

Health Consultation

Evaluation of Shallow Residential Soils

ARSENIC MINE SITE

TOWN of KENT, PUTNAM COUNTY, NEW YORK

EPA FACILITY ID: NYD982531469

Prepared by the
New York State Department of Health
Center for Environmental Health

April 30, 2019

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

Health Consultation: A Note of Explanation

A health consultation is a verbal or written response from ATSDR or ATSDR's Cooperative Agreement Partners 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 or ATSDR's Cooperative Agreement Partner which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

For copies of this document, or with other questions, you may contact the

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SUMMARY

The United States Environmental Protection Agency (USEPA) requested that the Agency for Toxic Substances and Disease Registry (ATSDR) evaluate soil samples collected in 2017 and 2018 at residential properties on the USEPA Arsenic Mine Site in Kent, Putnam County, New York. The USEPA collected samples to determine the extent of arsenic in residential soils and whether prompt action is needed to reduce harmful exposures to arsenic-contaminated soils and mine tailings. The New York State Department of Health (NYSDOH) reviewed the soil data collected by the USEPA and evaluated the public health implications of the contamination. This health consultation formalizes the NYSDOH's evaluation of the data, and this health consultation was prepared under a cooperative agreement with ATSDR.

The intent of this health consultation is to ensure that residents have the best information possible about how environmental contaminants might affect their health. A health consultation provides advice on specific public health effects that could occur following human exposure to a hazardous material. The evaluation of arsenic contaminated soil at select residential properties forms the basis for the conclusions and recommendations in this health consultation. The evaluation does not consider other possible sources of arsenic exposure such as inhalation of arsenic contaminated soil or dust, consumption of untreated drinking water, consumption of home raised animal products, or consumption of fruits and vegetables grown in contaminated soil. Consideration of these additional potential exposure pathways may likely support and strengthen the conclusions and recommendations contained in this health consultation.

CONCLUSION 1

The NYSDOH and ATSDR conclude that short-term ingestion exposure of children to arsenic in shallow (zero to six inches) soils with the highest arsenic levels at residential properties on the Arsenic Mine Site pose an immediate and significant threat to human health, thus constituting an urgent public health hazard.

BASIS FOR CONCLUSION

Short-term exposure to arsenic in residential soil could result in adverse health effects. For all ten residential properties evaluated, a single ingestion of a large amount of soil (i.e., 5 grams) containing the maximum arsenic soil level found at each property, by a 1 to 2-year-old child exhibiting pica¹ behavior, results in an arsenic dose that either exceeds or approaches the short-term arsenic exposure level that causes non-cancer health effects. On seven properties, a single ingestion of a smaller amount of soil (i.e., 200 milligrams) containing the maximum arsenic level results in an arsenic dose that either exceeds or approaches the short-term arsenic exposure level that causes non-cancer health effects. Health effects that can result from short-

¹ Pica is defined by behavior that involves eating and ingesting non-food substances, such as soil.

term, high-level arsenic exposure include vomiting, headaches, stomach cramps, diarrhea, and facial swelling, especially around the eyes. These effects are typically temporary and should subside when exposure to arsenic ceases.

CONCLUSION 2

The NYSDOH and ATSDR conclude that long-term ingestion and dermal exposure of children and adults to arsenic in shallow soil at residential properties on the Arsenic Mine Site pose a significant threat to human health and constitute a public health hazard.

BASIS FOR CONCLUSION

Long-term exposure to arsenic in residential soil could result in adverse health effects. For all ten residential properties evaluated, long-term arsenic exposure in soil results in an estimated lifetime cancer risk of over 1 in 10,000. For six of the residential properties, the arsenic exposure results in an estimated lifetime cancer risk of 1 in 1,000 or higher and for three properties, the estimated cancer risk is over 1 in 100, which is unusually high for environmental exposures. Long term exposure to high levels of arsenic is known to cause cancer of the skin, lung, and bladder in humans. Regarding non-cancer health risks, long-term exposure to arsenic in soil at all properties results in an arsenic dose that either exceeds or approaches the long-term arsenic exposure level that causes health effects. Long-term human exposure to arsenic also causes skin hyperpigmentation and keratosis, or a darkening and thickening of the skin on the hands and feet, as well as other adverse health effects [USEPA 1991; ATSDR 2007].

RECOMMENDATIONS

Based on the significantly increased risk for adverse health effects, the NYSDOH and ATSDR strongly recommend that the USEPA implement immediate actions to prevent or reduce the potential for residents, especially children, to be exposed to arsenic contamination in residential soils.

Until a long-term remedial action can be put in place, the NYSDOH and ATSDR recommend residents implement the following interim measures to reduce arsenic exposure:

- People, especially children, should minimize direct and repeated contact with bare soils.
- Maintain a grass or mulch cover wherever possible to help prevent direct contact with the soil.
- Wipe shoes on doormat or remove shoes before entering the home. Apply general good housekeeping practices by periodically damp mopping floors, vacuuming (using a HEPA filter if available), and cleaning furniture to help reduce exposure to outdoor soil that might be tracked indoors. Avoid the use of brooms.
- Avoid unnecessary digging in the dirt.

- Children and adults should wash hands after outdoor activities to help reduce the potential for exposure.
- Wash children's toys regularly.
- Refrain from landscaping activities that increase exposure to soil and create bare areas of soil.
- Refrain from eating food or smoking when working in the yard.
- Refrain from eating home raised fruits, vegetables, and animal products. If residents choose to garden, they should grow crops in raised bed gardens and containers with clean soil imported from a non-contaminated area or bagged soil bought commercially instead of the existing soil. Residents should wear gloves when gardening and dispose or wash gloves thoroughly after each use.
- Regularly wash pets that may go outdoors and contact the soil.
- Properly maintain water treatment systems in accordance with the manufacturer's specification.

People who have further questions about how to reduce their exposure to arsenic should contact the NYSDOH. The NYSDOH and ATSDR also recommend that residents who are concerned about possible exposure to, and effects from, arsenic contaminated soil should discuss these concerns with their health care provider.

NEXT STEPS

The NYSDOH and ATSDR will continue to coordinate with the USEPA, New York State Department of Environmental Conservation (NYSDEC), and the Putnam County Health Department, to implement the recommendations contained in this health consultation.

The NYSDOH and ATSDR will review information as it becomes available, evaluate the public health implications of any additional sampling results, and recommend public health actions as needed.

The NYSDOH will coordinate with the ATSDR, NYSDEC, Putnam County Health Department, USEPA, and the Town of Kent to provide health education to residents whose properties are affected by arsenic contamination. Activities may include public meetings, public availability sessions, preparation of factsheets, and information sessions and mailings for local physicians to assist them in responding to their patients' concerns.

The NYSDOH will continue, as needed, to provide support to community members about this health consultation or other health concerns that may arise. This report will be placed in the local repository and provided to people who request it.

FOR MORE INFORMATION

If you have questions about this health consultation or other health concerns that may arise, please contact the NYSDOH at 518-402-7860.

A copy of this health consultation will be available on the NYSDOH public website at:

<https://www.health.ny.gov/environmental/>

and the ATSDR public website at:

<https://www.atsdr.cdc.gov/HAC/PHA/HCPHA.asp?State=NY>.

BACKGROUND

Statement of Issue

The United States Environmental Protection Agency (USEPA) requested that the Agency for Toxic Substances and Disease Registry (ATSDR) evaluate soil samples collected at residential properties on the USEPA Arsenic Mine Site [site] in Kent, Putnam County, New York. The USEPA collected the samples to determine the extent of arsenic in residential soils and whether prompt action is needed to reduce harmful exposures to arsenic-contaminated soils and mine tailings. The New York State Department of Health (NYSDOH) reviewed the soil data collected by the USEPA and evaluated the public health implications of the contamination. This health consultation formalizes the NYSDOH's evaluation of the data. The NYSDOH prepared this health consultation under a cooperative agreement with ATSDR.

Site Description and History

The former Arsenic Mine is in the Town of Kent, in Putnam County, New York, near the intersection of Gipsy Trail Road and Mt. Nimham Court (Appendix A, Figure A1). Former mine entrances and tailings piles (residual materials separated out during mining activities) exist on nearby residential properties and the Nimham Mountain Multiple Use Area (MUA). There are two main mine entrances, or shafts. The shaft at the northern end of the mine, referred to as the northern entrance, is located on a private residential property. The shaft to the south, referred to as the southern entrance, is located within the Nimham Mountain MUA. The former mine entrances are now flooded or filled in, preventing casual entry.

