Health Consultation

ENVIRONMENTAL DATA REVIEW FOR WITCHCRAFT HEIGHTS
ELEMENTARY SCHOOL AND NEARBY PROPERTIES

SALEM, ESSEX COUNTY, MASSACHUSETTS

EPA FACILITY ID: MAN000103180

AUGUST 21, 2006

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.

You May Contact ATSDR Toll Free at
1-800-CDC-INFO
or
Visit our Home Page at: http://www.atsdr.cdc.gov

HEALTH CONSULTATION

ENVIRONMENTAL DATA REVIEW FOR WITCHCRAFT HEIGHTS ELEMENTARY SCHOOL AND NEARBY PROPERTIES

SALEM, ESSEX COUNTY, MASSACHUSETTS

EPA FACILITY ID: MAN000103180

Prepared by:

The U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry

Contents

Summary and statement of issues

The Agency for Toxic Substance and Disease Registry (ATSDR) was petitioned by a group of residents of Salem, Massachusetts to evaluate the possible implication of exposure to soil contaminants at the Witchcraft Heights Elementary School and nearby properties (the site).

Soil contamination was discovered during the process of expanding the school facility in the winter of 2001. Soil samples collected from the site revealed contamination of arsenic, lead, and other contaminants. Federal and local government agencies conducted numerous environmental investigations, assessment, and removal activities at the site. Over 2,000 environmental samples were collected and more than 12,000 tons of contaminated soil removed from the site.

In this health consultation, ATSDR evaluated available environmental sampling information for potential exposure to contaminants at the site. ATSDR identified the primary route of potential human exposure as being ingestion of soil and dust for residents who live on the site and students, teachers and other personnel who attend the school. Analysis of exposure pathways and review of site documents indicated that

- It is unlikely that adults and children at any of the properties on site will experience noncancerous harmful effects from exposure to arsenic in soil;
- Residents who have a continuous lifetime exposure to arsenic via ingestion have no apparent increased risk of developing cancer;
- It is unlikely that consuming home-grown vegetables and potential exposures during gardening activities will result in any adverse health effects for residents;
- Exposures to contaminants during construction and removal activities were minimal and are not likely to result in any adverse health effects for workers and residents;
- Residents are not exposed to arsenic contaminated groundwater.

ATSDR has categorized this site as constituting "no apparent public health hazard." ATSDR released a public comment version of this document on June 15, 2006. No comments were received.

Background

The Agency for Toxic Substance and Disease Registry (ATSDR) was petitioned by a group of residents of Salem, Massachusetts to evaluate the possible implication of exposure to soil contaminants at the Witchcraft Heights Elementary School and nearby residential properties (the site)[1].

The site consists of the Witchcraft Heights Elementary school property and the surrounding residential properties. The school was built in 1970 and covers approximately 16 acres of land. The school property is bordered on the north by Ord Street residential properties, on the east by Puritan Road residential properties, on the west by Belleview Avenue residential properties, and on the south by Brentwood Avenue residential properties. For the construction of the school and adjacent residences, fill potentially contaminated with tannery waste and apple orchard soil was used to cover exposed bedrock in the area. Soil contamination was discovered during the process of expanding the school facility in the winter of 2001. Soil samples collected from the site revealed contamination by arsenic, lead, and other contaminants [2–4].

Since the discovery of soil contamination, numerous environmental investigations, assessment, and removal activities have been conducted at the site. The Massachusetts Department of Environmental Protection (MADEP) undertook initial sampling and oversaw investigation on the school property and some residential properties. The City of Salem directed construction and investigations on the school property. In June 2002, MADEP requested assistance from the U.S. Environmental Protection agency (EPA) for investigation and cleanup on residential properties. In July 2002, ATSDR received a petition letter. The ATSDR regional office representatives participated in public meetings and responded to numerous health questions [2]. There were over 2,000 environmental samples collected and more than 12,000 tons of contaminated soil were removed from the site. The following is a summary of activities at the site [3–5]:

- December 2001, ash and sludgelike materials were discovered during the excavation for a new access road on the school property;
- April 2002, Alliance Environmental Group, Inc (AEG), under contract with the City of Salem, began phase I initial site investigation on the school property;
- June 2002, the EPA Superfund removal program began collecting soil samples at residential properties;
- July 2002, ATSDR received a petition letter from the City of Salem's board of heath representing a group of residents and started the petition process;
- January 2003, ATSDR officially accepted the petition and decided to prepare a public health consultation to evaluate the possible health implications of exposures to environmental contaminants from the site;
- April 2003, ATSDR conducted a public availability session for the site together with EPA and personnel from the board of health;
- May 2003, EPA began removal operations on selected residential properties;
- September 2003, Witchcraft Height Elementary school reopened after major renovation and cleanup—including the removal and appropriate disposal of more than 8,000 tons of arsenic-contaminated soil;
- October 2004, EPA removed more than 4,000 tons of contaminated soil from 21 properties.

The purposes of this health consultation are to review available environmental data, to assess the possible implication of exposures to soil contaminants, and to address community concerns.

Community health concerns

As part of its response to the petition to investigate the soil contamination, ATSDR staff participated in many public meetings, reviewed site documents, received numerous calls from residents, and conducted a public availability session to understand the concerns of community members regarding the contamination, investigation, and remediation at the site. Major environmental health issues include the following:

- Arsenic exposures—potential health effects from past exposures;
- Gardening issues—uptake of contaminants by plants, consuming home-grown vegetables, and potential exposures during gardening activities;
- Potential exposures to contaminants during construction and removal activities; and

- Environmental sampling and cleanup issues—representative sampling locations, cleanup schedule and criteria, and the effectiveness of the soil removal action levels for protection of public health.

ATSDR released a public comment version of this document on June 15, 2006. No comments were received.

ATSDR's exposure pathway analysis and evaluation process

ATSDR provides site-specific public health recommendations on the basis of the toxicological literature, levels of environmental contaminants detected at a site compared to accepted comparison values, an evaluation of potential exposure pathways and duration of exposure, and the characteristics of the exposed population. Whether a person will be harmed by exposure to hazardous substances depends upon several factors, including the type and amount of the contaminant, the manner in which the person was exposed, the duration of the exposure, the amount of the contaminant absorbed by the body, site conditions, genetic factors, and individual lifestyle factors. Ingestion of soil and dust is the primary exposure of concern for residents who live on the site and students, teachers, and other personnel at the school. A chemical can be present in the soil and dust—both as a result of natural causes and human activities. The following exposure pathways are associated with soil at this site.

Soil ingestion

The accidental ingestion of contaminated soil by both children and adults is a potential exposure pathway. This exposure occurs when people have direct contact with soils in their environment, for example, when children play outside or crawl on floors or when adults work in yards and gardens and contaminated soil or dust particles cling to their hands. Children or adults might accidentally swallow contaminated soil when they put their hands on or into their mouths. Because both people and pets track contaminated soils from outdoors into their homes, exposures can occur while people are in their homes and in their yards. Factors affecting whether people have contact with contaminated soil include the amount of grass cover, weather conditions, the amount of time spent outside, and personal habits.

The amount of chemicals to which people are exposed via ingestion depends on many factors, such as the level of contamination in soil and the type of activities engaged in. Although people might not be aware of it, everyone ingests some soil or dust every day. Preschool children often have close contact with soil and dust when playing. Because these children frequently engage in hand-to-mouth activity, their chances for exposure are increased. Children in elementary school, teenagers, and adults are also exposed to soil and dust, but generally less frequently and in smaller amounts.

When evaluating exposures, ATSDR also considers a wide range of human activities that might increase exposure to contaminants in soil. One activity of potential concern—particularly in preschool children—is a behavior called soil-pica (i.e., the eating or ingestion of large amounts of soil). Various studies have reported that this behavior occurs in as few as 4% or as many as 21% of children [6–8]. General pica behavior is greatest in children 1–2 years of age and decreases with age [9–14]. For this health consultation, ATSDR used a range of soil intake of 100 to 5,000 milligrams (about 1 teaspoon) of soil to estimate soil exposure for adults, children and soil-pica children (Appendix A).

Eating home-grown produce

Eating fruits, vegetables, herbs, or other produce grown locally in gardens with contaminated soil can cause exposure. This type of exposure occurs because many plants slowly absorb small amounts of the chemicals found in soils, or because contaminated soil can adhere to the exterior surface of produce. Some of these absorbed chemicals are essential nutrients and are actually good for people to eat. Other chemicals, however, can present health hazards if they are found at high enough levels and are consumed on a regular basis.

