Health Consultation

NAVAL WEAPONS STATION SEAL BEACH DETACHMENT
CONCORD

EVALUATION OF SOIL ARSENIC CONCENTRATIONS AT THE
MAGAZINE STUDY AREA

CITY OF CONCORD, CONTRA COSTA COUNTY, CALIFORNIA

EPA FACILITY ID: CA7170024528

MARCH 28, 2005

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.

HEALTH CONSULTATION

NAVAL WEAPONS STATION SEAL BEACH DETACHMENT CONCORD
EVALUATION OF SOIL ARSENIC CONCENTRATIONS AT THE MAGAZINE STUDY AREA

CITY OF CONCORD, CONTRA COSTA COUNTY, CALIFORNIA

EPA FACILITY ID: CA7170024528

Prepared by:
U.S. Department of Health and Human Services
Public Health Service
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation

Summary

Past operations and waste management practices at the Naval Weapons Station Seal Beach Detachment Concord (Detachment Concord) have resulted in some environmental contamination on-base. The Navy, under the oversight of the US Environmental Protection Agency (EPA) and the California Environmental Protection Agency (Cal/EPA), is actively investigating and remediating known and suspected areas of on-base contamination.

Arsenic was detected in soil samples taken in the Magazine Study Area of Site 22 at concentrations above the EPA and Cal/EPA regulatory levels. Some of the samples were taken within 100 feet of the base boundary. Private homes and a high school are located on the other side of the boundary. The Navy contacted ATSDR on August 31, 2004 and requested assistance in evaluating the potential public health concerns for the neighboring residents.

ATSDR reviewed information about the historical uses of the Magazine Study Area to help evaluate whether the arsenic concentrations measured in the soil would be expected to impact the public health of the people in the neighboring community. Specifically ATSDR was asked to address the following questions:

1. Is there a need to sample neighboring yards for arsenic contamination?
2. Are residents or students attending the neighboring high school exposed to harmful levels of arsenic when dust blows from the base during the annual tilling operation?
3. Are the results of the soil sampling appropriate for preparing a Human Health Risk Assessment for community exposure to the arsenic?

Conclusions

ATSDR concluded that incidental exposure to arsenic in the soil at the concentrations measured in the Magazine Study Area would not be expected to harm health. In addition, assuming that the arsenic present in the Magazine Study Area soil resulted from the Navy's past applications of pesticides and assuming that the Navy only applied the pesticides on Navy property, it is unlikely that the arsenic concentrations in the neighboring yards are any higher than the maximum concentration measured on-base. As a result there is no strong evidence that additional soil testing outside of the base is necessary to protect public health. However, at the request of members of the public, the Navy has agreed to conduct soil sampling in areas of adjacent yards that may have been impacted by overspray from the pesticide applications, and a sampling plan being developed. Residents may reduce their exposure to arsenic and other naturally occurring contaminants in the soil by following basic good hygiene principles such as wearing gloves; not eating, drinking or smoking while working with the soil; and washing hands after working or playing in the yard.

ATSDR concluded that the actual exposure of the community to the airborne arsenic released during the tilling operations would only be a few hours per year. The estimated arsenic intake would be small and likely below levels that could cause health effects. However, the short-term exposure to the generated dust could cause minor short-term irritation of the eyes, nose or throat. ATSDR suggests that as a prudent public health action, the Navy ensure dust control measures (i.e., favorable winds and soil moisture content) are considered when planning the operation.

ATSDR concluded that the existing surface soil sampling is appropriate for evaluating potential health impacts of the surrounding community to potential exposures to the arsenic measured in the soil in the Magazine Study Area using the public health assessment process.

This site was classified as a ‘no apparent public health hazard’ which means that although the community may be exposed to base-related contaminants, health effects are not expected to result from this exposure.

Background

Site Description and History

In December 1942, the Navy commissioned the ordnance-shipping depot at what is now the Tidal Area of Detachment Concord. When the munitions volume exceeded the capacity of this facility, a 5,143 acre parcel of land in the Diablo Creek Valley was acquired. This is now known as the Inland Area of Detachment Concord and includes the Magazine Study Area. Review of aerial photographs from 1939 and historical maps indicate that the Inland and neighboring residential areas were previously used for agricultural purposes (Tetra Tech 2003).

Previous investigations at Site 22 have focused on Building 7SH5. Since it was built in 1944, this building has been used for equipment storage, environment and vibration testing of missile components, maintenance operations, and manufacturing mobile laboratories. The Navy has used the Magazine Area surrounding Site 22 only for munitions storage (Tetra Tech 2003).