The area is sparsely populated, and the terrain is highly variable, with steep, forested hillsides. Occupied properties in the area generally consist of single-family residential homes. Public water is not available in the area; residents rely on private wells for their drinking water.

Mining began in the area around the mid-1800s and was continued by various companies until 1918. Rocks were crushed on site to concentrate the ore. Ultimately, the ore was used to manufacture shot, flint, glass, pharmaceuticals, poisons, and chemicals [Weston Solutions, Inc. 2017, 2018a, 2018b]. Mining operations ceased by 1918 due to the lack of a satisfactory smelting forge nearby for processing the ore. Some of the ten residential homes were constructed in the area that was used for mining operations.

In the 1950s, a property owner regraded the area around the northern mine entrance to create a small ski slope. Some remnants of electrical lines that powered a small ski lift are still visible. In December 1987, residents at a single property living adjacent to the northern mine shaft were hospitalized with arsenic poisoning from their drinking water well [NYSDOH 1987]. Putnam County Department of Health sampling determined that the residential drinking water well was contaminated with arsenic much above state and federal drinking water standards. Soil samples collected on the residential property confirmed that the home was built upon mine tailings/mine wastes. Due to arsenic poisoning, three residents in the home required

chelation therapy. In consultation with New York State Departments of Environmental Conservation and Health, the USEPA requested that ATSDR evaluate the health risk associated with arsenic contaminated drinking water for residents. ATSDR recommended the residents of this property be put on a permanent acceptable water supply totally disconnected from any source of arsenic [ATSDR 1988]. At that time, the USEPA installed an alternate drinking water system at the property, and both USEPA and Putnam County Health Department provided health education information to the family living at the property. Two additional private drinking water wells and one public supply well sampled by the Putnam County Health Department in 1987 were found to contain arsenic at concentrations approaching or slightly above the state and federal drinking water standards. A limited drinking water sampling event was conducted by the USEPA, and the Putnam County Health Department performed routine sampling through 1992. Installation of filter systems on the drinking water wells proved to be effective in removing arsenic.

The 1987 sampling event identified a need for additional information about the potential for arsenic exposures in the area. In the late 1980s and early 1990s, the Putnam County Health Department and the USEPA conducted limited soil sampling at properties near the northern mine entrance to evaluate the potential for exposures for people who may frequent the mine. They found high levels of arsenic in surface soils. Concentrations of arsenic up to 32,100 parts per million (ppm) were found in surface soils. In May 1988, the Putnam County Health Department placed warning signs near the northern mine entrance to alert persons to high arsenic levels in soil and tailing piles.

In 2016, arsenic contaminated sediments were found in the holding tanks of the alternate drinking water supply installed by the USEPA in the 1980s, which resulted in an additional site investigation. In August 2017, a USEPA contractor conducted a soil investigation of four properties. In December 2017, samples were collected at six additional properties and one previously sampled property, for a total of ten properties sampled between the two events [Weston Solutions, Inc. 2017; 2018a]. In June 2018, the USEPA collected additional soil samples from all ten properties [Weston Solutions, Inc. 2018b]. In 2017, the New York State Department of Environmental Conservation (NYSDEC) independently conducted an investigation in the nearby Nimham Mountain MUA near the southern mine shaft and exploratory pits. The NYSDEC investigation did not include residential properties but provided sampling data from both areas known to be impacted by mining activities as well as background areas. The USEPA provided residents with their 2017 and 2018 soil sample results and recommendations on how to reduce the potential for exposure to arsenic in soil.

In October 2018, the USEPA collected drinking water samples (before and after water treatment systems) and documented that filter systems installed and maintained by residents to remove contaminants from their drinking water continue to be effective, with the exception of one property. The USEPA recommended that the homeowner follow the manufacturer's suggested maintenance requirements to replace the filter or install a system capable of removing contaminants.

Based on the more extensive data available on arsenic in soil as compared to groundwater/private wells, the fact that the soil concentrations are quite elevated relative to common background and health screening levels, and the USEPA's request for this health consultation to focus on residential soils, this report centers on the potential exposures occurring from soil. An assessment of drinking water would not be expected to substantially alter the findings of elevated health risk contained in this health consultation.

Site Visits

On August 3, 2017, staff from the NYSDOH, NYSDEC, USEPA, and Putnam County Health Department visited the site. On November 7, 2018, NYSDOH, ATSDR, and USEPA conducted a site visit.

The 2017 site visit consisted of touring the residential property that includes the northern mine entrance and the nearby Nimham Mountain MUA where the southern mine entrance is located. During the 2017 site visit, staff noted that the area is well-forested with significant elevation changes throughout. The northern mine entrance is mostly filled in and the interior of the mine itself is not easily accessed. The sign previously placed near the northern mine shaft by the Putnam County Health Department was found face down on a fallen tree near the entrance to the ravine that contains the shaft entrance. Signage on the property indicates that the property owner is aware of the presence of the mine. The former ski slope area constructed in the 1950s is overgrown and does not appear to be accessed frequently due to steep terrain. Remnants of the former ski lift electrical and lighting system are visible, confirming the location of the slope. At the nearby Nimham Mountain MUA, the hiking trails appeared to be well-used and were largely bare soil with visible tailings along portions of the trail. The trails are near former mine exploratory pits that remain in the area. In May 2018, 'Danger Restricted Area Do Not Enter' signs were located near the mine entrance and exploratory pits, and 'Caution' signs notifying the public that arsenic contaminated soils have been detected in the area were posted by the NYSDEC along hiking trails and at the mine entrance and exploratory pits.

During the 2018 site visit, staff viewed each of the ten residential properties that are the subject of this health consultation, either from the property boundary or from within the boundaries, depending on whether the property owner granted access. Seven of the properties have homes on them that are occupied either full or part-time. Staff also revisited the Nimham Mountain MUA trails adjacent to the residential properties.

During the 2018 site visit, the USEPA staff provided the NYSDOH and ATSDR details of each of the ten residential properties and preliminary soil sampling results. NYSDOH staff recorded the number of occupants for each property, along with the presence of children, pets, livestock, gardens, and play areas. NYSDOH staff also noted the direction of overland flow for precipitation runoff, and surface soil sampling results were compared to property features. Livestock (e.g., cattle and chickens) were observed at one property. The residents told the USEPA staff they eat eggs produced at this property, but no milk or meat products are produced. The poultry area had been voluntarily relocated based on soil sampling results and

USEPA recommendations. No significant play areas were noted during the site visit, with the exception of an outdoor trampoline on one property. Gardening was observed on two properties: one vegetable garden in native soil, and one raised bed garden, for which the source of the soil is unknown

Demographics

The residential properties of concern are in the Town of Kent, Putnam County, New York, which is an area of about 40 square miles. The United States Census Bureau reports a population of 13,352, of which 76.6% are Caucasian, 5.7% are African-American, about 1.0% Asian, 0.6% Native American, and 16.1% Hispanic [United States Census Bureau 2017]. The ten properties in this health consultation encompass about 19 acres. Residential homes exist on seven properties. Less than 25 people live on the potentially affected properties; residents of one household live there only part-time.

Community Health Concerns

The community has raised both health- and property-related concerns. USEPA staff working with the community identified the most frequent concerns expressed by residents. One resident reports keeping children from playing in areas of exposed soil in the yard. Residents report significant concern about the impact of the level of arsenic on property values and property assessments for tax purposes. Residents have asked the USEPA about arsenic clean-up concentrations. Cancer cases have been reported in the area of concern. In the past, some residents in the study area were hospitalized due to arsenic exposure from their drinking water wells [NYSDOH 1987]. More recently, an unconfirmed report indicates case of elevated arsenic levels in blood. Residents have questioned whether local, state, and federal officials should allow people to live in the area, knowing that the arsenic mine exists. In June 2018, one household contacted Congressman Sean Patrick Maloney for assistance with the arsenic issue [personal communication, Sandra Richards, USEPA, November 2018].

DISCUSSION

The health consultation process assesses whether people have been exposed in the past, are currently exposed, or potentially could be exposed in the future to hazardous substances and, if so, whether that exposure is harmful or potentially harmful, and should therefore be stopped or reduced [ATSDR 2005]. The method for assessing whether a health hazard to a community exists is to evaluate environmental data (contaminants); determine whether a completed exposure pathway exists from a contaminant source to a receptor population (exposure evaluation); and, if so, determine whether exposure to the contamination is at a level that poses a health concern (public health implications evaluation).