ATSDR's approach to evaluating a potential health concern has two components. The first involves a screening process that could indicate the need for further analysis. The second involves a weight-of-evidence approach that integrates estimates of likely exposure with information about the toxicology and epidemiology of the substance(s) of interest.
Screening is a process of comparing appropriate environmental concentrations and doses to ATSDR or EPA comparison values (CVs). These comparison values include but not limited to

- ATSDR environmental media evaluation guides (EMEGs)
- Reference dose media evaluation guides (RMEGs)
- Minimum risk levels (MRLs)
- Cancer risk evaluation guidelines (CREGs)
- EPA reference doses (RfDs)
- EPA Risk-based concentrations (RBCs) or preliminary remediation goals (PRGs)

To determine what environmental guideline value to use, this health consultation followed ATSDR's general hierarchy and used professional judgment to select CVs that best apply to the site conditions [15]. For example, we used Hierarchy 1 environmental guidelines (such as CREGs and chronic EMEGs). In the absence of these values, we selected Hierarchy 2 intermediate EMEGs or RMEGs. When environmental guidelines listed in the ATSDR hierarchy were unavailable, we considered those from other sources (e.g., RBCs, MADEP regulations). These health-based CVs are media-specific concentrations considered safe using default conditions of exposure. Default conditions are typically based on estimates of exposure in most (i.e., the 90th percentile or more) of the general population. Comparison values are not thresholds of toxicity. When a level exceeds a comparison value, it does not mean that health effects could be expected. It does, however, indicate that further evaluation is warranted.

After identifying potential chemicals of concern through the screening process, ATSDR evaluates a number of parameters depending on the contaminant and site-specific exposure conditions. Such parameters can include biological plausibility, mechanisms of action, cumulative interactions, health outcome data, strength of epidemiological and animal studies, and toxicological and pharmacological characteristics of the contaminants.

Discussion

Available environmental data for the site and data quality evaluation

ATSDR evaluated the available environmental sampling information for potential exposure to contaminants at the site. The information included residential and school soil samples, air samples taken during excavation and removal activities, and groundwater samples from on-site monitoring wells.

Soil samples were analyzed for metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver), polynuclear aromatic hydrocarbons (PAHs), and total petroleum hydrocarbons (TPHs). Air samples taken during excavation and removal activities were analyzed for total dust and arsenic. As for the soil samples, groundwater samples were analyzed for all eight metals.

The laboratory analysis methods selected were US EPA SW-846, US EPA Methods for Chemical Analysis of Water and Wastes per 40 CFR Part 136, APHA Standard Methods for the Examination of Water and wastewater, American Society for Testing and materials (ASTM), and other recognized methodologies.

ATSDR also reviewed information on Quality Assurance/Quality Control (QA/QC) specifications for field data quality and laboratory data quality to verify the acceptability and adequacy of data. For example, ATSDR reviewed available Chain-of-Custody sheets, project narratives, and laboratory certifications. The laboratory analysis methods and the QA/AC procedures were appropriate.

Environmental data evaluation and public health implications

Environmental data are grouped into four categories and discussed in the following sections.

Residential soil samples

Approximately 1,700 residential soil samples were taken at this site between December 2001 and November 2002. All contaminants except arsenic were found at levels below their respective comparison values.

Arsenic is a naturally occurring element present at low levels in soil, water, food, and air. The U.S. Geological Survey reports the background range of arsenic in soil and other surficial materials as <0.1–97 mg/kg, with a mean value of 7.2 mg/kg [16]. MADEP determined that the background arsenic level for this site is 10 mg/kg and established an arsenic cleanup level of 27 mg/kg for this site [17].

To determine whether harmful effects might be possible, ATSDR reviewed the findings from numerous studies documenting the effects of acute and chronic exposures to arsenic in humans. The several factors that should be considered when evaluating the health hazard associated with arsenic in soil include the bioavailability of arsenic in soil, pica-like behavior in children, and carcinogenic effects. Children and children with soil-pica behavior are a special concern for acute exposures because ingesting high amounts of soil could lead to significant arsenic exposure.

ATSDR has developed a provisional acute and chronic oral MRL for arsenic of 0.005 mg/kg per day and 0.0003 mg/kg per day, respectively. The MRL is an exposure level below which noncancerous harmful effects are unlikely. The acute MRL is based on several transient (temporary) effects including nausea, vomiting, and diarrhea. When an estimated acute dose of arsenic is below 0.005 mg/kg per day, noncancerous harmful effects are unlikely. It should be noted that (1) the acute MRL is 10 times below the levels that are known to cause harmful effects in humans, (2) the acute MRL is based on people being exposed to arsenic dissolved in water instead of arsenic in soil—a fact that might influence how much arsenic can be absorbed, and (3) the MRL applies to noncancerous effects only and is not used to determine whether people could develop cancer [18].

The Department of Health and Human Services, the International Agency for Research on Cancer, and EPA have all determined that arsenic is carcinogenic to humans.

Over 1,100 surface soil samples and 500 subsurface soil samples were taken from the residential properties in 2002. Arsenic concentrations in surface and subsurface soil samples ranged from 2.4 to 230 mg/kg and 0.71 to 671 mg/kg, respectively (Table 1). Many samples exceeded the applicable Massachusetts Contingency Plan (MCP) Method 1 S-1 standard of 30 mg/kg for contaminated soil, which is accessible with high frequency of use and high intensity of use. The most likely exposure to contaminants at the site is occasional ingestion or infrequent dermal contact with contaminated surface soil by residents engaged in general activities in the yard such as playing, digging, mowing, and gardening. Conservative dose calculation and cancer risk evaluation (Appendix A) indicated that

- it is unlikely that adults and children at any of the properties at the site would experience noncancerous harmful effects from exposure to arsenic in soil, and
- residents who have a continuous lifetime exposure to arsenic via ingestion have no apparent increased risk of developing cancer.

In addition, the cleanup criteria established by the MADEP are protective of public health; therefore, removal of arsenic contaminated soil at selected properties (Table 1) minimized any potential exposures to arsenic at levels of concern at the site.

To address community concerns about plant uptake of contaminants from soil, ATSDR reviewed the relevant literature. Arsenic is largely immobile in agricultural soils and tends to concentrate and remain in upper soil layers indefinitely [19].Terrestrial plants can accumulate arsenic by root uptake from the soil or by absorption of airborne arsenic deposited on the leaves [20]. But the arsenic level taken up by plants is comparatively low [21–22]. The dominant pathway for transport of arsenic to the leafy vegetables (kale) is by direct atmospheric deposition, while arsenic in the root crops (potatoes and carrots) results from both soil uptake and atmospheric deposition [23]. Data are not available for arsenic concentration in garden produce; however, on the basis of soil arsenic levels found at the site, ATSDR does not expect significant uptake of arsenic by garden produce.

School property soil samples

From December 2001 to December 2002, over 300 surface and subsurface soil samples were taken throughout the school property. Soil samples were analyzed for metals, PAHs, and TPHs. Arsenic is the only contaminant of concern for the area. Arsenic concentrations in soil samples ranged from 2.9 to 239 mg/kg (Table 2). The average concentration of arsenic in soil on the school property was 32.21 mg/kg which exceeded the MCP Method 1 S-1 standard (30 mg/kg). These arsenic levels are similar to those found at the surrounding residential properties. Students, teachers, and other personnel may be exposed to contaminants at the site through occasional ingestion or infrequent dermal contact with contaminated surface soil from general activities such as playing, walking, mowing, and landscaping. As discussed previously, it is unlikely that adults and children experience harmful effects from exposure to arsenic in soil on the school property. In addition, approximately 8,000 tons of arsenic-contaminated soil was removed and appropriately disposed of on the basis of cleanup criteria established by MADEP. The removal activity minimized potential exposures to arsenic at the site and is protective of public health.

Air Monitoring during excavation and removal activities

Air was sampled during the excavation and removal activities to monitor airborne contaminants that may be released into the environment. The air samples were analyzed for total dust and arsenic. Dust was monitored using personal DataRAM (PDR) at locations of removal activities. Arsenic air samples were also collected using low-flow pumps with membrane filter cassettes at these removal sites. Sampling locations were determined on the basis of predominant wind direction, work activities, and areas of concern [24].

