Health Consultation

PUBLIC COMMENT RELEASE

STATE STREET, HARRISON STREET, 52ND STREET SITE

ARSENIC IN SOIL IN EAST OMAHA

OMAHA, DOUGLAS COUNTY, NEBRASKA

NOVEMBER 4, 2005

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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

Health Consultation: A Note of Explanation

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

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

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HEALTH CONSULTATION

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ARSENIC IN SOIL IN EAST OMAHA

OMAHA, DOUGLAS COUNTY, NEBRASKA

Prepared by:

Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
and Division of Regional Operations

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Statement of Issues

The Agency for Toxic Substances and Disease Registry (ATSDR) is a federal health agency based in Atlanta, Georgia and whose 10 regional offices include Kansas City, Kansas. 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. The purpose of this health consultation is to decide whether those arsenic levels in soil are a public health hazard for adults and children.

Background

Site Investigation Area

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.

In March 1999, to characterize the extent of contamination and to prioritize clean-up activities for the Omaha Lead Site, the EPA began collecting soil samples from residential properties in Omaha. Previous soil sampling was also 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.

Within the investigation area, EPA has been removing contaminated soil from properties since 1999. The first clean ups 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.

Following these initial clean ups, in subsequent years EPA used the following criteria:

- In 2002, EPA began removing soils from residential properties at which lead levels exceeded an average of 2,500 ppm.
- In 2003, EPA began removing soils from residential properties at which lead levels exceeded an average of 1,200 ppm.

In 2004, EPA released the Interim Record of Decision (ROD) for the Omaha Lead Site. The ROD stated that EPA would clean up soils at residential properties at which soil levels exceeded an average of 800 ppm lead. EPA currently is cleaning up lead-contaminated soils from residential properties that meet these criteria.

Arsenic Background Levels

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 (1) that 95% of arsenic levels from uncontaminated areas should be less than 11.5 ppm arsenic, and (2) that 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

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 soil sample for each section was created by collecting five different soil samples from the section and mixing them together to form one composite soil sample per section. Therefore, each property could have several composite soil samples, depending upon the number sections into which the property was divided. 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.

In east Omaha, 777 properties currently have average arsenic levels in soil above 70 ppm. The property with the highest average arsenic level in soil has 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) for a yard-wide average of 1,184 ppm. 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. 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.

Diagram 1

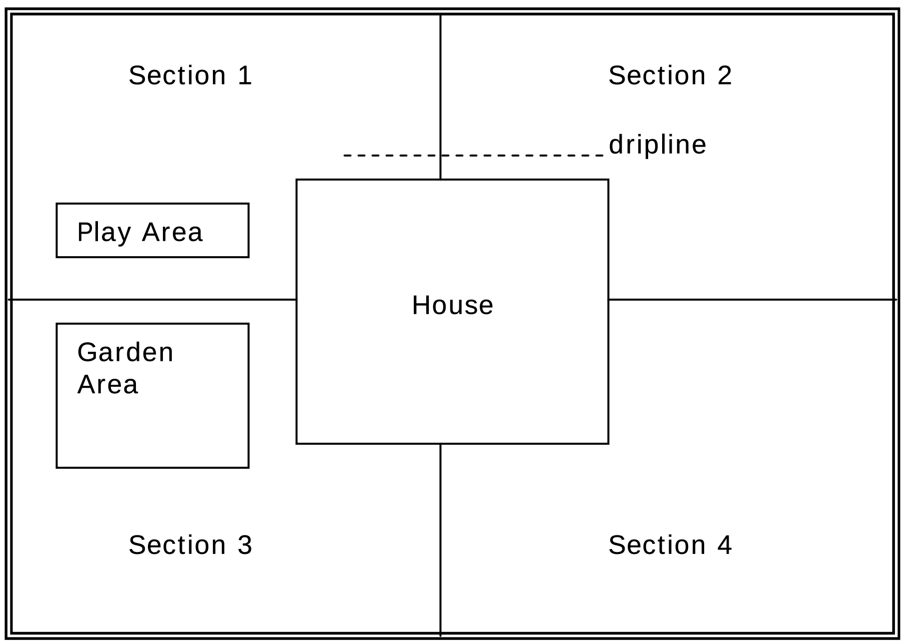

Table 1. Number of Current Properties at Different Arsenic Concentrations

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

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.