Environmental Contamination

USEPA obtained soil data from depths up to 24 inches below the ground surface at ten residential properties in 2017 and 2018. Discrete soil samples were obtained from six-inch intervals at each sample location. Sample analyses were performed by a USEPA approved contract laboratory for total arsenic. Data on arsenic concentrations were obtained using approved laboratory analytical methods. All laboratory samples were also analyzed using an X-ray fluorescence (XRF) screening tool. The XRF is a screening tool and accuracy can vary based on the composition of the sample. For this reason, the NYSDOH used only laboratory validated soil data to evaluate exposure and risks. For the purpose of estimating exposures, the NYSDOH used arsenic concentrations found in the zero to six-inch soil interval, which is considered shallow soil.

Sampling information for each property is found in Table 1. For privacy purposes, the properties are identified as Properties 1 through 10.

**Table 1. Arsenic Mine Residential Properties
Shallow Surface Soil Arsenic Results**

Location	Number of Samples Collected^a	Range (mg/kg)
Property 1	13	19.7 – 49,300
Property 2	9	10.3 - 6050
Property 3	8	26.6 – 56,000
Property 4	5	19.6 – 20,600
Property 5	7	24.3 - 181
Property 6	10	3.2 - 687
Property 7	6	22 - 317
Property 8	7	9 - 99.5
Property 9	8	66.5 - 1520
Property 10	7	3.6 - 841

^a Laboratory validated samples collected from the zero to six-inch interval below ground surface
mg/kg = milligrams of arsenic per kilogram of soil

Exposure Pathways

An exposure pathway is the process by which a person can come into contact with a hazardous substance that originates from some source of contamination. There are three basic exposure routes: inhalation, ingestion, or direct contact with skin. A completed exposure pathway occurs when all five of the following elements exist:

1. Source of contamination;
2. Environmental media and transport mechanism;
3. Point of exposure;
4. Route of exposure; and
5. Receptor population.

A potential exposure pathway exists when any one of the five elements comprising an exposure pathway is missing or uncertain.

Completed Exposure Pathway for Residential Properties

Residents whose yards are the subject of this health consultation could be exposed to arsenic contaminated shallow soil through ingestion and dermal contact.

Potential Completed Pathway for Vacant Residential Properties

Persons using the vacant properties (i.e., properties with no habitable buildings) could be exposed to arsenic contaminated shallow soil on these properties through ingestion and dermal contact.

The source of contamination is the point at which the contaminant is released to the environment (e.g., waste disposal area or point of discharge). If the original source is unknown, the contaminant source is the soil, air, biota, or water (environmental media) that are contaminated at the point of exposure. The point of exposure is a location where actual or potential human contact with a contaminated medium could occur.

Environmental media and transport mechanisms carry contaminants from the source to points where people could be exposed.

The route of exposure is the way a contaminant enters or contacts the body (i.e., ingestion, inhalation, or absorption through the skin).

The receptor populations are those who are exposed or could be exposed to contaminants at a point of exposure.

Fruits and vegetables grown in arsenic-contaminated soil can take up arsenic [Meharg and Hartley-Whitaker 2002; Zhao et al. 2008], and eating these homegrown fruits and vegetables can contribute to arsenic exposure. Because the requested focus of this health consultation is

the evaluation of health risks from exposure to arsenic in soil through incidental ingestion and dermal contact, this evaluation does not address the potential contribution of this food exposure pathway, nor the potential for arsenic exposure through consumption of home-raised animal products. Consideration of these additional potential exposure pathways may likely support and strengthen the conclusions and recommendations provided in this document. Exposure to arsenic in soil by the inhalation pathway is not assessed in this health consultation because the contribution of this pathway to the total arsenic exposure is negligible (compared to ingestion and dermal contact) and would not change the conclusions.

Public Health Implications

The maximum arsenic soil concentration at all properties exceeds both the 6 NYCRR Part 375 New York State Residential Soil Clean Up Objective of 16 mg/kg [NYSDEC/NYSDOH 2006] and ATSDR's chronic Environmental Media Evaluation Guide of 16 mg/kg [ATSDR 2019].

Soil Cleanup Objectives are contaminant-specific soil concentrations that represent remedial goals, and consider current, intended, or reasonably anticipated future land use. They are set at a soil concentration at which health effects are not likely to occur. ATSDR's chronic Environmental Media Evaluation Guides are comparison values used to identify contaminants that require further evaluation; they are considered protective of public health.²

The maximum arsenic soil concentration at all properties also exceeds ATSDR's short-term (acute) Environmental Media Evaluation Guide of 27 mg/kg for a pica child. [ATSDR 2019]. At eight properties, the maximum arsenic soil concentration exceeds ATSDR's short-term Environmental Media Evaluation Guide of 260 mg/kg for non-pica children. ATSDR's acute Environmental Media Guides are soil comparison values used to identify contaminants for further evaluation. They are considered protective against health effects resulting from short-term (14 days or less) exposure.

Because the concentrations exceed both the New York State Soil Clean Up Objective and the ATSDR Environmental Media Evaluation Guides, the health risks for exposure to arsenic in soil on the residential properties were further evaluated.

Risk Assessment Methods

The following sections summarize a risk assessment for arsenic in soil on the residential properties. In environmental health, risk assessment is a process that is used to characterize the health risks to humans from environmental exposures [USEPA 2018]. It uses a standard approach that combines assumptions about the frequency and magnitude of the exposures with information about the toxicity of the chemical to draw conclusions about the risk for human health effects. Risk assessment is used as a tool to evaluate potential exposures; it

² Both the New York State Residential Soil Cleanup Objective and the ATSDR chronic Environmental Health Evaluation Guide for arsenic are based on background levels because the health based soil value derived from arsenic toxicity information and generic assumptions of daily exposure via soil ingestion are below typical arsenic background levels in soil.

cannot be used to predict actual health outcomes. Information obtained from risk assessments is one of several considerations in the development of risk management decisions about reducing exposures to environmental chemicals.

The NYSDOH estimated arsenic exposures using methods from ATSDR's Exposure Dose Guidance for Soil and Sediment Ingestion [ATSDR 2018] and Exposure Dose Guidance for Soil/Sediment Dermal Absorption [ATSDR 2016]. The NYSDOH evaluated long-term health risks assuming people are exposed to soil and indoor dust (from outdoor soil) by incidental ingestion and dermal contact seven days per week for the part of the year when the ground is not frozen and/or there is no snow cover.³ Because the length of time people could have been exposed to contaminated soil is unknown, the NYSDOH used an exposure duration of 33 years to evaluate cancer risks, which is the 95th percentile value for residential occupancy [USEPA 2011].

For properties having at least eight surface soil samples for arsenic, the NYSDOH used the 95 percent upper confidence limit (95% UCL) of the arithmetic mean soil concentration to determine the exposure point concentrations for site-related contaminants.⁴ The exposure point concentration is the contaminant concentration in soil that a person could be exposed to, and is used to evaluate cancer and non-cancer health risks from exposure to arsenic in soil. The 95% UCL provides a conservative estimate of the average concentration.

For properties having fewer than eight sample results, both the maximum detected soil arsenic level and the average soil arsenic level from the property were used as the exposure point concentrations. To evaluate short-term exposures involving soil ingested in a single episode, the NYSDOH used the maximum detected soil arsenic level from each property. A summary of the sampling data and the exposure point concentrations used for each property is found in Appendix B, Table B1.

The NYSDOH estimated lifetime cancer risks by multiplying the estimated arsenic exposure by the USEPA arsenic cancer potency factor [USEPA 1995]. The cancer potency factor is a numerical estimate of a contaminant's carcinogenic strength (potency). The NYSDOH evaluated the non-cancer health effects risk for seven age ranges by comparing the estimated arsenic exposures from soil to its USEPA reference dose [USEPA 1991]. A reference dose is a lifetime exposure to the contaminant that is expected to be without appreciable risk for non-cancer health effects.

Short-term health risks resulting from a single episode of soil ingestion were evaluated by comparing the exposure based on the highest arsenic soil concentration on each property to ATSDR's acute minimal risk level (MRL) for arsenic [ATSDR 2007]. All evaluations of arsenic in soil assume a relative bioavailability factor of 60% [USEPA 2016; ATSDR 2018] to account for the fraction of arsenic that is released from the soil matrix and absorbed following ingestion. A

³The ground is not frozen and/or there is no snow cover in New York State for an average of 224 days per year.

⁴ To determine the exposure point concentrations for properties with at least eight surface soil samples, data were analyzed using ProUCL 5.1.00 (USEPA 2016) developed by the USEPA to calculate the 95% UCL.

general summary of the health effects of arsenic is presented in Appendix C. Examples of calculations for the evaluation of cancer and non-cancer health risks are found in Appendix D.