Average dust concentrations ranged from 0 to 0.182 mg/m^3 and were below the safe concentration of 0.65 mg/m^3 that EPA determined for the site (Table 3). Arsenic was not detected at any location above specified laboratory reporting limits (Table 4) and was below the EPA action level of 0.005 mg/m^3 [24].Therefore, exposures to contaminants during construction and removal activities were minimal and it is not likely to result in any adverse health effects for workers or residents.

Groundwater samples

There are seven groundwater monitoring wells on the site and seven groundwater samples were collected and analyzed for metals from May to September, 2002. Only two metals (barium and lead) were detected above the laboratory's method reporting limit. No metals have been detected in the groundwater above their respective CVs. In addition, ground water in the area is not used as drinking water source. Therefore, the groundwater exposure pathway does not exist at the site.

Child health considerations

ATSDR considers children in its evaluations of all exposures, and we use health guidelines that are protective of children. In general, ATSDR assumes that children are more susceptible to chemical exposures than are adults.

ATSDR has taken into account that children are at a greater risk for exposure than are adolescents or adults because

- The normal behavior of children might result in higher rates of ingestion of arsenic contaminated soil and dust,
- Children might also receive a higher dose of arsenic because they have lower body weights than do adults, and
- Some children might eat soil excessively (soil-pica behavior) and therefore have a higher exposure dose to arsenic in soil.

ATSDR has considered these factors in the development of its conclusions for this site. The CVs used for this health consultation are intended to represent exposures that could be continued for a lifetime for the general population—including potentially susceptible subgroups such as children—without appreciable health risks.

Conclusions

After reviewing the available environmental data, ATSDR determined that the primary route of potential human exposure is ingestion of soil and dust for residents who live on the site and students, teachers, and other personnel attending the school. Environmental data evaluation indicated that

- Adults and children at any of the properties on the site are unlikely to experience noncancerous harmful effects from exposure to arsenic in soil in the past, present, or future;
- Residents who have a continuous lifetime exposure to arsenic via ingestion have no apparent increased risk of developing cancer;
- Consuming home-grown vegetables and potential exposures during gardening activities is unlikely to result in any adverse health effects for residents;
- Exposures to contaminants during construction and removal activities were minimal and are not likely to result in any adverse health effects for workers and residents;
- Groundwater exposure pathway to arsenic does not exist at the site;
- ATSDR has categorized this site as constituting "no apparent public health hazard;" this indicates that human exposure to contaminated soil at the site may have occurred in the past, may now be occurring, or may occur in the future, but the exposure is not expected to cause any adverse health effects.

Recommendations

None at this time.

Public health action plan

Actions taken:

- MADEP conducted initial sampling and oversaw investigation on the school property and some residential properties.
- The City of Salem directed construction and investigations on the school property.
- EPA investigated and removed contaminated soil residential properties.
- The ATSDR regional office representatives participated in public meetings and responded to numerous health questions.
- Over 2,000 environmental samples were collected and more than 12,000 tons of contaminated soil were removed from the site.

Actions planned:

ATSDR will continue to work with MADEP to respond to public health questions and concerns about the site.

Authors and reviewers

Jane Zhu

Environmental Health Scientist
Consultation Section
Exposure Investigation and Consultation Branch
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry (ATSDR)

Gary Perlman
Regional Representative
Division of Regional Operations
Agency for Toxic Substances and Disease Registry (ATSDR)

Reviewers

Susan Moore

Chief, Exposure Investigation and Consultation Branch
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry (ATSDR)

Peter Kowalski

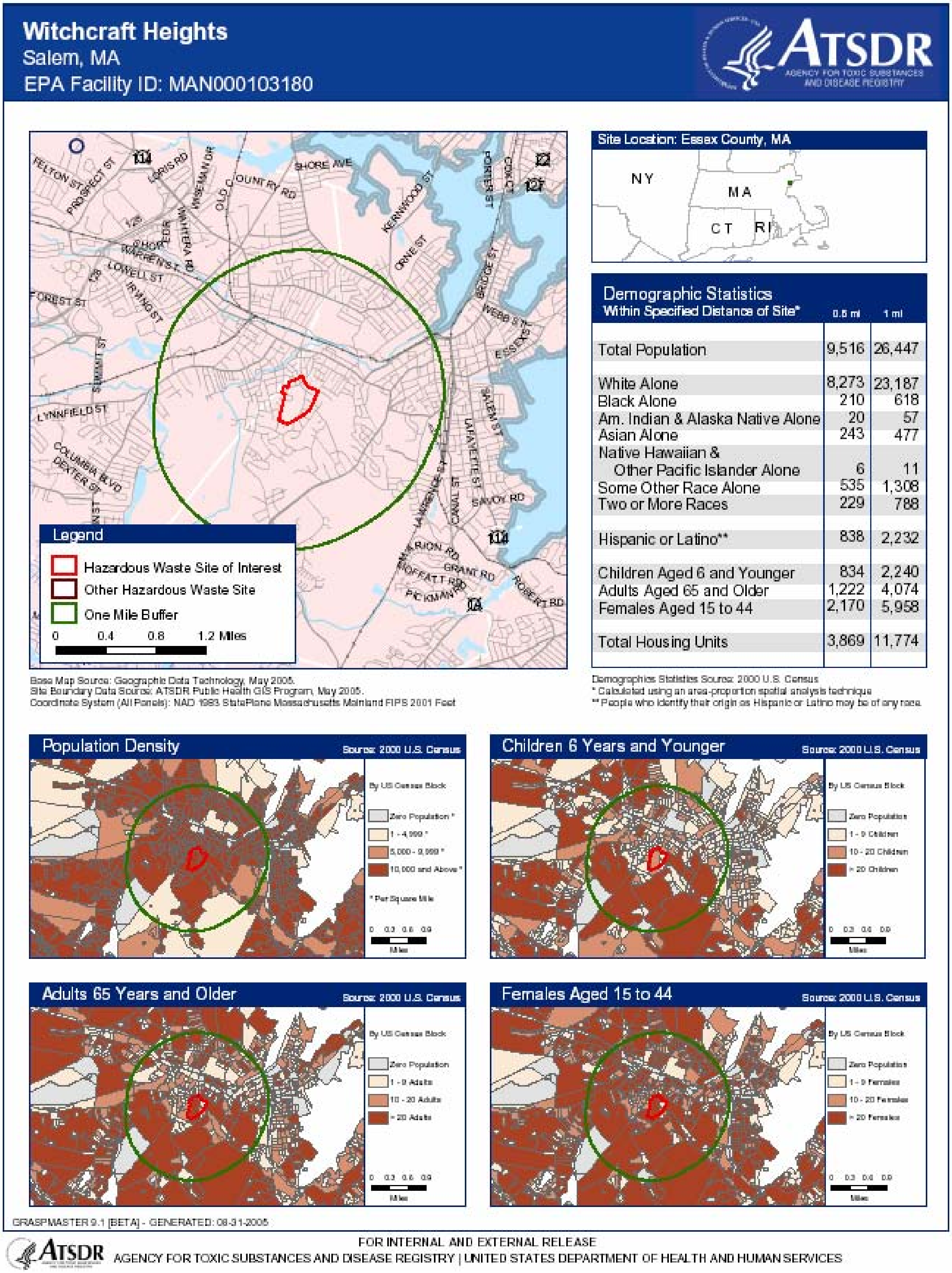
Exposure Investigation and Consultation Branch
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry (ATSDR)