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

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 addition, 17% of the residents are Hispanic.[1] Table 2 shows detailed demographic information.

Demographic information shows that about one of every 4 households includes a preschool child. This information is used to estimate the number of preschool children with soil pica behavior. The Discussion section of this health consultation has more information about soil pica behavior.

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

Source: 2000 US Census

Discussion

Exposure to Arsenic in Soil

Soil Ingestion

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

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.

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.

Soil Pica Behavior

Pica behavior, or the eating of non-food items, is well known in children. Children have been observed eating paint chips, matches, paper, clay, soil, and numerous other non-food items. Children who eat large amounts of soil have a behavior called "soil-pica." Soil pica behavior is most likely to occur in preschool children as part of their normal exploratory behavior. Children between the ages of 1 and 2 have the greatest tendency for soil-pica behavior, but this tendency decreases as they become older.

The exact number of children who eat soil is not known. Studies have reported that soil pica behavior occurs in as few as 4% of children or in as many as 21% of children (Barltrop 1966; Robischon 1971; Shellshear 1975; Vermeer and Frate 1979.) A recent study by ATSDR and the Colorado Department of Health and Environment reports 20% of preschool children with soil pica behavior (ATSDR 2005a). Studies on children with soil pica behavior have shown that they can eat up to a teaspoon of dirt (or 5,000 milligrams) (Stanek and Calabrese 2000; Calabrese and Stanek 1993; Calabrese et al. 1989; Wong 1988).

Limited information is available concerning how often and how long soil pica behavior occurs in children. Some preschool children might eat soil once during their preschool years, while others might go through a stage of eating soil several times during a week, or even over several months. Soil-pica behavior might occur for several days in a row, or a child might skip days between eating soil (Calabrese and Stanek 1998; Calabrese and Stanek 1993; Wong 1988; ATSDR 2001)

Estimating Exposure to Arsenic

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 unlikely 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. 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 95th 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%.

Because the types of arsenic at the VBI70 Site and at the SH52 Site are similar, and because the relative bioavailability of arsenic is better characterized at the VBI70 Site, ATSDR chose a relative bioavailability of 42% for arsenic in soil.

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.

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

$$\text{Absorbed Arsenic Dose} = \frac{(\text{arsenic concentration in soil})(\text{milligrams soil ingested})(\text{\% absorption})(\text{exposure frequency})(0.000001\ \text{kg/mg})}{\text{weight in kgs}}$$

A range of doses are 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 male. Therefore, because of differences in weight and differences in soil intake, the estimated dose of arsenic can vary by age.

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).

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

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.

Children

Estimated Doses in Children with Soil Pica Behavior

Children with soil pica behavior have the highest amount of exposure to arsenic in soil because they ingest large 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)

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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.

exposures of 0.005 mg/kg/day. When this guideline is exceeded, a concern might exist for harmful effects.

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. If preschool children live at a property where average arsenic level is 70 ppm, their estimated dose is 0.005 mg/kg/day, which is ATSDR's health guideline for acute exposure. Of the properties tested, 777 have average arsenic levels above 70 ppm (see Table 1).

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	0.005	yes
1,000	0.08	0.005	yes
900	0.073	0.005	yes
800	0.065	0.005	yes
700	0.057	0.005	yes
600	0.05	0.005	yes
500	0.044	0.005	yes
450	0.036	0.005	yes
350	0.028	0.005	yes
300	0.025	0.005	yes
250	0.02	0.005	yes
200	0.016	0.005	yes
150	0.01	0.005	yes
100	0.008	0.005	yes
70	0.005	0.005	equals
50	0.004	0.005	no

Possible Harmful Effects in Children with Soil Pica Behavior

Children with soil pica behavior who live at properties where the average arsenic level exceeds 600 ppm have an estimated dose of 0.05 mg/kg/day. Additionally, they might experience harmful effects from arsenic should they eat soil from the yard. Children with soil pica behavior who live at properties with average arsenic levels between 70 and 600 ppm are also at risk of harmful effects from arsenic, and this risk increases as the average arsenic level approaches 600 ppm.