Cancer Risks

Based on convincing evidence from scientific studies of people exposed to high levels of arsenic in drinking water, ingestion of arsenic increases the risk for skin, lung and bladder cancer [ATSDR 2007; NRC 2001; NTP 2016]. The USEPA and US Department of Health and Human Services classify arsenic as a known human carcinogen [USEPA 1991; NTP 2016].

The estimated increased lifetime cancer risk posed by long-term exposure to arsenic in surface soil on the residential properties ranged from 4 in 100,000 to 6 in 100 (Table 2). If the 95% UCL and maximum arsenic soil values are used to represent exposure, all ten properties have estimated lifetime cancer risk levels that typically trigger measures to reduce exposure (i.e., 1 in 10,000 or higher). For six properties, the estimated lifetime cancer risk is 1 in 1,000 or higher. Estimated cancer risks for several of the properties are unusually high for environmental exposures. USEPA's generally acceptable risk for environmental exposures ranges from 1 in 10,000 to 1 in 1,000,000 as discussed in the National Contingency Plan (NCP), 40 CFR 300.430. The NYSDOH concludes that the arsenic on the residential properties poses a significantly elevated risk for cancer health effects.

The NYSDOH has increased concern about the significance of the estimated cancer risk because of evidence from studies of people and animals that suggests the very young could be more sensitive to the carcinogenic effects of arsenic than adults [Ahlborn et al. 2009; Marshall et al. 2007; Smith et al. 2006; Tokar et al, 2011; Waalkes et al. 2003, 2006, 2007, 2009].

Table 2: Estimated Lifetime Cancer Risk for Long-Term Exposure to Arsenic in Soil on Residential Properties on the Arsenic Mine Site

Parcel	Arsenic Soil Concentration (mg/kg) ^a	Estimated Lifetime Cancer Risk ^b
Property 1	48,071 ^c	6 in 100
Property 2	4,247 ^c	5 in 1,000
Property 3	25,406 ^c	3 in 100
Property 4	20,600 ^d	3 in 100
	4,142 ^e	5 in 1,000
Property 5	181 ^d	2 in 10,000
	79 ^e	1 in 10,000
Property 6	512 ^c	6 in 10,000
Property 7	317 ^d	4 in 10,000
	116 ^e	1 in 10,000
Property 8	100 ^d	1 in 10,000
	35 ^e	4 in 100,000
Property 9	1,398 ^c	2 in 1,000
Property 10	841 ^d	1 in 1,000
	199 ^e	2 in 10,000

^a For properties having 8 or more surface soil samples, the arsenic exposure point concentration is the 95% UCL of the mean. For properties having less than 8 surface soil samples, both the maximum and average arsenic concentrations are used as the exposure point concentration.

^b The cancer risk is calculated by multiplying the estimated arsenic exposure from soil for each of seven age groups by the USEPA cancer potency factor for arsenic [USEPA 1995]. The cancer risks for each age group are then added to obtain an estimate of the lifetime cancer risk for 33 years of exposure to arsenic in soil at each property. Cancer risks estimates at higher exposures have additional uncertainty because the assumed shape of the dose-response curve used to derive the cancer potency factor may no longer hold. See Appendix D for additional details on the cancer risk calculations.

^c Denotes 95% UCL of the mean arsenic soil concentration.

^d Denotes maximum arsenic soil concentration.

^e Denotes average arsenic soil concentration.

mg/kg = milligrams of arsenic per kilogram of soil

Non-cancer Risks

Long-Term Exposure

The estimated long-term exposure to the arsenic in residential surface soil exceeded the USEPA arsenic reference dose of 0.0003 mg/kg/day [USEPA 1991] on all ten properties. The arsenic reference dose is based on skin darkening (hyperpigmentation) and localized overgrowth of skin (keratosis) in humans exposed to high levels of arsenic in their drinking water over long periods of time [USEPA 1991]. Because soil on the properties exceeded the reference dose (hazard quotient greater than 1, Table 3), the NYSDOH evaluated the margin of exposure, which is a measure of how many times lower the soil arsenic exposure is when compared to the arsenic exposure that has been shown to cause non-cancer health effects. The higher the margin of exposure, the greater the difference (and margin of protection) between the

estimated soil exposure and the human effect level. A margin of exposure equal to 1 means that the estimated soil exposure is the same as the human effect level, and a margin of exposure less than one means that the estimated exposure in soil is higher than the exposure that has caused health effects. Similarly, if the margin of exposure is 10, this means that the estimated exposure is 10 times below the human effect level.

The estimated long-term exposure to arsenic in soil on four properties is greater than the arsenic exposure level that caused hyperpigmentation in humans (margin of exposure less than 1; properties 1, 2, 3 and 4; Table 3). This effect level (0.014 mg/kg/day [USEPA 1991]) is exceeded by 27-fold on property 1, 14-fold on property 3, 11-fold on property 4, and 2-fold on property 2. Therefore, long-term exposure to arsenic in soil on these properties poses a significantly elevated risk for non-cancer health effects, such as hyperpigmentation and keratosis.

On property 9, the soil exposure is about equal to the human effect level (margin of exposure of 1.3). For the other properties (properties 5, 6, 7, 8, and 10), the margin of exposure ranges from about 2 to 51 (Table 3). For these properties, this means the difference between the arsenic exposure from soil and the arsenic effect level in humans is too small, which indicates inadequate protection exists against non-cancer health effects. The NYSDOH concludes that long-term exposure to soil arsenic at these residential properties constitutes a significantly elevated risk for long-term non-cancer health effects.

Table 3: Non-cancer Hazard Quotients for Long-Term Exposure to Arsenic in Soil on Residential Properties on the Arsenic Mine Site

Parcel	Arsenic Soil Concentration (mg/kg) ^a	Estimated Exposure (mg/kg/day) ^b	Hazard Quotient ^c	Margin of Exposure ^d
Property 1	48,071 ^e	0.38	1,269	< 1
Property 2	4,247 ^e	0.034	112	< 1
Property 3	25,406 ^e	0.20	671	< 1
Property 4	20,600 ^f	0.16	544	< 1
	4,142 ^g	0.033	109	< 1
Property 5	181 ^f	0.0014	4.7	10
	79 ^g	0.0006	2	22
Property 6	512 ^e	0.0041	14	3.5
Property 7	317 ^f	0.0025	8	6
	116 ^g	0.00091	3	15
Property 8	100 ^f	0.00078	2.6	18
	35 ^g	0.00027	0.9	51
Property 9	1,398 ^e	0.011	37	1.3
Property 10	841 ^f	0.0066	22	2.1
	199 ^g	0.0016	5	9

^a For properties having eight or more surface soil samples, the arsenic exposure concentration is the 95% UCL of the mean. For properties having less than 8 surface soil samples, both the maximum and average arsenic concentrations are used as exposure point concentrations.

^b Exposure estimates are for an infant, for whom the soil ingestion rate and body weight yield the largest contaminant dose among the seven life stages evaluated (see Appendix D). Contaminant exposure is assumed to occur via soil ingestion and dermal exposure. Examples of detailed calculations are presented in Appendix D. Estimated exposures were rounded to two significant figures for presentation in the text tables.

^c The hazard quotient is calculated by dividing the estimated contaminant exposure by the USEPA arsenic reference dose of 0.0003 mg/kg/day [USEPA 1991], which the ATSDR has adopted as its chronic MRL. The highest hazard quotient, calculated using ATSDR's reasonable maximum exposure parameters for infants, is shown (see also Appendix D).

^d The margin of exposure is calculated by dividing the human effect level for arsenic (0.014 mg/kg/day [USEPA 1991]) by the estimated arsenic exposure from soil. A margin of exposure less than 1 means the estimated exposure is higher than the human arsenic exposure reported to have caused health effects.

^e Denotes 95% UCL of the mean arsenic soil concentration.

^f Denotes maximum arsenic soil concentration.

^g Denotes average arsenic soil concentration.

mg/kg = milligrams of arsenic per kilogram of soil; mg/kg/day = milligrams of arsenic per kilogram of body weight per day

Short-Term Exposure

The NYSDOH also evaluated the health risks associated with a one-time episode in which a 1 to 2-year-old child is assumed to ingest both an unusually large amount of soil (5 grams, representing pica behavior) or the daily amount of soil specified in ATSDR's reasonable maximum exposure scenario (200 milligrams). In each case, the soil concentration is assumed to be the highest level of arsenic found in surface soil samples on each property. The arsenic exposures in these short-term scenarios (estimated using ATSDR guidance [ATSDR 2018]) are compared to the ATSDR acute MRL for arsenic of 0.005 mg/kg/day [ATSDR 2007]. The ATSDR acute MRL is a short-term exposure (up to 14 days) that is expected to be without an appreciable risk for non-cancer health effects. The acute MRL is based on swelling (edema) of the face and gastrointestinal and upper respiratory symptoms in people exposed to arsenic-contaminated soy sauce for 2-3 weeks [ATSDR 2007]. The specific health effects include nausea, vomiting, headaches, stomach cramps, diarrhea, fatigue, chills, sore throat, and nasal discharge. These effects typically diminish once the exposure to arsenic is stopped.