References

1. Scott J. Letter from Joanne Scott (Board of Health, Salem, MA) to Gary Perlman (ATSDR) regarding a petition for a Public Health Assessment at the Witchcraft Heights Elementary School and at properties in the neighborhood of the school. July 16, 2002.
2. ATSDR. AROA for Witchcraft Heights Elementary School. 7/08/2002.
3. Alliance Environmental Group, Inc. IRA Supplemental Investigation Report, 3 and 10 Puritan Road. June 4, 2002.
4. Alliance Environmental Group, Inc. Site Investigation Summary Report, Witchcraft Heights Elementary School. June 17, 2002.
5. Alliance Environmental Group, Inc. Phase I Initial Site Investigation, LSP Opinion, and Tier classification, Witchcraft Heights Elementary School. December, 2002.
6. Barltrop D. The prevalence of pica. Am J Dis Child 1966; 112:116–23.
7. Robischon P. Pica practice and other hand-mouth behavior and children's developmental level. Nurs Res 1971; 20:4–16.
8. Shellshear ID. Environmental lead exposure in Christchurch children: Soil lead a potential hazard. N Z Med J 1975; 81:382–86.
9. Vermeer DE, Frate DA. Geophagia in rural Mississippi: environmental and cultural contexts and nutritional implications. Am J Clin Nutr 1979; 32:2129–35.
10. Danford DE. Pica and nutrition. Annl Rev Nutr 1982; 2:303–22.
11. Stanek EJ, Calabrese EJ. Daily soil ingestion estimates for children at a Superfund site. Risk Anal 2000; 20(5):627–35.
12. Calabrese EJ, Stanek EJ. Soil-pica not a rare event. J. Environ Sci Health. 1993; A28 (2):273–84.
13. US Environmental Protection Agency. Exposure factors handbook, volume 1 – general factors. Washington D.C; 1997 August.
14. Calabrese EJ, Stanek EJ. Soil ingestion estimates in children and adults: A dominant influence in site-specific risk assessment. Environmental Law Reporter, News and Analysis. 1998; 28:10660–71.
15. Agency for Toxic Substances and Disease Registry. Public Health Guidance Manual. Chelsea, Michigan: Lewis Publishers; 1992.
16. US Geological Survey. Element concentrations in soils and other surfical materials of the conterminous US. Carson City, NV: US Department of the Interior; 1984
17. US Environmental Protection Agency. EPA cleanup to resume in the Spring– Community Update #3, Witchcraft Heights site, Salem, Massachusetts. New England, 1/24/2003.
18. Agency for Toxic Substances and Disease Registry. Toxicological profile for arsenic (update). Atlanta: US Department of Health and Human Services; 1999
19. Sanok WJ, Ebel JG, JR, Manzell KL et al, 1995. Residues of arsenic and lead in potato soils on Long Island. Chemosphere 30(4):803–6.
20. US Environmental Protection Agency. Exposure and risk assessment for arsenic. Washington DC: Office of Water Regulations and Standards. PB 85-221711. EPA 440/4-85-005. 1.1-4.68; 1982.
21. Gebel TW, Suchenwirth RHR, Bolten C et al. Human biomonitoring of arsenic and antimony in case of an elevated geogenic exposure. Environ Health Prospect 1998;106(1):33–39.

22. Pitten F-A, Muller G, Konig P et al. Risk assessment of former military base contaminated with organoarsenic-based warfare agent: uptake of arsenic by terrestrial plants. Sci Total Environ 1999; 226:237–45.
23. Larsen EH, Moseholm L, Nielsen MM. Atomospheric deposition of trace elements around point sources and human health risk assessment: II. Uptake of arsenic and chromium by vegetables grown near a wood preservation factory. Sci Total Environ 1992; 126(3):263–75.
24. Weston Solutions, Inc. Superfund Technical Asseement and response Team. Air monitoring plan for the Witchcraft Height site Salem, Essex County, Massachusetts. Wilmington, Massachusetts 01887. 2002.

Figure 1. Site map



Demographic Statistics Within Specified Distance of Site*	0.5 mi	1 mi
Total Population	9,516	26,447
White Alone	8,273	23,187
Black Alone	210	618
Am. Indian & Alaska Native Alone	20	57
Asian Alone	243	477
Native Hawaiian & Other Pacific Islander Alone	6	11
Some Other Race Alone	535	1,308
Two or More Races	229	788
Hispanic or Latino**	838	2,232
Children Aged 6 and Younger	834	2,240
Adults Aged 65 and Older	1,222	4,074
Females Aged 15 to 44	2,170	5,958
Total Housing Units	3,869	11,774

Table 1. Summary of residential surface and subsurface soil samples

Property	Number of samples (depth 0–3")	Arsenic concentration range (depth 0–3") (mg/kg)	Number of samples (depth >3")	Arsenic concentration range (depth >3") (mg/kg)	Cleanup status
1	9	13.1–25.5	10	7.2–64.4	N
2	11	16.3–41.7	10	6.0–95.0	Y
3	10	33.4–65.5	17	10.7–90.8	Y
4	15	5.1–14.6	9	5.0–18.9	N
5	15	5.2–11.7	11	4.1–8.5	N
6	19	6.5–90.1	6	0.71–7.9	N
7	33	4.7–54.5	13	2.3–18	N
8	18	4.1–16.7	5	3.7–6.8	N
9	21	4.2–18.8	4	4.7–6.6	N
10	20	4.0–11.4	6	3.7–7.0	N
11	20	7.7–20	7	4.3–17.6	N
12	20	11.5–49.3	6	5.7–170	Y
13	27	19.0–64.5	6	20.0–555	Y
14	28	3.4–102	0	NA	Y
15	39	6.0–42.1	7	4.2–15.3	N
16	23	5.2–12.5	7	5.1–9.1	N
17	25	6.7–25.1	6	6.4–11.9	N
18	23	3.5–16.7	6	3.4–12.8	N
19	23	3.2–6.3	7	2–6.1	N
20	20	3.8–31.4	3	3.7–26.2	N
21	21	6.1–40.9	8	3.5–24.2	N
22	14	6.2–27.9	12	3.7–77.0	N
23	15	5.9–16.5	7	3.4–13.2	N
24	14	6.5–29.5	13	2.1–24.1	N
25	27	4.1–52.1	12	2.5 –10.6	N
26	25	5.1–45.7	13	3.1–10.6	N
27	38	2.4–21.2	6	4.2–15.4	N
28	21	8.5–51.5	6	5.2–40.9	N
29	18	11.2–50.2	38	7.7–45.7	Y
30	22	8.6–47.3	22	3.8–32.3	Y
31	18	7.1–58.8	8	5.3–23.2	N
32	19	6.1–34.6	4	7.4–25.3	N

Property	Number of samples (depth 0–3")	Arsenic concentration range (depth 0–3") (mg/kg)	Number of samples (depth >3")	Arsenic concentration range (depth >3") (mg/kg)	Cleanup status
33	25	5.9–26.4	5	3.6–7.1	N
34	22	8.6–32.7	5	5.5–34.5	N
35	15	16.6–53.5	15	7.5–161	Y
36	22	9.3–44.8	21	3.6–44	Y
37	21	20.5–59.3	16	4.5–56.3	Y
38	19	11.5–41.5	7	2.3–29.1	Y
39	23	10–46.1	16	5.3–39.9	Y
40	20	7.9–55.1	14	17.1–671	Y
41	21	9.6–90	13	13.3–303	Y
42	32	16.5–61.7	20	2.6–29.8	Y
43	13	13.9–40.8	10	5.9–23.1	N
44	18	22.2–53.3	8	9.0–53	Y
45	20	9–24.8	8	8.9–30.7	N
46	19	5–35.3	12	5.1–32	Y
47	13	9.3–28.1	11	3.5–27	N
48	22	2.4–31.1	12	4.3–34.3	N
49	19	5.5–230	8	3.7–13.9	Y
50	19	3.8–76.2	6	3.1–36.5	N
51	23	4.1–34.7	5	3.0–32.1	N
52	21	5.4–67.9	9	4.6–56.5	Y
53	15	4.2–8.7	6	5.4–10	N
54	15	5.5–54	5	6.2–37	Y
55	20	6.0–35.9	10	0.76–33.8	Y
56	16	8.9–36.9	6	6.1–13.4	N
57	18	5.3–14.8	6	3.8–25.7	N