The Magazine Study Area is on the southwestern side of the Inland Area and shares its boundary with a residential area in the city of Concord. This boundary is approximately 1.6 miles long. The Magazine area extends a little less than ½ mile into the base, and occupies a little less than 0.8 square miles.

Arsenic concentrations in the surface soil of the Magazine Area were found to be higher than background levels. The elevated concentrations are believed to have resulted from arsenical pesticides used by the Navy to control weeds, insects and rodents around munitions bunkers. It is also possible that past agricultural practices included application of pesticides containing arsenic.

Summary of Measured Data

ATSDR reviewed soil sampling data obtained during the summer of 2004. The results included 40 surface soil samples and 4 soil profiles. The surface soil samples were collected from the soil surface to a depth of 6 inches. The soil profiles included soil samples collected from the surface to a depth of 6 inches, from a depth of 1 foot to 1 ½ feet (ft), and from 2 ½ - 3 ft. In addition, the arsenic concentration was measured in the surface vegetation at three sampling locations.

The arsenic concentrations in the surface soil samples ranged from 2.6 milligrams per kilogram (mg/kg) to 199 mg/kg. Twenty-four of the 44 surface soil samples (55%) contained less than 10 mg/kg of arsenic and 61% contained less than 20 mg/kg. Arsenic concentrations less than 10 mg/kg are typically found along the boundary between the Magazine Study Area and other base property. Concentrations less than 10 mg/kg are also found along the northern portion of the base boundary. Concentrations less than 10 mg/kg are believed to represent background conditions for this area (Wallerstein and Tyahla 2004). Arsenic concentrations greater than 20 mg/kg were found in the Magazine Study Area and along the base boundary from the southern-most sampling area north - about three-quarters of the distance towards the northern edge of the property. Concentrations greater than 20 mg/kg are believed to represent arsenic concentrations that were likely a result of arsenical pesticide use.

Analysis of the four soil profiles, indicates arsenic concentrations in the 1 - 1 ½ and 2 ½ - 3 foot depths tend to be less than 15 mg/kg, even when the surface soil concentration is as high as 77.6 mg/kg. This suggests that the arsenic is primarily in the surface soil and is not migrating down through the soil or into the groundwater. This is consistent with other research that indicates arsenic is largely immobile in agricultural soils and tends to remain in the upper soil layers indefinitely (ATSDR 2000).

Only trace amounts of arsenic were detected in the three vegetation samples (less than 0.33 mg/kg). The arsenic concentrations in the host soil varied from 8.7 - 137 mg/kg. These results indicate that the arsenic is strongly incorporated into the soil and not bioavailable to plants growing in that soil. This finding is also consistent with other research. While a few species of plants are able to accumulate significant amounts of arsenic from soil, the majority of plant species that have been tested do not (Tu et al 2002, ATSDR 2000).

Other research indicates that only a small fraction of the arsenic measured in soil will be absorbed into the body of an animal that ingests the soil. Measured values of bioavailability for inorganic arsenic in soil to terrestrial animals appear to range from 0.2 - 24.7%. The bioavailability decreases with time after the application as the arsenic binds with the soil. While it is expected that only a small fraction of the arsenic in the soil would be bioavailable to people who accidentally ingest the soil, ATSDR conservatively assumes the bioavailability of arsenic in soil to be equal to 40% (ATSDR 2000, Groen et al 1994, Roberts et al 2002, Sharma et al 2004, Turpeinen et al 2003).

Evaluation

At the request of the Navy, ATSDR evaluated two potential exposure pathways. First ATSDR evaluated whether neighboring residents (adults and children) would be exposed to harmful levels of arsenic from gardening or playing in their yards or on the high school athletic fields. Second ATSDR evaluated whether neighboring residents (adults and children) would be exposed to harmful levels of arsenic potentially in the dust blown from the base by the wind. (The calculations for these evaluations are shown in Appendix A).

ATSDR relied on previously published reports and historical knowledge of site personnel to provide the necessary background information. If changes are necessary to this background information, it may be necessary to review the evaluation to ensure that the results are still applicable. The following points summarize the provided background information used in the evaluation:

1. The high levels of arsenic measured in the soil at the Magazine Study Area resulted from historic arsenical pesticide use by the previous farmers and the Navy.
2. The Navy did not apply pesticides outside the base boundary

- Off-base arsenic concentrations above background levels are expected to be due to historic pesticide use by the previous farmers.
- The previous farmers are expected to have applied less arsenical pesticides than the Navy applied on-base. Arsenic concentrations in the off-base soil are not expected to exceed the concentrations measured in the Magazine Study Area.

3. The Magazine Study Area is surrounded by drainage ditches that divert surface water runoff to an off-base drainage system
    - Surface water run-off from the Magazine Study Area may drain into Seal Creek or another drainage creek and eventual empty into Suisan Bay.
    - It is unlikely that significant amounts of surface water from the Magazine Study Area drains directly into the residential yards that border the base.