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

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

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

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 soil pica frequency of 3 days per week,
- 42% arsenic bioavailability, and
- an 11-kg (24-pound) child.

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. For example, if children with soil pica behavior weigh 16 kg (about 35 pounds), ingest 1,000 mg soil ($^{1}/_{5}$ teaspoon), and the arsenic's bioavailability is 20%, a child's estimated dose is 0.0005 mg/kg/day—if he or she lives at a property with 70 ppm average arsenic. This estimated dose of arsenic is not likely to cause harmful effects in children with soil pica behavior.

Some uncertainty exists in deciding whether adverse health effects might occur in children. This uncertainty is 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 not enough to cause health effects.

It should be pointed out, however, that some of 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

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, that means10 to 40 preschool children with soil pica behavior live at properties with average arsenic levels exceeding 70 ppm. As also mentioned previously, soil pica behavior is most likely to occur in 1 and 2-year-old children, and it occurs less frequently as preschool children become older.

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. Children who ingest 200 mg soil daily and who live at the most contaminated properties (i.e., the property with average arsenic levels at 1,187 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.

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, and the ability of that arsenic to cross the gut.

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.

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/day6*	*Exceeds ATSDR's Provisional Acute Oral MRL of 0.005 mg/kg/day*
1,184	0.0009	no	0.006	yes
900	0.0007	no	0.0046	no
70	0.0001	no	0.0004	no

Adults

Estimated Doses 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 42% 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.

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 one. At that one property, the estimated absorbed dose of arsenic is 0.0004 mg/kg/day, which exceeds 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 dose for adults of 0.0004 mg/kg/day who live at the most contaminated property is below the no-effect level in humans of 0.0008 mg/kg/day, harmful skin effects in adults who live at this property are not likely.

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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 a 42% 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 42% bioavailability.

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.

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	0.0003	yes
900	0.00026	0.0003	no
800	0.00023	0.0003	no
500	0.00014	0.0003	no

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, arsenical medications, or 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.

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.

A key parameter in this calculation 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 of 30 years for adults, the mathematical model suggests that an increase 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.

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.

8 To estimate the absorbed dose of arsenic in adults, ATSDR assumed 50 mg of soil ingested daily, 42% bioavailability, and 70-kg body weight.

- The mathematical model, at least for arsenic, is based on key input from the Taiwan study. This input 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).
- 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).

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

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.

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.

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).

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.

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

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.

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.

Conclusions

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.

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 low 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.

Recommendations

1. 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.
2. 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.

Public Heath Action Plan

1. ATSDR will develop 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. Appendix C contains a pictorial showing ways to protect family members from contaminants in soil.
2. ATSDR will participate in community meetings to discuss potential health issues associated with arsenic contamination at the site, and will work with community groups and concerned residents to respond to public health concerns and to questions from local residents.
3. ATSDR will continue to evaluate additional environmental data to determine whether people are currently exposed to unsafe levels of arsenic at the site.