NA = not available

Mg/kg = milligram per kilogram

N = property not on the cleanup list

Y = property cleaned up

Table 2. Summary of school soil samples

Date sampled	Sample ID	Location	Arsenic concentration (mg/kg)
4/16/2002	L2-1	loam pile	35.9
4/16/2002	L2-2	loam pile	46.8
4/16/2002	L2-3	loam pile	34.6
4/16/2002	L2-4	loam pile	53
4/16/2002	L2-5	loam pile	36.9
4/16/2002	L2-6	loam pile	36.4
4/16/2002	L2-7	loam pile	27.8
4/16/2002	L2-8	loam pile	40.9
4/16/2002	L2-9	loam pile	37
4/16/2002	L2-10	loam pile	19.7
4/16/2002	P2-1	gravel pile	8.33
4/16/2002	P2-2	gravel pile	7
4/16/2002	P2-3	gravel pile	9
4/16/2002	P2-4	gravel pile	6
4/16/2002	P2-5	gravel pile	16.9
4/16/2002	P2-6	gravel pile	5.5
4/16/2002	P2-7	gravel pile	4.3
4/16/2002	P2-8	gravel pile	9.8
4/16/2002	P2-9	gravel pile	10.2
4/16/2002	P2-10	gravel pile	7
4/16/2002	P2-11	gravel pile	7.3
4/16/2002	P2-12	gravel pile	6.1
4/19/2002	CS-1	excavation	95.8
4/19/2002	CS-2	excavation	5.57
4/19/2002	CS-3	excavation	ND(3.6)
4/16/2002	CS-4	excavation	ND(3.55)
4/19/2002	CS-5	excavation	ND(3.91)
4/23/2002	WH-1	site wide	4.6
4/23/2002	WH-2	site wide	6.7
4/23/2002	WH-3	site wide	29.2
4/23/2002	WH-4	site wide	23.1
4/23/2002	WH-5	site wide	ND(3.66)
4/23/2002	WH-6	site wide	ND(3.39)
4/23/2002	WH-7	site wide	ND(3.62)
4/23/2002	WH-8	site wide	16.5
4/23/2002	WH-9	site wide	6.2
4/23/2002	WH-10	site wide	21
4/23/2002	WH-11	site wide	20.2
4/23/2002	WH-12	site wide	2.9
4/23/2002	WH-13	site wide	ND(3.2)
4/23/2002	WH-14	site wide	37.8
4/23/2002	WH-15	site wide	4.2
4/23/2002	WH-16	site wide	35.8

Date sampled	Sample ID	Location	Arsenic concentration (mg/kg)
4/23/2002	WH-17	site wide	19
4/23/2002	WH-18	site wide	57.8
4/23/2002	WH-19	site wide	22.9
4/23/2002	WH-20	site wide	26.5
4/23/2002	WH-21	site wide	10.7
4/23/2002	WH-22	site wide	9.2
4/23/2002	WH-23	site wide	12.2
4/23/2002	WH-24	site wide	14.3
4/23/2002	WH-25	site wide	12.5
4/23/2002	WH-26	site wide	10.8
4/23/2002	WH-27	site wide	9.6
4/23/2002	WH-28	site wide	ND(3.52)
4/23/2002	WH-29	site wide	11
4/23/2002	WH-30	site wide	7.9
4/23/2002	WH-31	site wide	3.8
4/23/2002	WH-32	site wide	7.1
4/23/2002	WH-33	site wide	10.9
4/23/2002	WH-34	site wide	18.9
4/23/2002	WH-35	site wide	ND(3.55)
4/23/2002	WH-36	site wide	ND(3.64)
4/23/2002	WH-37	site wide	4.5
4/23/2002	Int-1	site wide	11.1
4/23/2002	Int-2	site wide	9.3
4/23/2002	Int-3	site wide	8.8
4/23/2002	Int-4	site wide	13
5/7/2002	Blast-1	rock fragment	ND(3.83)
5/7/2002	Blast-2	rock fragment	ND(3.54)
5/7/2002	Blast-3	rock fragment	4.96
5/7/2002	Blast-4	rock fragment	ND(3.48)
5/7/2002	Blast-5	rock fragment	ND(3.33)
5/29/2002	S-20	gas easement	14.2
5/29/2002	S-21	gas easement	59.8
5/29/2002	S-22	gas easement	177
5/29/2002	S-23	gas easement	93.4
5/29/2002	S-24	gas easement	93.6
5/29/2002	S-35	school building	5.01
5/29/2002	S-36	school building	ND(4.16)
5/29/2002	S-39	school building	3.9
5/29/2002	S40	school building	4.4
6/6/2002	DP-1	DP-RW	29.2
6/6/2002	DP-2	DP-RW	30.2
6/6/2002	DP-3	DP-RW	20.1
6/6/2002	DP-4	DP-RW	18.1
6/6/2002	DP-5	DP-RW	17.2
6/6/2002	DP-6	DP-RW	21.9
6/6/2002	DP-8	DP-RW	18.3

Date sampled	Sample ID	Location	Arsenic concentration (mg/kg)
6/6/2002	DP-9	DP-RW	13.7
6/6/2002	DP-10	DP-RW	17.1
6/6/2002	DP-11	DP-RW	20.4
6/6/2002	DP-12	DP-RW	20.1
6/6/2002	DP-13	DP-RW	25.1
6/6/2002	DP-14	DP-RW	17.2
6/6/2002	DP-15	DP-RW	20
6/6/2002	DP-16	DP-RW	24.4
6/6/2002	SC-1	TS-ES	40
6/6/2002	SC-2	TS-ES	62.7
6/6/2002	SC-3	TS-ES	63.5
6/6/2002	SC-4	TS-ES	17.8
6/6/2002	SC-5	TS-ES	10.3
6/6/2002	SC-6	TS-ES	37.8
6/10/2002	S-200	southern ball field	19.3
6/10/2002	S-201	southern ball field	28.6
6/10/2002	S-202	southern ball field	8
6/10/2002	S-205	southern ball field	8.5
6/10/2002	S-207	southern ball field	7.5
6/10/2002	S-209	southern ball field	4.1
6/10/2002	S-211	southern ball field	ND(4.42)
6/10/2002	S-214	southern ball field	ND(3.38)
6/10/2002	S-215	southern ball field	ND(4.57)
6/10/2002	S-216	southern ball field	5
6/10/2002	S-217	southern ball field	5.7
6/10/2002	S-218	southern ball field	ND(3.46)
6/10/2002	S-219	southern ball field	4.2
6/12/2002	S-300	northern ball field	57.3
6/12/2002	S-301	northern ball field	52.2
6/12/2002	S-302	northern ball field	85
6/12/2002	S-303	northern ball field	73.7
6/12/2002	S-304	northern ball field	9.4
6/12/2002	S-305	northern ball field	8.6
6/12/2002	S-306	northern ball field	4.9
6/12/2002	S-307	northern ball field	35.5
6/12/2002	S-308	northern ball field	36.7
6/12/2002	S-309	northern ball field	61.8
6/12/2002	S-310	northern ball field	22.7
6/12/2002	S-311	northern ball field	25.2
6/12/2002	S-312	northern ball field	9.9
6/12/2002	S-313	northern ball field	6.9
6/12/2002	S-314	northern ball field	6.3
6/12/2002	S-315	northern ball field	5.1
6/12/2002	S-316	northern ball field	5.1
6/12/2002	S-317	northern ball field	8.4
6/12/2002	S-318	northern ball field	32

Date sampled	Sample ID	Location	Arsenic concentration (mg/kg)
6/12/2002	S-320	northern ball field	3.5
6/12/2002	S-321	northern ball field	223
6/12/2002	S-322	northern ball field	239
6/12/2002	S-323	northern ball field	55.5
6/12/2002	S-324	northern ball field	69.4
6/12/2002	S-325	northern ball field	69.8
6/12/2002	S-326	northern ball field	63.1
6/12/2002	S-327	northern ball field	22.9
6/12/2002	S-328	eastern slope	7.9
6/12/2002	S-329	eastern slope	7.6
6/12/2002	S-330	eastern slope	37.4
6/12/2002	S-331	eastern slope	67.8
6/12/2002	S-332	eastern slope	80.3
6/12/2002	S-333	eastern slope	38.2
6/12/2002	S-334	eastern slope	89.9
6/12/2002	S-335	eastern slope	54.1
6/12/2002	S-336	eastern slope	48.1
6/12/2002	S-337	eastern slope	41.1
6/12/2002	S-338	eastern slope	7.7
6/12/2002	S-339	eastern slope	157
6/12/2002	S-340	eastern slope	133
11/19/2002	WHS-1	eastern slope	35
11/19/2002	WHS-2A	eastern slope	75.1
11/19/2002	WHS-2B	eastern slope	ND(NA)
11/19/2002	WHS-3A	eastern slope	23.2
11/19/2002	WHS-3B	eastern slope	43.9

ND = not detected at or above specified laboratory reporting limit. Values in parentheses are laboratory reporting limits.
NA = not available
DP-RW = detention pond and retaining wall area
TS-ES = top of the slop on the eastern site of the site