ATSDR also based the evaluation on the following assumptions:

1. Arsenic concentrations in the soil of residential and high school yards adjacent to the boundary could be as high as that measured in the Magazine Study Area.
2. The measured arsenic distribution in the soil profiles and the low accumulation of arsenic in the vegetation indicates the arsenic is strongly attached to the soil particles.
    - As a result the arsenic may not be highly bioavailable, however ATSDR conservatively assumed 40% of the arsenic measured in the soil could be bioavailable during potential incidental ingestion exposures and 100% bioavailable during potential inhalation exposures.

Is there a need to sample neighboring yards for arsenic contamination?

Probably not.

ATSDR calculated the potential arsenic exposure of adults and children who might garden or play in yards where the soil concentration was estimated to be equal to the maximum arsenic concentration measured in the Magazine Study Area. ATSDR assumed that both adults and children were in the yards for several hours a day, 6 days a week, and every week of the year. ATSDR further assumed that the adults and children were in direct contact with the soil each time they were in the yard so that approximately one-third of their expected 24-hour incidental soil and dust ingestion contained arsenic contaminated soil. The estimated arsenic ingestion was below levels known or anticipated to cause health effects (Tables 1, 2, and 3).

ATSDR also calculated the potential arsenic exposure for high school athletes working out and playing in the school yards. Again ATSDR assumed the soil concentration in the school yard was equal to the maximum concentration measured in the Magazine Study Area. ATSDR further assumed that the athletes were in the yards several hours a day, 5 days a week, 40 weeks a year, and that they ingested approximately 6 times more soil than adults working in the yards would be expected to ingest. The estimated arsenic ingestion for these athletes was also below levels known or anticipated to cause health effects (Tables 1, 2, and 3).

On the basis of this evaluation, incidental exposure to soil containing even the maximum concentration of arsenic detected in on-base soil is not expected to harm the health of high school athletes or people in the neighborhood. Assuming that the arsenic present in the Magazine Study Area soil resulted from historic application of arsenical pesticides by the Navy and that the Navy only applied pesticides on Navy property, it is unlikely that arsenic concentrations in the neighboring yards are any higher than the maximum concentration measured on-base. As a result there is no strong evidence that additional soil testing outside of the base is necessary to protect public health. However, at the request of members of the public, the Navy has agreed to conduct soil sampling in areas of adjacent yards that may have been impacted by overspray from pesticide application. The Navy is currently developing a plan to sample these properties.

As a prudent public health action, residents may reduce their exposure to arsenic and other naturally occurring contaminants in the soil by following basic good hygiene practices including wearing gloves while working with the soil and not eating, drinking or smoking while working with the soil; washing and peeling home-grown produce before consumption; and washing hands after working or playing in the yard. In addition, maintaining vegetative ground-cover (such as grass) will significantly reduce exposures to all soil contaminants, and leaving shoes worn outside at the door will reduce the amount of soil contaminants brought into the home.

Are residents or students attending the neighboring high school exposed to harmful levels of arsenic when dust blows from the base during the tilling operation?

Probably not.

Typically, once each spring the Navy tills the 50 ft wide section between the two fences that separate the Magazine Study Area and the adjacent residential community. ATSDR used a variety of techniques to estimate the amount of dust that might be generated by the tilling operation to evaluate the potential exposure for residents and high school students from the dust and especially the arsenic found in the dust. The EPA National Emission Inventory Method (Roe and Hemmer 2004) was used to estimate the emissions from tilling operations. Depending on the amount of silt in the d soil, the amount of dust released into the air while tilling could range from 1.2 - 4.2 pounds of PM10 (particulate matter with an aerodynamic diameter of 10 micrometers or less) (Table 4).

ATSDR used SCREEN-3, a conservative air dispersion screening model, to roughly estimate the possible downwind air concentrations of PM10 and arsenic. Basically, SCREEN-3 calculates the expected worst-case downwind concentration using estimates about the amount of contaminant released during an activity and the initial size of the release. For this application SCREEN-3 was used to estimate the air concentration of PM10 at 10 meters (m) and 100 m (approximately 32 and 330 ft) downwind from the tilling operation. The arsenic concentration in the air was estimated by assuming the fraction of arsenic in the PM10 was similar to that measured in the soil (Tables 5, 6, 7, and 8). The estimated arsenic concentration is below levels known or anticipated to cause health effects (Table 9).