Short-Term Exposure from Pica Behavior

For all the properties, a single ingestion of a large amount of soil (5 grams) by a 1 to 2-year-old child exhibiting pica behavior results in exposures that exceed the ATSDR acute MRL (hazard quotient greater than 1, Table 4). Since the MRL is exceeded, the NYSDOH evaluated the short-term margin of exposure, or how many times lower the short-term arsenic soil exposure is, when compared to the short-term arsenic exposure that causes health effects. This evaluation showed that for eight properties (properties 1, 2, 3, 4, 6, 7, 9, and 10), the estimated short-term exposure to arsenic in soil resulting from pica behavior is greater than the short-term arsenic exposure level reported to cause edema and gastrointestinal and upper respiratory symptoms in humans (margin of exposure less than 1, Table 4). For three properties (properties 1, 3, and 4), the estimated exposure exceeds this short-term effect level (0.05 mg/kg/day [ATSDR 2007]) more than 100-fold. Since pica behavior for a 1 to 2-year-old child can result in an arsenic soil exposure that significantly exceeds exposures known to cause short-term arsenic health effects, the arsenic levels in soil pose an immediate and significant threat to human health and constitute an urgent public health hazard. For the remaining properties where pica behavior resulted in an estimated exposure that exceeded the acute MRL (properties 5 and 8), the margin of exposure is too small, which indicates inadequate protection exists against short-term non-cancer health effects, and arsenic in soil on these properties constitutes a significantly elevated risk for the short-term non-cancer arsenic health effects.

Short-Term Exposure from RME Soil Ingestion

Using the reasonable maximum exposure (RME) soil ingestion rate (200 milligrams/episode), the exposure at seven properties exceeds the MRL (hazard quotient greater than 1, Table 4). Since the MRL is exceeded, the NYSDOH again evaluated the short-term margin of exposure for these properties. This evaluation showed that the arsenic soil exposure exceeds the short-term effect level on properties 1, 2, 3, and 4 (margin of exposure less than 1, Table 4). Because incidental ingestion of soil (assuming the RME ingestion rate of 200 milligrams per episode for a

1 to 2-year-old child) can result in an arsenic exposure that exceeds exposures known to cause short-term arsenic health effects, the arsenic levels in soil on properties 1, 2, 3 and 4 pose an immediate and significant threat to human health and constitute an urgent public health hazard.

For properties 6, 9, and 10, the short-term arsenic exposure from soil in the RME scenario exceeds ATSDR's acute MRL and results in a margin of exposure that is too small, which indicates inadequate protection exists against short-term non-cancer health effects. Therefore, exposure to arsenic in soil on these residential properties shown in Table 4 constitutes a significantly elevated risk for the short-term non-cancer arsenic health effects previously described.

Table 4: Non-cancer Hazard Quotients for Short-Term Exposure to Arsenic in Soil on Residential Properties on the Arsenic Mine Site

Parcel	Arsenic Soil Conc. ^a (mg/kg)	Estimated Pica Behavior Exposure ^b (mg/kg/day)	Estimated RME Exposure ^b (mg/kg/day)	Short-Term HQ ^c	Short-Term HQ ^c	Short-Term MOE ^d	Short-Term MOE ^d
				Pica	RME	Pica	RME
Property 1	49,300	13	0.52	2,595	104	< 1	< 1
Property 2	6,050	1.6	0.064	318	13	< 1	< 1
Property 3	56,000	15	0.59	2,947	118	< 1	< 1
Property 4	20,600	5.4	0.22	1,084	43	< 1	< 1
Property 5	181	0.048	0.0019	9.5	0.38	1.0	26
Property 6	687	0.18	0.0072	36	1.4	< 1	6.9
Property 7	317	0.083	0.0033	17	0.7	< 1	15
Property 8	100	0.026	0.0011	5.2	0.2	1.9	47
Property 9	1,520	0.4	0.016	80	3.2	< 1	3.1
Property 10	841	0.22	0.0089	44	1.7	< 1	5.7

^a The highest arsenic concentration in soil on each property is used as the exposure point concentration to evaluate short-term exposure risks.

^b Exposure estimates are for 1 to 2-year-old child weighing 11.4 kilograms who ingests 5,000 milligrams (pica) or 200 milligrams (RME) of soil per episode (see Appendix D). Estimated exposures were rounded to two significant figures for presentation in the text tables.

^c The hazard quotient is calculated by dividing the estimated contaminant exposure by the ATSDR acute arsenic MRL of 0.005 mg/kg/day [ATSDR 2007].

^d The margin of exposure is calculated by dividing the short-term human effect level for arsenic (0.05 mg/kg/day [ATSDR 2007]) by the estimated arsenic exposure from soil. A margin of exposure less than 1 means the estimated exposure is higher than the short-term human arsenic exposure reported to have caused health effects.

HQ = hazard quotient; mg/kg = milligrams of arsenic per kilogram of soil; mg/kg/day = milligrams of arsenic per kilogram of body weight per day; MOE = margin of exposure; RME = reasonable maximum exposure

STRENGTHS AND LIMITATIONS

This evaluation of the risks for adverse health effects from arsenic in residential shallow soil has both strengths and limitations. The strengths include consideration of sensitive subgroups, use of high-end estimates for soil ingestion rates, consideration of both the oral and dermal pathways for arsenic exposure from soil, and use of the maximum arsenic soil level or the 95% UCL of the mean arsenic soil level as exposure point concentrations.

The focus of this health consultation is the evaluation of health risks from exposure to arsenic in soil on the residential properties. The limitations include uncertainties about how well the soil sampling data represent people's actual exposure. The evaluation does not consider potential additional arsenic exposures through past or potential current inhalation of arsenic contaminated soil or dust, consumption of untreated drinking water, consumption of home raised animal products, or consumption of fruits and vegetables grown in contaminated soil. This evaluation also does not consider other potential arsenic exposures that could result from residents' use of nearby trails in the Nimham Mountain MUA. Though action is planned by NYSDEC to cover the trails with gravel in early 2019, until that time soil from these trails could be tracked into homes on footwear or by pets, leading to additional exposure by incidental ingestion and dermal contact. Consideration of these additional potential exposure pathways would not change the conclusions and recommendations provided in this document but may likely support and strengthen them.

The conclusions described in this report are based on an evaluation of USEPA's soil data obtained in 2017 and 2018 from the zero to six inches below ground surface interval. The NYSDOH typically evaluates risks for adverse health effects from exposures to contaminants in surface soils collected from zero to two inches below a grass cover system because this interval is considered a better indicator of actual exposure than the zero to six-inch interval. The difference in sampling depth of the available data introduces a small level of uncertainty in the estimates of contaminant exposure.

CONCLUSIONS

The evaluation of arsenic contaminated soil at select residential properties on the Arsenic Mine Site is the primary focus of this health consultation and the basis for the conclusions and recommendations.

CONCLUSION 1

The NYSDOH and ATSDR conclude that short-term ingestion exposure of children to arsenic in shallow (zero to six inches) soils with the highest arsenic levels at residential properties on the Arsenic Mine Site pose an immediate and significant threat to human health, thus constituting an urgent public health hazard.

BASIS FOR CONCLUSION

Short-term exposure to arsenic in residential soil could result in adverse health effects. For all ten residential properties evaluated, a single ingestion of a large amount of soil (i.e., 5 grams) containing the maximum arsenic soil level found at each property, by a 1 to 2-year-old child exhibiting pica behavior, results in an arsenic dose that either exceeds or approaches the short-term arsenic exposure level that causes non-cancer health effects. On seven properties, a single ingestion of a smaller amount of soil (i.e., 200 milligrams) containing the maximum arsenic level results in an arsenic dose that either exceeds or approaches the short-term arsenic exposure level that causes non-cancer health effects. The health effects that can result from short-term, high-level exposure to arsenic include vomiting, headaches, stomach cramps, diarrhea, and facial swelling, especially around the eyes. These effects are typically temporary and should subside when exposure to arsenic ceases.

CONCLUSION 2

The NYSDOH and ATSDR conclude that long-term ingestion and dermal exposure of children and adults to arsenic in shallow soil at residential properties on the Arsenic Mine Site pose a significant threat to human health and constitute a public health hazard.