Table 3. Summary of air monitoring for total dust during excavation and removal activities

Sample ID	Sample Date	Maximum concentration (mg/m^3)	Average concentration (mg/m^3)	*Sample Location*
1	12/2/2002	0.318	0.014	201102A
2	12/2/2002	0.234	0.016	201102B
3	12/2/2002	0.124	0.008	201102C
4	12/2/2002	0.11	0.009	201102D
5	12/2/2002	0.101	0.011	201102E
6	12/3/2002	0.215	0.019	031202A
7	12/3/2002	0.07	0.008	031202B
8	12/3/2002	0.031	0.003	031202C
9	12/3/2002	0.095	0.015	031202D
10	12/3/2002	0.363	0.008	031202E
11	12/5/2002	0.422	0.021	051202A
12	12/5/2002	1.133	0.038	051202B
13	12/5/2002	0.252	0.011	051202C
14	12/5/2002	0.197	0.018	051202D
15	12/5/2002	0.123	0.009	051202E
16	12/6/2002	0.046	0	061202A
17	12/6/2002	0.785	0.023	061202B
18	12/6/2002	0.16	0	061202C
19	12/10/2002	1.952	0.008	101202A
20	12/10/2002	5.958	0.029	101202B
21	12/10/2002	17.952	0.036	101202C
22	12/10/2002	8.32	0.034	101202D
23	12/10/2002	6.907	0.023	101202E
24	12/11/2002	2.704	0.016	111202A
25	12/11/2002	1.567	0.007	111202B

Sample ID	Sample Date	Maximum concentration (mg/m³)	Average concentration (mg/m³)	*Sample Location*
26	12/11/2002	1.063	0.027	111202C
27	12/11/2002	0.913	0.015	111202D
28	12/11/2002	1.466	0.023	111202E
29	12/17/2002	0.222	0.014	171202A
30	12/17/2002	0.645	0.006	171202B
31	12/17/2002	0.652	0.004	171202C
32	12/17/2002	0.1	0.012	171202D
33	12/17/2002	0.852	0.006	171202E
34	11/19/2002	0.462	0.003	191102A
35	11/19/2002	0.344	0	191102B
36	11/20/2002	0.078	0.031	201102A
37	11/20/2002	0.128	0.024	201102B
38	11/21/2002	1.245	0.182	211102A
39	11/21/2002	0.6	0.114	211102B
40	1/22/2003	0.579	0.014	220103A
41	1/22/2003	0.224	0.01	220103B
42	1/22/2003	0.216	0	220103C
43	1/22/2003	0.728	0.002	220103D
44	1/22/2003	0.659	0.004	220103E
45	1/23/2003	0.162	0.012	230103A
46	1/23/2003	0.391	0.014	230103B
47	1/23/2003	0.318	0	230103C
48	1/23/2003	0.232	0.004	230103D
49	1/23/2003	3.28	0.012	230103E
50	1/24/2003	0.151	0.017	240103A
51	1/24/2003	0.421	0.019	240103B

Sample ID	Sample Date	Maximum concentration (mg/m³)	Average concentration (mg/m³)	***Sample Location***
52	1/24/2003	0.291	0	240103C
53	1/24/2003	0.157	0.008	240103D
54	1/24/2003	0.525	0.008	240103E
55	11/25/2002	0.149	0.01	251102A1
56	11/25/2002	0.026	0.002	251102A2
57	11/25/2002	0.202	0.014	251102B
58	11/25/2002	0.928	0.017	251102C
59	11/25/2002	1.055	0.018	251101D
60	11/25/2002	0.633	0.019	251102E
61	11/26/2002	0.216	0.005	261102A
62	11/26/2002	0.157	0.009	261102B
63	11/26/2002	0.115	0.023	261102C
64	11/26/2002	0.106	0.005	261102D
65	11/26/2002	0.197	0.015	261102E

Note:
mg/m³ = milligrams per cubic liter

Table 4. Summary of Air Monitoring for Arsenic during Excavation and Removal Activities

Sample ID	Location	Date	*Result ($\mu g/m^3$)*
WHS-01	Trailer	05/22/02	<0.17
WHS-02	C-building—doorway	05/22/02	<0.16
WHS-03	D Building—west hallway	05/22/02	<0.17
WHS-04	D Building—east hallway	05/22/02	<0.20
WHS-05	C-building—main connector	05/22/02	<0.23
D09690	Excavator	11/27/02	ND(0.08)
D09691	Bobcat	11/27/02	ND(0.09)
D09693	Bobcat	12/02/02	ND (0.09)
D09694	Bobcat	12/03/02	ND (0.11)
D09695	Bobcat	12/05/02	ND (0.10)
D09696	Excavator	12/06/02	ND (0.11)
D09698	Excavator	12/10/02	ND (0.10)
D09699	Witchcraft Rd	12/11/02	ND (0.09)
851980	Ord Street	10/29/02	ND (0.24)
851981	Ord Street	10/29/02	ND (0.24)
851982	Witchcraft Rd	10/29/02	ND (0.24)
851983	Puritan Rd	10/29/02	ND (0.26)
851985	Ord Street	10/30/02	ND (0.22)
851986	Ord Street	10/30/02	ND (0.22)
851987	Puritan Rd	10/30/02	ND (0.22)
851988	Witchcraft Rd	10/30/02	ND (0.22)
851990	Puritan Rd	10/31/02	ND (0.22)
851991	Ord Street	10/31/02	ND (0.22)
851992	Ord Street	10/31/02	ND (0.22)
851993	Witchcraft Rd	10/31/02	ND (0.22)
851995	Witchcraft Rd	11/01/02	ND (0.26)
851996	Ord Street	11/01/02	ND (0.26)
851997	Puritan Rd	11/01/02	ND (0.26)
851998	Ord Street	11/01/02	ND (0.26)
852000	Ord Street	11/04/02	ND (0.22)
852001	Ord Street	11/04/02	ND (0.22)
852002	Puritan Rd	11/04/02	ND (0.22)
852003	Witchcraft Rd	11/04/02	ND (0.22)
852005	Personal air	11/04/02	ND (0.22)
852006	Personal air	11/04/02	ND (0.22)
852007	Personal air	11/05/02	ND (0.22)
852008	Personal air	11/05/02	ND (0.22)
852009	Ord Street	11/05/02	ND (0.21)
852010	Ord Street	11/05/02	ND (0.21)
852011	Puritan Rd	11/05/02	ND (0.21)
852012	Witchcraft Rd	11/05/02	ND (0.21)
852014	Personal air	11/06/02	ND (0.48)
852015	Personal air	11/06/02	ND (0.48)
852016	Ord Street	11/06/02	ND (0.28)
852017	Ord Street	11/06/02	ND (0.28)

Sample ID	Location	Date	*Result ($\mu g/m^3$)*
852018	Puritan Rd	11/06/02	ND (0.28)
852019	Witchcraft Rd	11/06/02	ND (0.28)
852021	Personal air	11/07/02	ND (0.22)
852022	Personal air	11/07/02	ND (0.22)
852023	Ord Street	11/07/02	ND (0.22)
852024	Ord Street	11/07/02	ND (0.22)
852025	Puritan Rd	11/07/02	ND (0.22)
852026	Witchcraft Rd	11/07/02	ND (0.22)
852028	Personal air	11/08/02	ND (0.22)
852029	Personal air	11/08/02	ND (0.22)
852030	Ord Street	11/08/02	ND (0.21)
852031	Ord Street	11/08/02	ND (0.21)
852032	Puritan Rd	11/08/02	ND (0.22)
852033	Witchcraft Rd	11/08/02	ND (0.22)
852035	Witchcraft Rd	11/08/02	ND (0.22)
852040	Personal air	11/08/02	ND (0.21)
852041	Personal air	11/08/02	ND (0.21)
852042	Ord Street	11/08/02	ND (0.22)
852043	Ord Street	11/08/02	ND (0.22)
852044	Puritan Rd	11/08/02	ND (0.22)
852045	Witchcraft Rd	11/08/02	ND (0.22)
852046	Witchcraft Rd	11/08/02	ND (0.22)
852048	Personal air	11/12/02	ND (0.24)
852049	Personal air	11/12/02	ND (0.24)
852050	Ord Street	11/12/02	ND (0.21)
852051	Ord Street	11/12/02	ND (0.21)
852052	Puritan Rd	11/12/02	ND (0.21)
852053	Witchcraft Rd	11/12/02	ND (0.21)
852054	Witchcraft Rd	11/12/02	ND (0.21)
852056	Personal air	11/13/02	ND (0.28)
852057	Personal air	11/13/02	ND (0.28)
852058	Ord Street	11/13/02	ND (0.28)
852059	Ord Street	11/13/02	ND (0.28)
852060	Puritan Rd	11/13/02	ND (0.28)
852061	Witchcraft Rd	11/13/02	ND (0.28)
852062	Witchcraft Rd	11/13/02	ND (0.28)
852064	Ord Street	11/14/02	ND (0.22)
852065	Ord Street	11/14/02	ND (0.22)
852066	Puritan Rd	11/14/02	ND (0.22)
852067	Witchcraft Rd	11/14/02	ND (0.23)
852068	Witchcraft Rd	11/14/02	ND (0.23)
849665	Not available	11/15/02	ND(0.22)
852070	Excavator	11/18/02	ND(0.48)
852072	Excavator	11/19/02	ND(0.21)
852075	Excavator	11/20/02	ND(0.21)
8520777	Excavator	11/21/02	ND(0.21)
850110	Excavator	11/22/02	ND(0.27)

