRF until 2004, when they switched to the Innov-X. The Innov-X instrument has a detection limit for arsenic of 13 ppm in soil whenever the testing time is extended to 2 minutes. For the Niton XL, EPA reports the detection limit for arsenic as 40 ppm.

XRF calibration

Calibration of the XRF instrument occurred daily. The one-step calibration process prepared the instrument to measure lead, arsenic, and other metals in soil. Preparation of the soil sample for measurement required several steps. After removing debris, the composited soil samples were passed through a sieve to ensure uniformity of soil material, and the sieved soil was thoroughly mixed. The XRF instrument measured a portion of the prepared soil sample for lead, arsenic, and other metals.

Confirmatory analysis

To ensure the accuracy of the XRF measurements, EPA sent 1 out of 10 soil samples (10%) for laboratory analysis. When the Niton XRF was used and a soil sample needed to be sent to the laboratory for confirmatory analysis, EPA split the sieved soil sample in half. One portion was used to determine the arsenic concentration using the Niton XRF, while the other portion was sent to the lab to determine arsenic concentration. When EPA began using the Innov-X in 2004, the same sample that was used in the Innov-X instrument to determine arsenic concentration was then sent for lab analysis.[9] The soil sample was not split.

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[9] The most likely reason for switching to the Innov-X is because the Innov-X does not use a radioactive source to measure arsenic. Because the instrument does not use a radioactive source, less paperwork is involved in maintaining and transporting the instrument.

Validity of Arsenic Data, Continued

Accuracy of XRF measurements

The accuracy of the XRF instruments in measuring arsenic in soil is well documented; thus the concentration of arsenic measured by laboratory analysis should be very close to the arsenic concentration measured by XRF. EPA has thoroughly investigated using XRF technology at Superfund sites and in 1998 released a report describing this technology specifically for the Niton XL XRF (EPA 1998). EPA's technology report has this to say about using the Niton XL instrument to measure lead, arsenic, and other metals:

"The results of the demonstration show that the Niton XL Spectrum analyzer can provide useful, cost-effective data for environmental problem-solving and decision-making."

Results of confirmatory analysis

Over 1,110 samples had detectable levels of arsenic in both laboratory and XRF analysis, and these samples were used to compare the two methods. Figure B-1 shows the regression analysis comparing the arsenic concentration from laboratory analysis with the corresponding XRF arsenic concentration. In most of the comparisons, the concentration of arsenic from the two methods is similar, with the correlation coefficient being 0.82.

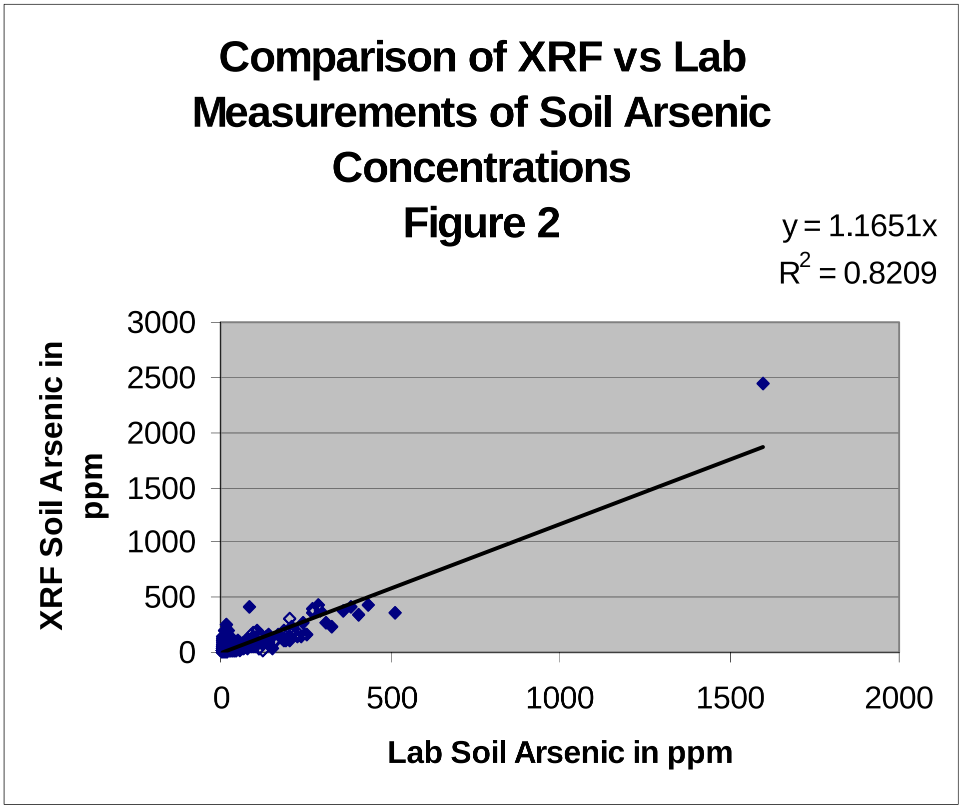
Explanation of inconsistencies

In some cases, the laboratory analysis concentration of arsenic is significantly different from the XRF concentration of arsenic. Because over 3,000 comparisons were made between XRF arsenic and laboratory arsenic, some differences are expected. The most likely reason for these differences comes from the prepared soil sample being split at the site when using the Niton XRF method. With Niton XRF, the soil sample was divided into two portions after mixing, with one portion used for the XRF measurement and the other portion sent for laboratory analysis. Even when a soil sample is thoroughly mixed, some differences in arsenic concentration can exist in the two halves of the split sample. In discussions with technical representatives for the Niton Corporation, uneven distribution of arsenic when a sample is split is the most likely reason for a difference in arsenic concentrations for the two measurements.

Conclusion: validity of results

Because in all likelihood the difference between the split soil samples results is from unequal distribution while mixing and dividing the soil, the arsenic levels measured by the XRF are valid for making public health decisions.

Figure B-1. Comparison of XRF vs lab measurements of soil arsenic concentrations



Appendix C

Pictorial: ways to protect your family's health