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Appendix A. Figures

Figure A-1

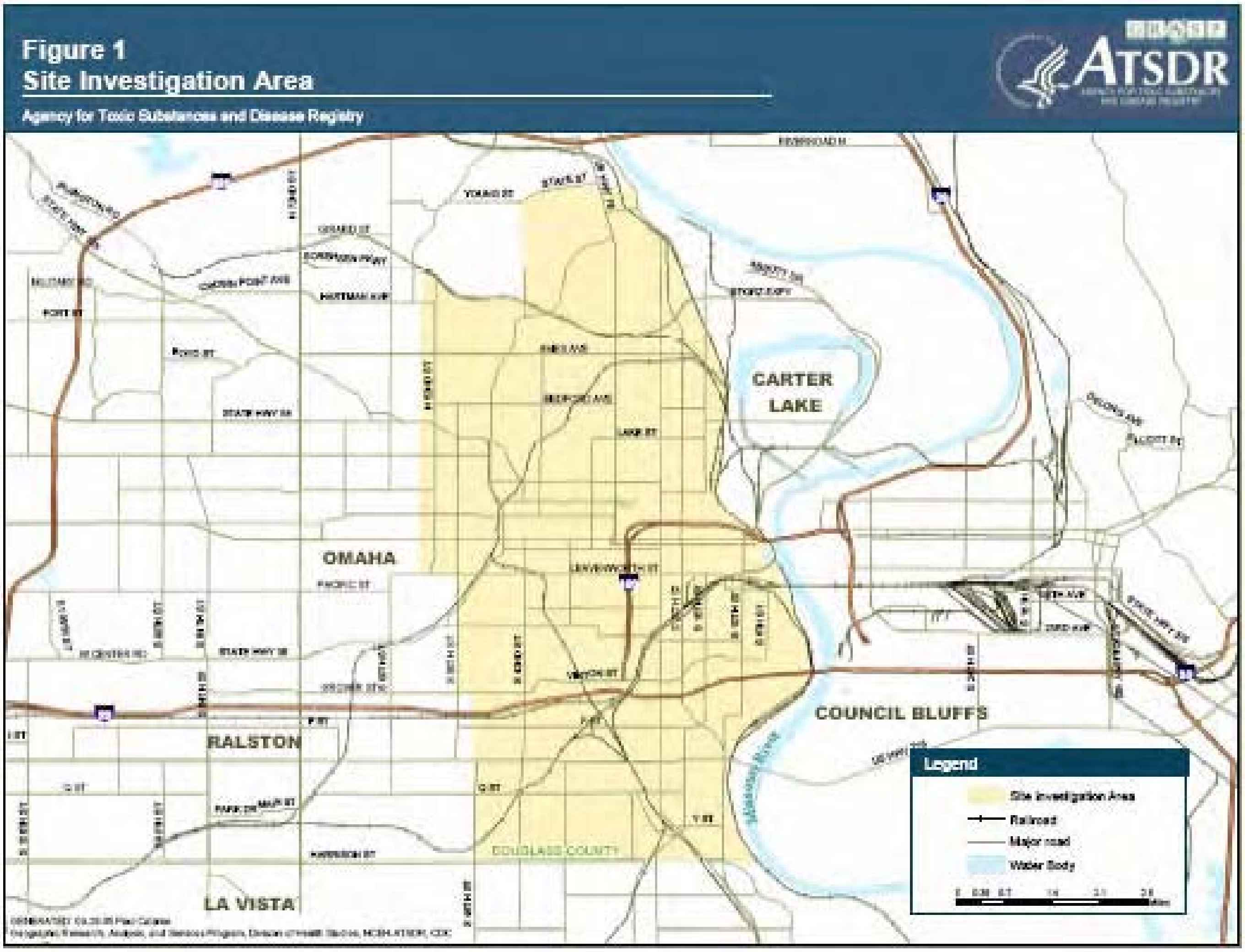

Figure A-2

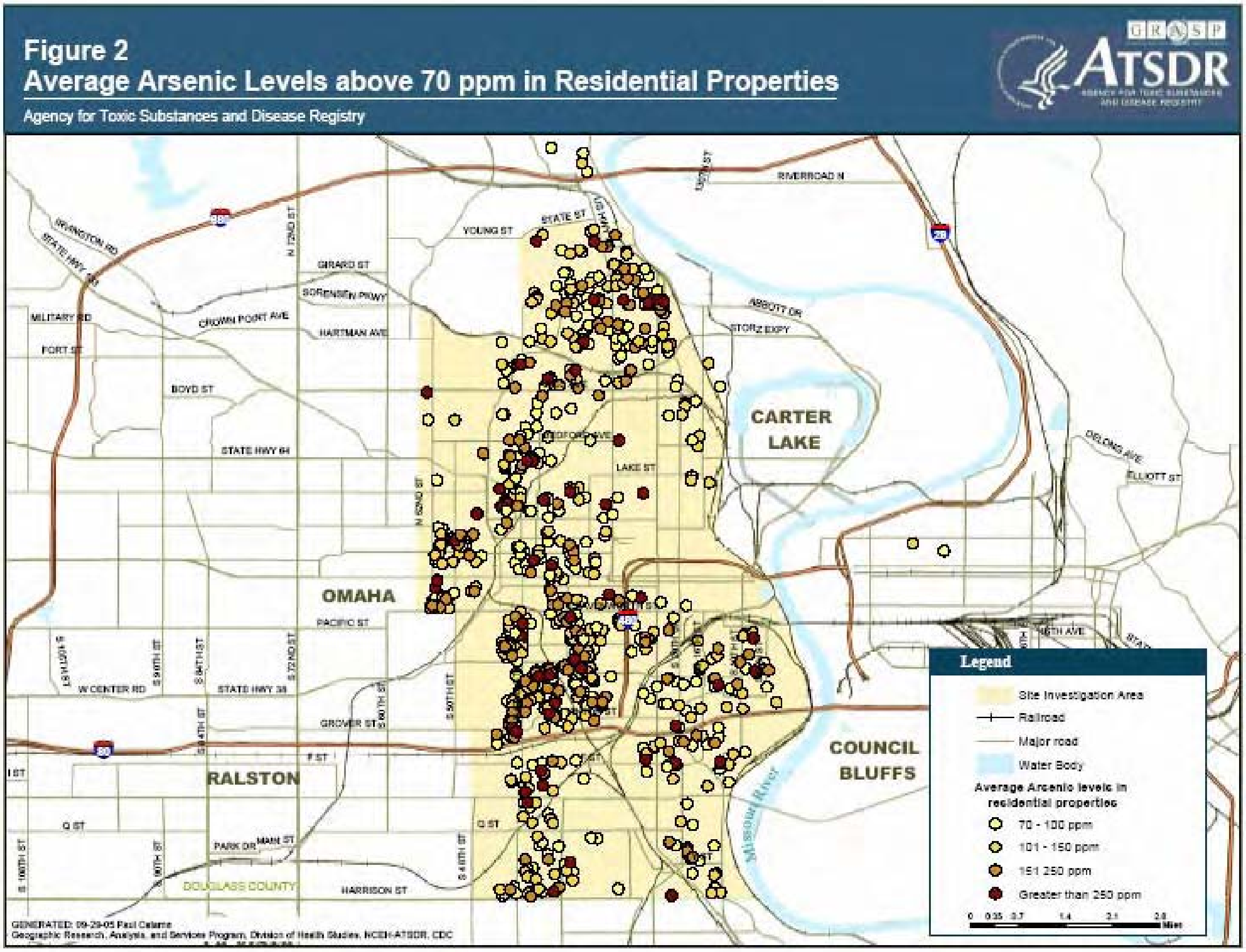
Figure 2
Average Arsenic Levels above 70 ppm in Residential Properties
Agency for Toxic Substances and Disease Registry
ATSDR
OMAHA
CARTER LAKE
COUNCIL BLUFFS
RALSTON
Missouri River
DOUGLASS COUNTY
Legend
Site Investigation Area
Railroad
Major road
Water Body
Average Arsenic levels in residential properties
70 - 100 ppm
101 - 150 ppm
Greater than 250 ppm
GENERATED: 09-29-05 Paul Calame
Geographic Research, Analysis, and Services Program, Division of Health Studies, NCEH-ATSDR, CDC

Appendix B. Validity of Arsenic Data

Sample Design and Preparation

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.

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.

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.

Confirmatory Analysis of XRF Measurements

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.

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:

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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.