$\mu g/m^3$ = micrograms per cubic liter

ND = not detected at or above specified laboratory reporting limit. Values in parentheses are laboratory reporting limits.

Appendix A.

Dose calculation for estimating arsenic exposure doses and cancer risk evaluation

The major exposure pathway by which residents can be exposed to arsenic at the site is incidental ingestion of contaminated soil. Children and children with soil-pica behavior are a special concern for acute exposures because ingesting high amounts of soil could lead to significant arsenic exposure.

Estimate ingestion exposure dose for arsenic

The following assumptions were made to estimate ingestion exposure dose for arsenic:

(1) an adult resident's body weight is 70 kg,

(2) an adult resident's soil ingestion rate is 100 mg/day

(3) a child's body weight is 16 kg,

(4) a child's soil ingestion rate is 200 mg/day,

(5) a soil-pica child's maximum soil ingestion rate is 5,000 mg/day at a soil-pica frequency of 3 days per week.

The following mathematical formula was used to estimate the daily intake of arsenic:

$$ID = C \times IR \times BA \times EF \times 10^{-6}/BW$$

Where,

ID = ingestion exposure dose (mg/kg day^{-1})

C = contaminant concentration (mg/kg), the maximum arsenic concentration in surface soil of 230 mg/kg are used to represent the worst case scenario for acute exposures, and the site clean up level of 27 mg/kg are used to represent chronic exposures. The top five arsenic concentrations in surface soil of 230, 102, 90.1, 90, 76.2 mg/kg are used to calculate the doses for soil-pica child.

IR = ingestion rate (mg/day)

BA = bioavailability factor (unitless, conservatively assumed to be 42% on the basis of an EPA study by Casteel and colleagues [1].

EF = exposure factor (unitless, conservatively assumed to be 1.0 for adults and children, and 0.429 for soil-pica children)

BW = body weight (kg)

For adults and children, the following table shows the estimated absorbed doses at acute and chronic exposure durations:

Population	Estimated arsenic doses (acute exposures)	Acute MRL (mg/kg day^{-1})	Estimated arsenic doses (chronic exposures)	*Chronic MRL (mg/kg day^{-1})*
Adult	0.0001	0.005	0.00001	0.0003
Child	0.0012	0.005	0.0001	0.0003

It is unlikely that adults and children at any of the properties at site sampled experience non-cancerous harmful effects from exposure to arsenic in soil.

For soil-pica children, the following table shows the five highest arsenic levels in residential properties and the cleanup level at the site along with the estimated absorbed doses of arsenic:

Average arsenic concentration (mg/kg)	Estimated arsenic doses in children with pica behavior (mg/kg day^{-1})	Acute MRL (mg/kg day^{-1})	*Exceeds health guideline*
230	0.013	0.005	yes
102	0.005	0.005	no
90.1	0.005	0.005	no
90	0.005	0.005	no
76.2	0.004	0.005	no
27	0.002	0.005	no

Only the property with the maximum arsenic concentration of 230 mg/kg has an estimated arsenic absorbed dose in children with pica behavior that exceeded the acute MRL of 0.005 mg/kg. However, the hot spot in the yard is located near a chain-link fence along the property line where it is not readily accessible to small children, and the average surface soil arsenic concentration for the property is 19.68 mg/kg. Therefore, it is unlikely that a soil-pica child might have a dose that caused temporary harmful effects. In addition, the EPA cleanup program removed more than 4,000 tons of contaminated soil from 21 properties which meet the criteria established by MADEP including the property with the hot spot. The cleanup criteria are protective of public health for the site.

Cancer Risk Evaluations for surface soil arsenic levels

Ingestion dose-arsenic (summer)

In this calculation, we are estimating the lifetime average daily dose (LADD) of arsenic a child/adult age 1–30 years would receive from ingestion of soil during 5 warm weather months.

LADDcs = IRc × [Soil] × EF × ED × C1 × C2 × 1/BWc × 1/ATca

LADDcs =200mg/d × 27mg/kg × 150d/y × 6 yr × 10^{-6} kg/mg × y/365 d ×1/16 kg × 1/70 yr
=200 × 27 × 150 × 6 × (0.000001) × (1/365) × (1/16) × (1/70)
= 1.2E-5 mg/kg day^{-1}

LADDas = IRas × [Soil] × EF × ED × C1 × C2 × 1/BWa × 1/ATca

LADDas = 100 mg/d × 27 mg/kg × 40 d/y × 24 yr × 10^{-6} kg/mg × y/365 d × 1/70 kg × 1/70 yr
=100 × 27 × 40 × 24 × (0.000001) × (1/365) × (1/70) × (1/70)
= 1.4E-6 mg/kg day^{-1}

Ingestion dose-arsenic (winter)

In this calculation, we are estimating the lifetime average daily dose of arsenic a child/adult age 1–30 years would receive from ingestion of soil during 7 cold weather months- includes daily contact with soil outdoors or in house dust which may be ingested

LADDcw = IRc × [Soil] × EF ×ED ×C1 × C2 × 1/BWc ×1/ATca

LADDcw =200mg/d × 27mg/kg × 210d/y × 6 yr × 10^{-6} kg/mg × y/365 d ×1/16 kg × 1/70 yr.
=200 × 27 × 210× 6 × (0.000001) v (1/365) × (1/16) × (1/70)
= 1.7E-5 mg/kg/ day

LADDaw = IRaw × [Soil] × EF × ED × c1 × c2 × 1/BWa × 1/ATca

LADDaw = 10 mg/d × 27mg/kg × 325 d/y × 24 yr × 10^{-6} kg/mg × y/365 d × 1/70 kg × 1/70 yr
=10 × 27 × 325 × 24× (0.000001) × (1/365) × (1/70) × (1/70)
= 1.20E-6 mg/kg/ day

Excess Lifetime Cancer Risks (ELCR)

ELCR = (LADDcs+LADDas+LADDcw+LADDaw) ×CSF
ELCR = (**1.2E-5** + **1.4E-6** + **1.7E-5** + **1.20E-6**) × CSF
ELCR = 3.2E-5 mg/kg day^{-1} × 1.5 mg/kg day^{-1}
ELCR = 5E-05

Definitions

Parameter	**Definition**
[Soil]	soil concentration; 27 mg/kg (Total 95% UCL for all arsenics)
ATca	averaging time for cancer risk; 70 years
BWa	adult 50th percentile body weight [2]; 70 kg
BWc	child 50th percentile body weight for age 1–6 yrs [3] ; 16 kg
c1	conversion factor; 10^{-6} kg/mg
c2	conversion factor; 1 year/365 days
CSF	cancer slope factor for arsenics 1.5 (mg/kg day^{-1} [4]
ED	exposure duration; 6 years for child, 24 years for adult
EF	exposure frequency; days/year child: 5 × 30 days for summer; 7 × 30 days for winter. Adult: summer 40 days per summer (4 times per month for 5 months.) Adult: winter 365–40 days
IRas	soil ingestion rate for an adult in summer; 100 mg/day [5]
IRaw	soil ingestion rate for an adult in winter [6]

IRc	soil ingestion rate for a child; 200 mg/day [5]
LADDas	lifetime average daily summer dose from ingestion for adult, aged 7–30 years
LADDaw	lifetime average daily winter dose from ingestion for adult, aged 7–30 years
LADDcs	lifetime average daily summer dose from ingestion for child, aged 1–6 years
LADDcw	lifetime average daily winter dose from ingestion for child, aged 1–6 years

Using a conservative risk evaluation, residents who have a continuous 30 years exposure to those chemicals via ingestion have no apparent increased risk (5E–05) of developing cancer.