BASIS FOR CONCLUSION

Long-term exposure to arsenic in residential soil could result in adverse health effects. For all ten residential properties evaluated, long-term arsenic exposure in soil results in an estimated lifetime cancer risk of over 1 in 10,000. For six of the residential properties, the arsenic exposure results in an estimated lifetime cancer risk of 1 in 1,000 or higher, and for three properties, the estimated cancer risk is over 1 in 100, which is unusually high for environmental exposures. Long term exposure to high levels of arsenic is known to cause cancer of the skin, lung, and bladder in humans. Regarding non-cancer health risks, long-term exposure to arsenic in soil at all properties results in an arsenic dose that either exceeds or approaches the long-term arsenic exposure level that causes health effects. Long-term human exposure to arsenic also causes skin hyperpigmentation and keratosis, or a darkening and thickening of the skin on the hands and feet, as well as other adverse health effects [USEPA 1991; ATSDR 2007].

RECOMMENDATIONS

1. Based on the significantly increased risk for adverse health effects, the NYSDOH and ATSDR strongly recommend that the USEPA implement immediate actions to prevent or reduce the potential for residents, especially children, to be exposed to arsenic in the contaminated residential soils.
2. Until a long-term remedial action can be put in place, the NYSDOH and ATSDR recommend residents implement the following interim measures to reduce arsenic exposure:
 - People, especially children, should minimize direct and repeated contact with bare soils.
 - Maintain a grass or mulch cover wherever possible to help prevent direct contact with the soil.
 - Wipe shoes on doormat or remove shoes before entering the home. Apply general good housekeeping practices by periodically damp mopping floors, vacuuming (using a HEPA filter if available), and cleaning furniture to help reduce exposure to outdoor soil that might be tracked indoors. Avoid the use of brooms.
 - Avoid unnecessary digging in the dirt.
 - Children and adults should wash hands after outdoor activities to help reduce the potential for exposure.
 - Wash children's toys regularly.
 - Refrain from landscaping activities that increase exposure to soil and create bare areas of soil.
 - Refrain from eating food or smoking when working in the yard.
 - Refrain from eating home raised fruits, vegetables, and animal products. If residents choose to garden, they should grow crops in soils in raised bed gardens and containers with clean soil imported from a non-contaminated area or bagged soil bought commercially instead of the existing soil. Residents should wear gloves when gardening and dispose or wash gloves thoroughly after each use.
 - Regularly wash pets that may go outdoors and contact the soil.
 - Properly maintain water treatment systems in accordance with the manufacturer's specification.
3. People should contact the NYSDOH if they have additional questions regarding how to reduce exposure. The NYSDOH and ATSDR also recommend that residents who are concerned about possible exposure to, and effects from, arsenic contaminated soil should discuss these concerns with their health care provider.

PUBLIC HEALTH ACTION PLAN

1. The NYSDOH will coordinate with the ATSDR, NYSDEC, Putnam County Health Department, USEPA, and the Town of Kent to quickly provide health education to residents whose properties are affected by arsenic contamination. Activities may include public meetings, public availability sessions, preparation of factsheets, and information sessions and mailings for local physicians to assist them in addressing their patients' concerns.
2. The NYSDOH and ATSDR will continue to coordinate with the USEPA, NYSDEC, and Putnam County Health Department to implement the recommendations contained in this health consultation.
3. The NYSDOH and ATSDR will review information as it becomes available, evaluate the public health implications of any additional sampling results, and recommend public health actions, as needed.
4. The NYSDOH will continue, as needed, to provide support to community members related to this health consultation or other site-related health concerns that may arise. This report will be placed in the local repository and provided to people who request it.

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REPORT PREPARATION

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Appendix A: Figures

Figure A1. Location of the Site



Appendix B: Tables

Table B1. Arsenic Mine Residential Properties Surface Soil Arsenic Results

Location	Number of Samples	Range (mg/kg)	Mean^a (mg/kg)	95% UCL^b (mg/kg)
Property 1	13	19.7 – 49,300	10,690	48,071
Property 2	9	10.3 – 6,050	873	4,247
Property 3	8	26.6 – 56,000	12,734	25,406
Property 4	5	19.6 – 20,600	4,142	na
Property 5	7	24.3 - 181	79	na
Property 6	10	3.2 - 687	193	512
Property 7	6	22 - 317	116	na
Property 8	7	9 - 99.5	35	na
Property 9	8	66.5 – 1,520	298	1,398
Property 10	7	3.6 - 841	199	na

^a The mean arsenic result is used as the exposure point concentration for properties on which less than 8 validated samples were taken.

^b The 95% upper confidence limit (UCL) of the mean is used as the exposure point concentration for properties on which 8 or more validated samples were taken.

mg/kg = milligrams of arsenic per kilogram of soil; na = not applicable.

Appendix C: Health Effects of Site-Related Chemicals

All chemicals can cause health effects. The risk for adverse health effects from any chemical depends on the chemical's toxicity, the amount of the chemical to which a person is exposed, and how long and how often the exposure occurs. The risks also depend on the characteristics of the exposed person, such as age, sex, diet, family traits, lifestyle, genetic background, the presence of other chemicals in their body (e.g., alcohol, prescription drugs), and general state of health.

Arsenic is found in ores of copper, lead and other minerals, and in soil, groundwater and surface water. Arsenic compounds have been used in wood preservatives and in commercial pesticides. Below is some general information about the kinds of health effects that are associated with exposure to the arsenic.

Exposure to arsenic is known to cause cancer in humans. There is convincing evidence from a large number of scientific studies of people who have been exposed to high levels of arsenic in drinking water that ingestion of inorganic arsenic increases the risk for skin, lung and bladder cancer [ATSDR 2007; NRC 2001; NTP 2016]. The USEPA and US Department of Health and Human Services classify arsenic as a known human carcinogen [USEPA 1991; NTP 2016]. Some people exposed to high levels of arsenic in drinking water for long periods of time also developed a characteristic darkening and thickening of the skin on the hands and feet. Long-term exposure to high levels of arsenic is also associated with nerve and liver damage, high blood pressure, damage to the vascular system (i.e., blood vessels of the heart and brain), and could lead to learning deficiencies [ATSDR 2007].

References for Appendix C

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Appendix D: Sample Calculations

Table D1. ATSDR Recommended Soil/Indoor Dust or Sediment Ingestion Rates

Exposure Group	Soil/Indoor Dust or Sediment Ingestion ¹ (mg/kg/day)	Body Weight ² (kg)
Birth to < 1 year	150	7.8
1 to < 2 years	200	11.4
2 to < 6 years	200	17.4
6 to < 11 years	200	31.8
11 to < 16 years	100	56.8
16 to < 21 years	100	71.6
Adults ≥ 21 years	100	80
Children with pica behavior (1 to < 2 and 2 to < 6 years)	5,000 per event	11.4

¹Soil/indoor dust or sediment ingestion rates are the reasonable maximum exposure scenario from ATSDR's Exposure Dose Guidance for Soil/Sediment Ingestion [ATSDR 2018].

²Mean body weight

mg/kg/day = milligrams per kilogram per day; kg = kilograms

Sample calculations use the 95% UCL of the mean to evaluate chronic arsenic exposure and the maximum arsenic soil concentration to evaluate acute exposure. All calculations are done using ATSDR's Exposure Dose Guidance for Soil/Sediment Ingestion [ATSDR 2018] and ATSDR's Exposure Dose Guidance for Soil/Sediment Dermal Absorption [ATSDR 2016].