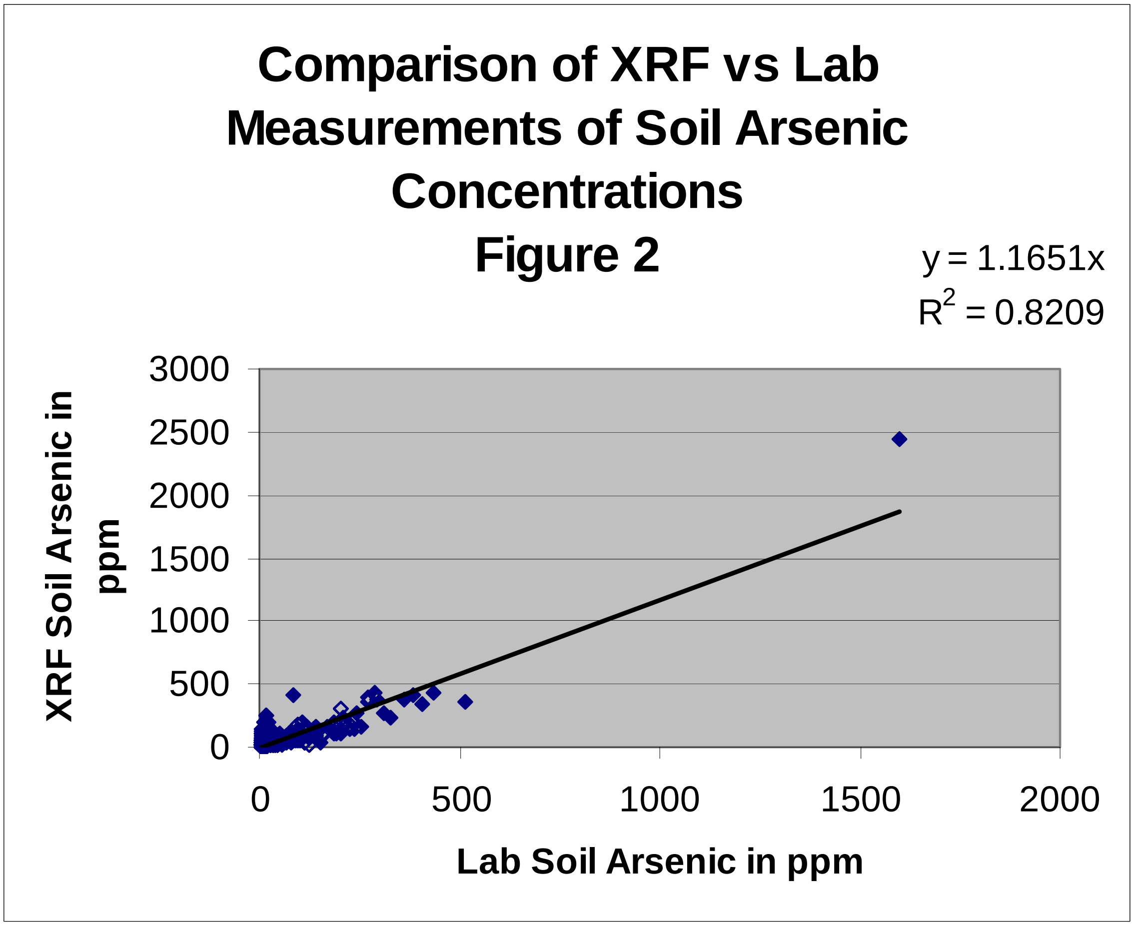
> "The results of the demonstration show that the Niton XL Spectrum analyzer can provide useful, cost-effective data for environmental problem-solving and decision-making."

Results of Laboratory Versus XRF Arsenic Measurements

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 2 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.

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.

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.


Comparison of XRF vs Lab Measurements of Soil Arsenic Concentrations
Figure 2
y = 1.1651x
R2 = 0.8209
XRF Soil Arsenic in ppm
3000
2500
2000
1500
1000
500
0
0
500
1000
1500
2000
Lab Soil Arsenic in ppm

Appendix C. Pictorial: Ways to Protect Your Family's Health