References

1. Casteel SW, Evans T, Dunsmore ME, et al. 2001. Relative bioavailability of arsenic in mining wastes. Denver, CO: US Environmental Protection Agency, Region 8.

2. ATSDR 1993. Public Health Assessment Guidance Manuel, Agency for Toxic Substances and Disease Registry, 1993.

3. ATSDR 1993. Public Health Assessment Guidance Manuel, Agency for Toxic Substances and Disease Registry, 1993.

4. IRIS. EPA Integrated Risk Information System. Cancer slope factor for Arsenic. Available at http://www.epa.gov/iris/subst/0278.htm. Accessed 06April 2006

5. EPA 1997. Exposure Factors Handbook. EPA/600/P-95/002Fa. Available at http://www.epa.gov/ncea/pdfs/efh/front2.pdf Accessed on 17 March 2006.

6. ATSDR 2000, Health Consultation Assessment of Surface Soil sampling Data at the Millbrooke Condominiums Site East Windsor, Hartford County, Connecticut,

Appendix B. ATSDR's comparison values and definitions

ATSDR comparison values (CVs) are media-specific concentrations considered safe under default exposure scenario. ATSDR uses them as screening values to identify contaminants (site-specific substances) that require further evaluation to determine the potential for adverse health effects. Generally, a chemical at a site requires further evaluation when its maximum concentration in air, water, or soil exceeds one of ATSDR's comparison values. Comparison values are *not*, however, thresholds of toxicity. While concentrations at or below the relevant comparison value may reasonably be considered safe, it does not automatically follow that any environmental concentration that exceeds a comparison value would be expected to produce adverse health effects. Indeed, the purpose behind these highly conservative, health-based standards and guidelines is to enable health professionals to recognize and resolve potential public health problems *before* they become actual health hazards. The probability that adverse health outcomes will actually occur as a result of exposure to environmental contaminants depends on individual lifestyles and genetic factors and site-specific conditions that affect the route, magnitude, and duration of actual exposure, and not on environmental concentrations alone.ATSDR derives screening values on the basis of noncancerous effects by dividing a no-observed-adverse-effect level (NOAEL) by lowest-observed-adverse-effect levels (LOAELs). These levels stem from animal or human studies and include cumulative safety margins (variously called safety factors, uncertainty factors, or modifying factors) that typically range from 10 to 1,000 or more. By contrast, cancer-based screening values come from linear extrapolations from animal data obtained at high doses because human cancer incidence data for very low levels of exposure simply do not exist, and probably never will.

Listed below are the comparison values that ATSDR uses to select chemicals for further evaluation, along with the abbreviations for the most common units of measure.

EMEG = environmental media evaluation guides

RMEG = reference dose media evaluation guide

MRL = minimal risk level

ppm = parts per million (mg/L, mg/kg)

ppb = parts per billion (µg/L, µg/kg)

kg = kilogram (1,000 gram)

mg = milligram (0.001 gram)

µg = microgram (0.000001 gram)

L = liter

m^3 = cubic meter (= 1,000 L)

acute exposure: exposure to a chemical for a duration of 14 days or less.

cancer risk evaluation guide (CREG): estimated contaminant concentration in water, soil, or air that would be expected to cause no more than one excess case of cancer in a million persons exposed over a lifetime. CREGs are calculated from EPA's cancer slope factors.

chronic exposure: exposure to a chemical for 365 days or more.

environmental media evaluation guide (EMEG): concentration of a contaminant in water, soil, or air unlikely to produce any appreciable risk of adverse, non-cancer effects over a specified duration of exposure. EMEGs are derived from ATSDR minimal risk levels by factoring in default body weights and ingestion rates. ATSDR computes separate EMEGs for acute (≤14 days), intermediate (15–364 days), and chronic (≥365 days) exposures.

intermediate exposure: exposure to a chemical for a duration of 15–364 days.

lowest observed adverse effect level (LOAEL): The lowest exposure level of a chemical in a study or group of studies that produces statistically or biologically significant increase(s) in frequency or severity of adverse health effects between the exposed and control populations.

minimal risk level (MRL): estimate of daily human exposure to a hazardous substance that is not likely to pose an appreciable risk of adverse noncancer health effects over a specified route and duration of exposure.

no-observed-adverse-effect level (NOAEL): The dose of a chemical at which no statistically or biologically significant increases in frequency or severity of adverse health effects were seen between the exposed population and its appropriate control. Effects may be produced at this dose, but they are not considered to be adverse.

uncertainty factor (UF): a factor used in deriving the MRL or reference dose or reference concentration from exposure data.

The following comparison values were used for this health consultation:

Environmental media evaluation guide (EMEGs)

Reference dose media evaluation guide (RMEGs)

Cancer risk evaluation guides (CREGs)

MADEP has established an arsenic cleanup level of 27 mg/kg for this site.

Appendix C. ATSDR's levels of public health hazard

Category A: Urgent public health hazard

This category is used for sites where short-term exposures (<1 year) to hazardous substances or conditions could result in adverse health effects that require rapid intervention.

This determination represents a professional judgment based on critical data that ATSDR has judged sufficient to support a decision. Such a designation does not necessarily mean that the available data are complete; in some cases, additional data may be required to confirm or further support the decision made.

Criteria:

Evaluation of available relevant information* indicates that site-specific conditions or likely exposures have had, are having, or are likely to have an adverse impact on human health that requires immediate action or intervention. Such site-specific conditions or exposures may include the presence of serious physical or safety hazards, such as open mine shafts, poorly stored or maintained flammable or explosive substances, or medical devices, which, if ruptured, could release radioactive materials.

Category B: Public health hazard

This category is used for sites that pose a public health hazard because of the existence of long-term exposures (>1 yr) to hazardous substances or conditions that could result in adverse health effects.

This determination represents a professional judgment based on critical data that ATSDR has judged sufficient to support a decision. Such a designation does not necessarily mean that the available data are complete; in some cases, additional data may be required to confirm or further support the decision made.

Criteria:

Evaluation of available relevant information* suggests that, under site-specific conditions of exposure, long-term exposures to site-specific contaminants (including radionuclides) have had, are having, or are likely to have an adverse impact on human health that requires one or more public health interventions. Such site-specific exposures may include the presence of serious physical hazards, such as open mine shafts, poorly stored or maintained flammable or explosive substances, or medical devices, which, if ruptured, could release radioactive materials.

Category C: Indeterminate public health hazard

This category indicates that a professional judgment on the level of health hazard cannot be made because information critical to such a decision is lacking.

Criteria:

This category is used for sites for which available *critical* data are insufficient with regard to the extent of exposure and/or toxicological properties at estimated exposure levels. Using professional judgment, the health assessor must determine the importance of such data and the likelihood that the data can and will be obtained in a timely manner. Where some data—even limited data—are available, health assessors should, to the extent possible, select other hazard categories and support their decision with a clear narrative that explains the limits of the data and the rationale for the decision.

Category D: No apparent public health hazard

This category designates sites where human exposure to contaminated media may be occurring, may have occurred in the past, and/or may occur in the future, but the exposure is not expected to cause any adverse health effects.

This determination represents a professional judgment based on critical data that ATSDR has judged sufficient to support a decision. Such a designation does not necessarily mean that the available data are complete; in some cases, additional data may be required to confirm or further support the decision made.

Criteria:

Available relevant information* indicates that, under site-specific conditions of exposure, exposures to site-specific contaminants in the past, present, or future are not likely to result in adverse impact on human health.

Category E: No public health hazard

This category is used for sites that, because of the absence of exposure, do *not* pose a public health hazard.

Criteria:

Sufficient evidence indicates that no human exposures to contaminated media have occurred, none are occurring, and none are likely to occur in the future.

* *Examples include environmental, demographic, health outcome, exposure, toxicological, medical, or epidemiologic data and information about community health concerns.*