1. Calculation of Chronic Non-cancer Dermal Administered Dose:

$$DAD = \frac{C_{soil} \times EF \times CF \times AF \times ABS_d \times SA}{BW \times ABS_{GI}}$$

DAD = Dermal administered dose (mg/kg/day)

C_{soil} = Contaminant concentration in soil (mg/kg)

EF = Exposure frequency

CF = Conversion factor (10⁻⁶ kg/mg)

AF = Adherence factor of soil to skin (mg/cm²/event)

ABS_d = Dermal absorption fraction

SA = Surface area available for contact (cm²)

BW = Age-specific body weight (kg)

ABS_{GI} = Gastrointestinal absorption factor

Calculation of Arsenic Dermal Doses for Property 1

Exposure Point Concentration¹ = 48,071 mg/kg

Sample Depth: 0-6 inches

Age Group	Soil Concentration (mg/kg)	Exposure Frequency ²	Soil Adherence Factor ³ (mg/cm ² -event)	Dermal Absorption Factor ⁴	Surface Area ⁵ (cm ²)	Body Weight (kg)	Dermal Absorbed Dose ⁶ (mg/kg/day)	GI Absorption Factor ⁷	Dermal Administered Dose ⁸ (mg/kg/day)
Birth to < 1 yr	48,071	0.614	0.2	0.03	1,772	7.8	4.02E-02	1	4.02E-02
Child 1 to < 2 yr	48,071	0.614	0.2	0.03	2,299	11.4	3.57E-02	1	3.57E-02
Child 2 to < 6 yr	48,071	0.614	0.2	0.03	2,592	17.4	2.64E-02	1	2.64E-02
Child 6 to < 11 yr	48,071	0.614	0.2	0.03	3,824	31.8	2.13E-02	1	2.13E-02
Child 11 to <16 yr	48,071	0.614	0.2	0.03	5,454	56.8	1.70E-02	1	1.70E-02
Child 16 to <21 yr	48,071	0.614	0.2	0.03	6,083	71.6	1.50E-02	1	1.50E-02
Adults ≥ 21 yr	48,071	0.614	0.07	0.03	6,030	80	4.67E-03	1	4.67E-03

¹Exposure point concentration = 95% upper confidence limit of the mean (mg/kg)

²Exposure frequency = (224 days/365 days) x (7 days/7 days). Based on exposure 7 days per week over 224 days per year with no snow cover or frozen ground in New York State.

³The soil adherence factor (AF) is a measure of soil adherence to the skin [USEPA 2004]

⁴The dermal absorption factor (ABS_d) represents the fraction of a chemical that is absorbed through the skin after dermal contact

⁵Surface area (SA) is the amount of skin surface that is available for contact with soil [USEPA 2011]

⁶Dermal absorbed dose = (soil concentration) *(EF)*(CF)*(AF)*(ABS_d)*(SA)/ (Body weight)

⁷The GI absorption factor (ABS_{GI}) is the fraction of chemical absorbed by the gastrointestinal tract [EPA 2004]

⁸Dermal administered dose = (dermal absorbed dose)/(ABS_{GI})

2. Calculation of Chronic Non-cancer Ingestion Exposure Dose: Total Non-cancer Dose from Ingestion and Dermal Exposure, Hazard Quotient, and Margin of Exposure:

A. Non-cancer Ingestion Exposure Dose:

$$D = \frac{C \times IR \times CF \times EF \times RBA}{BW}$$

D = Oral dose (mg/kg/day)

C = Contaminant concentration in soil (mg/kg)

IR = Age-specific soil intake rate (mg/day)

CF = Conversion factor (10^{-6} kg/mg)

EF = Exposure frequency

BW = Age-specific body weight (kg)

RBA = relative bioavailability for arsenic (0.6)

B. Total Non-cancer Dose from Ingestion and Dermal Exposure:

Total oral and dermal exposure dose = dermal administered dose + ingestion exposure dose

C. Hazard Quotient (HQ):

$$HQ = \frac{\text{Total oral and dermal administered exposure dose}}{\text{Reference dose}}$$

Calculation of Arsenic Ingestion and Dermal Non-cancer Risk in Soil for Property 1

Exposure Point Concentration¹ = 48,071 mg/kg

Sample Depth: 0-6 inches

Age Group	Soil Concentration (mg/kg)	Soil Intake ² (mg/day)	Exposure Frequency ³	Body Weight (kg)	Relative Bioavailability Factor ⁴	Ingestion Exposure Dose ⁵ (mg/kg/day)	Dermal Administered Dose ⁶ (mg/kg/day)	Total Oral and Dermal Exposure Dose ⁷ (mg/kg/day)	Reference Dose ⁸ (mg/kg/day)	Hazard Quotient ⁹
Birth to < 1 yr	48,071	150	0.614	7.8	0.60	3.40E-01	4.02E-02	3.81E-01	0.0003	1,268.69
Child 1 to < 2 yr	48,071	200	0.614	11.4	0.60	3.11E-01	3.57E-02	3.46E-01	0.0003	1,154.11
Child 2 to < 6 yr	48,071	200	0.614	17.4	0.60	2.03E-01	2.64E-02	2.30E-01	0.0003	766.07
Child 6 to < 11 yr	48,071	200	0.614	31.8	0.60	1.11E-01	2.13E-02	1.33E-01	0.0003	442.03
Child 11 to <16 yr	48,071	100	0.614	56.8	0.60	3.12E-02	1.70E-02	4.82E-02	0.0003	160.53
Child 16 to <21 yr	48,071	100	0.614	71.6	0.60	2.47E-02	1.50E-02	3.98E-02	0.0003	132.53
Adults ≥ 21 yr	48,071	100	0.614	80	0.60	2.21E-02	4.67E-03	2.68E-02	0.0003	89.31

¹Exposure point concentration = 95% upper confidence limit of the mean (mg/kg)

²ATSDR-recommended soil ingestion rates [ATSDR 2018]

³Exposure frequency = (224 days/365 days) x (7 days/7 days). Based on exposure 7 days per week over 224 days per year with no snow cover or frozen ground in New York State.

⁴The ratio of the absolute bioavailability (absorbed dose) of arsenic in soil to the absolute bioavailability of arsenic in water [ATSDR 2016].

⁵Exposure dose = (soil concentration)*(soil intake)*(exposure frequency)*(CF)*(RBA)/(body weight).

⁶Dermal administered dose is calculated in the previous table

⁷Total oral and dermal exposure dose = ingestion exposure dose + dermal administered dose

⁸Reference dose = 0.0003 mg/kg/day [USEPA 1991].

⁹Hazard quotient = total contaminant dose/reference dose.

mg/kg: milligrams per kilogram; mg/kg/day: milligrams per kilogram per day; RME: reasonable maximum exposure; CTE: central tendency exposure.

D. Margin of Exposure (MOE):

$$\text{MOE} = \frac{\text{Effect Level or LOEL}}{\text{Estimated Oral and Dermal Exposure Dose}}$$

Effect level: For chronic arsenic exposure, lowest observed effect level (LOEL) for hyperpigmentation, keratosis, and vascular complication in humans of 0.014 mg/kg/day [USEPA 1991].

Age Group	Total Oral and Dermal Exposure Dose (mg/kg/day)	Margin of Exposure ¹
Birth to < 1 yr	3.81E-01	0.04
Child 1 to < 2 yr	3.46E-01	0.04
Child 2 to < 6 yr	2.30E-01	0.06
Child 6 to < 11 yr	1.33E-01	0.11
Child 11 to <16 yr	4.82E-02	0.29
Child 16 to <21 yr	3.98E-02	0.35
Adults ≥ 21 yr	2.68E-02	0.52

¹The ratio of the exposure associated with health effects (a LOEL of 0.014 mg/kg/day [USEPA 1991]) and the combined oral and dermal exposure from soil. A margin of exposure less than one means that the oral and dermal exposure exceeds the exposure associated with health effects.
mg/kg/day = milligrams per kilogram per day

3. Calculation of Cancer Dermal Administered Dose:

$$DAD = \frac{C_{soil} \times ED/AT \times CF \times EF \times AF \times ABS_d \times SA}{BW \times ABS_{GI}}$$

DAD = Dermal administered dose (mg/kg/day)

C_{soil} = Contaminant concentration in soil (mg/kg)

ED = Exposure duration (years)

AT= Averaging time (78 years)

CF = Conversion factor (10⁻⁶ kg/mg)

EF = Exposure frequency

AF = Adherence factor of soil to skin (mg/cm²/event)

ABS_d = Dermal absorption fraction

SA = Surface area available for contact (cm²)

BW = Age-specific body weight (kg)

ABS_{GI} = Gastrointestinal absorption factor

Calculation of Arsenic Dermal Doses for Property 1

Exposure Point Concentration = 48,071 mg/kg

Sample Depth: 0-6 inches

Age Group	Exposure Duration (years)	Fraction of Lifetime	Soil Concentration (mg/kg)	Exposure Frequency ²	Soil Adherence Factor ³ (mg/cm ² -event)	Dermal Absorption Factor ⁴	Surface Area ⁵ (cm ²)	Body Weight (kg)	Dermal Absorbed Dose ⁶ (mg/kg/day)	GI Absorption Factor ⁷	Dermal Administered Dose ⁸ (mg/kg/day)
Birth to < 1 yr	1	0.0128	48,071	0.614	0.2	0.03	1,772	7.2	5.16E-04	1	5.16E-04
Child 1 to < 2 yr	1	0.0128	48,071	0.614	0.2	0.03	2,299	11.4	4.58E-04	1	4.58E-04
Child 2 to < 6 yr	4	0.0513	48,071	0.614	0.2	0.03	2,592	17.4	1.35E-03	1	1.35E-03
Child 6 to < 11 yr	5	0.0641	48,071	0.614	0.2	0.03	3,824	31.8	1.36E-03	1	1.36E-03
Child 11 to <16 yr	5	0.0641	48,071	0.614	0.2	0.03	5,454	56.8	1.09E-03	1	1.09E-03
Child 16 to <21 yr	5	0.0641	48,071	0.614	0.2	0.03	6,083	71.6	9.64E-04	1	9.64E-04
Adults ≥ 21 yr	12	0.1538	48,071	0.614	0.07	0.03	6,030	80	7.18E-04	1	7.18E-04

¹Exposure point concentration = 95% upper confidence limit of the mean (mg/kg)

²Exposure frequency = (224 days/365 days) x (7 days/7 days). Based on exposure 7 days per week over 224 days per year with no snow cover or frozen ground in New York State.

³The soil adherence factor (AF) is a measure of soil adherence to the skin [USEPA 2004].

⁴The dermal absorption factor (ABS_d) represents the fraction of a chemical that is absorbed through the skin after dermal contact.

⁵Surface area (SA) is the amount of skin surface that is available for contact with soil [USEPA 2011].

⁶Dermal absorbed dose = (soil concentration)*(ED/AT)*(CF)*(EF)*(AF)*(ABS_d)*(SA)/ (Body weight).

⁷The GI absorption factor (ABS_{GI}) is the fraction of chemical absorbed by the gastrointestinal tract [USEPA 2004].

⁸Dermal administered dose = (dermal absorbed dose)/(ABS_{GI}).

4. Calculation of Cancer Ingestion Exposure Dose; Total Cancer Dose from Ingestion and Dermal Exposure, and Cancer Risk:

A. Cancer Ingestion Exposure Dose

$$D = \frac{C \times \left(\frac{ED}{AT}\right) \times IR \times CF \times EF \times RBA}{BW}$$

D = Oral dose (mg/kg/day)

C = Contaminant concentration in soil (mg/kg)

ED = Exposure duration (years)

AT = Averaging time (78 years)

IR = Age-specific soil intake rate (mg/day)

CF = Conversion factor (10^{-6} kg/mg)

EF = Exposure frequency

BW = Age-specific body weight (kg)

RBA = relative bioavailability of arsenic (0.6)

B. Total Cancer Dose from Ingestion and Dermal Exposure and Cancer Risk:

Total oral and dermal cancer dose = cancer dermal administered dose + cancer ingestion dose

C. Cancer Risk

Cancer risk = Total oral and dermal administered exposure dose x cancer potency factor

D. Lifetime cancer risk

Lifetime cancer risk = sum of cancer risk for each age group

Calculation of Arsenic Ingestion and Dermal Cancer Risk in Soil for Property 1
Exposure Point Concentration¹ = 48,071 mg/kg, Exposure Duration = 33 years
Sample Depth: 0-6 inches

Age Group	Exposure Duration (years)	Fraction of Lifetime	Soil Concentration (mg/kg)	Exposure Frequency ²	Body weight (kg)	Soil Intake ³ (mg/day)	Relative Bioavailability Factor ⁴	Ingestion Exposure Dose ⁵ (mg/kg/day)	Dermal Administered Dose ⁶ (mg/kg/day)	Total Oral and Dermal Exposure Dose ⁷ (mg/kg/day)	Cancer Risk ⁸
Birth to < 1 yr	1	0.013	48,071	0.614	7.8	150	0.6	4.36E-03	5.16E-04	4.88E-03	7.31E-03
Child 1 to < 2 yr	1	0.013	48,071	0.614	11.4	200	0.6	3.9E-03	4.58E-04	4.4E-03	6.6E-03
Child 2 to < 6 yr	4	0.051	48,071	0.614	17.4	200	0.6	1.0E-02	1.35E-03	1.2E-02	1.8E-02
Child 6 to < 11 yr	5	0.064	48,071	0.614	31.8	200	0.6	7.1E-03	1.36E-03	8.5E-03	1.3E-02
Child 11 to < 16 yr	5	0.064	48,071	0.614	56.8	100	0.6	2.0E-03	1.09E-03	3.1E-03	4.6E-03
Child 16 to < 21 yr	5	0.064	48,071	0.614	71.6	100	0.6	1.5E-03	9.64E-04	2.5E-03	3.8E-03
Adults ≥ 21 yr	12	0.154	48,071	0.614	80	100	0.6	3.4E-03	7.18E-04	4.1E-03	6.2E-03
Total risk for 33 year exposure										5.9E-02	

¹Exposure point concentration = 95% upper confidence limit of the mean (mg/kg)

²Exposure frequency = (224 days/365 days) x (7 days/7 days). Based on exposure 7 days per week over 224 days per year with no snow cover or frozen ground in New York State.

³ATSDR-recommended soil ingestion rates [ATSDR 2018].

⁴The ratio of the absolute bioavailability (absorbed dose) of arsenic in soil to the absolute bioavailability of arsenic in water [ATSDR 2016].

⁵Exposure dose = (fraction of lifetime)*(soil concentration)*(conversion factor)*(exposure frequency)*(soil intake)/(body weight).

⁶Dermal administered dose is calculated in the previous table

⁷Total oral and dermal exposure dose = ingestion exposure dose + dermal administered dose

⁸Cancer risk = (total exposure dose)*(cancer potency factor)

Cancer potency factor = (1.5 mg/kg/day)⁻¹ [USEPA 1995].

mg/kg: milligrams per kilogram; mg/kg/day: milligrams per kilogram per day;

5. **Calculation of Acute Non-cancer Exposure Dose and Margin of Exposure:**

A. Acute Non-cancer Ingestion Exposure Dose for a Child 1 year to < 2 years:

$$D = \frac{C \times IR \times CF \times EF \times RBA}{BW}$$

D = Oral dose (mg/kg/day)

C = Contaminant concentration in soil (mg/kg)

IR = Age-specific soil intake rate for a pica child (5,000 mg/day)

CF = Conversion factor (10⁻⁶ kg/mg)

EF = Exposure frequency

BW = Age-specific body weight (11.4 kg)

RBA = relative bioavailability factor for arsenic (0.6)

Calculation of Acute Arsenic Ingestion Non-cancer Risk in Soil for Property 1

Exposure Point Concentration¹ = 49300 mg/kg

Sample Depth: 0-6 inches

Age Group	Soil Concentration (mg/kg)	Soil Intake ² (mg/day)		Exposure Frequency ³	Body Weight (kg)	Relative Bioavailability Factor ⁴	Exposure Dose ⁵ (mg/kg/day)		Acute MRL ⁶ (mg/kg/day)	Hazard Quotient ⁷	
		RME	Pica				RME	Pica		RME	Pica
Child 1 to < 2 yr	49,300	200	5,000	1.000	11.4	0.60	5.19E-01	1.30E+01	0.005	104	2,595

¹Exposure point concentration = maximum soil arsenic concentration at the property (mg/kg)

²ATSDR-recommended soil ingestion rates [ATSDR 2018]

³Exposure frequency = 1 for the acute scenario

⁴The ratio of the absolute bioavailability (absorbed dose) of arsenic in soil to the absolute bioavailability of arsenic in water [ATSDR 2016].

⁵Exposure dose = (soil concentration)*(soil intake)*(conversion factor)*(exposure frequency)*(relative bioavailability)/(body weight).

⁶Acute MRL = 0.005 mg/kg/day [ATSDR 2007].

⁷Hazard quotient = contaminant dose/MRL.

mg/kg: milligrams per kilogram; mg/kg/day: milligrams per kilogram per day; RME: reasonable maximum exposure

B. Calculation of Margin of Exposure for Acute Exposure for a Child 1 year to < 2 years

$$MOE = \frac{\textit{Effect Level or LOEL}}{\textit{Estimated Acute Exposure Dose}}$$

Effect level: For acute arsenic exposure, lowest observed effect level (LOEL) for edema and gastrointestinal effects in people of 0.05 mg/kg/day [ATSDR 2007].

Age Group	Exposure Dose (mg/kg/day)		Margin of Exposure ¹	
	RME	Pica	RME	Pica
Child 1 to < 2 yr	5.19E-01	1.30E+01	0.10	0.004

¹The ratio of the exposure associated with short-term health effects (a LOEL of 0.05 mg/kg/day [ATSDR 2007]) and the short-term oral dose from soil. A margin of exposure less than one means that the oral exposure exceeds the exposure associated with health effects.

References for Appendix D

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