This analysis technique is expected to significantly over-estimate the downwind PM10 and arsenic concentrations for several reasons. First, SCREEN-3 estimates the downwind concentration at *steady-state conditions*; this means SCREEN-3 calculates the downwind concentration assuming the emissions are continuously occurring at the same rate. In reality, the emissions will only occur during the actual tilling operation. At the end of the tilling operation the emissions cease and the dust plume will disperse. Second, the model only estimates the downwind concentration, if the wind is blowing predominately north or east during the tilling operation, there will be very little dust transport into the neighboring community. Third, the arsenic concentrations in the soil near the fence ranged from 18.8 - 199 mg/kg, but ATSDR conservatively assumed that the arsenic concentration in the PM10 was equal to 199 mg/kg.

The estimated PM10 concentration at 10 m (32 ft) *downwind* of the operation is relatively high; however the actual time of exposure to the dust would be relatively short. Assuming that the length of the area between the fences to be tilled is approximately 5,400 ft and that two passes of the tractor (traveling approximately 10 miles per hour) are necessary to completely till the 50-ft wide section, tilling will be completed in less than 15 minutes. As soon as the dust is released into the air, the plume will begin to disperse and migrate downwind. The dust concentration in the plume decreases rapidly with distance and is well under the National Ambient Air Quality Standard (EPA 2004) for PM-10 at 100 m. The maximum estimated arsenic concentration in the air is higher than ATSDR's screening value; however this screening value is meant for chronic (long term) exposures. The estimated arsenic intake is well below levels expected to cause health effects because the frequency and duration of the exposure (a few hours per year) are very low.

The actual concentration of arsenic in the air in the community, and the actual exposure for people in the community are expected to be lower than those predicted. This is a result of the dispersion and mixing of the dust caused by shifts in the wind during and following the tilling operation and by the variability in the arsenic concentration of the soil (3 of the 7 samples from the fence line used in this analysis had arsenic concentrations less than 30 mg/kg).

The short-term exposure to the generated dust could be a nuisance for residents who live near the fence; causing short-term minor health effects or causing residents to have to clean the settled dust. Specific health effects resulting from dust exposure depends on a combination of factors including the concentration of dust, duration of exposure and composition of the dust (Mengesha and Bekele 1998). However some studies indicate that short-term health effects, most commonly eye, nose and throat irritation, could be possible in some exposure situations (Pan et al 2000, Gomez et al 1992). ATSDR suggests, as a prudent public health action, that the Navy ensure dust control measures (such as favorable winds and soil moisture content) are considered when planning the yearly tilling operation.

Are the results of the soil sampling appropriate for preparing a Human Health Risk Assessment for community exposure to the arsenic?

ATSDR performs public health assessments. These involve detailed comparisons of measured environmental concentrations and estimated exposures to toxicological and epidemiological information. By nature, public health assessments tend to be less quantitative than Human Health Risk Assessments. Regulators who routinely prepare Human Health Risk Assessments can provide a better evaluation of the data for that purpose. ATSDR reviewed this data and believes it to be appropriate for a public health evaluation. For additional information on the purpose and use of public health assessments please contact Sue Neurath (404-498-0374) or visit the ATSDR web-site (http://www.atsdr.cdc.gov/ or http://www.atsdr.cdc.gov/HAC/pha.html). For additional information on the purpose and use of Human Health Risk Assessments please see EPA's Risk Assessment Guidance for Superfund (RAGS Part A) available on the EPA web-site (http://www.epa.gov/superfund/programs/risk/ragsa/).

Response to Restoration Advisory Board Comments

A draft version of this health consultation was discussed during the September 2004 Restoration Advisory Board (RAB) meeting. The board member comments and questions are shown in italics and bold type, followed by ATSDR's response.

(1) The majority of the Inland Area is leased for beef cattle grazing. Could people who eat this beef be exposed to arsenic at concentrations that could cause health effects?

No.

ATSDR evaluated this exposure concern in the public health assessment. For this evaluation ATSDR made several conservative assumptions including:

1. All of the cattle's diet was by foraging on the base
2. Although the Magazine Study Area represents about 11% of the Inland Area, cattle ingested 15% of their food from the area
3. While foraging in the Magazine Study Area the cattle constantly ingest soil with an arsenic concentration equal to the average value of the measured concentrations above the background level

The results of the evaluation indicate small concentrations of arsenic would be expected in the beef, but that the level would be less than the typical concentrations reported in grains, meat, fish, and poultry. No health effects are expected for people who regularly consume beef from cattle or calves that graze on-base.

(2) The Magazine Study Area drains into Diablo/Seal Creek. Can residents or school children be exposed to arsenic contaminated sediment?

After the release of the draft health consultation, the Navy contacted ATSDR to provide additional information about surface water drainage in the Magazine Storage Area. ATSDR modified the assumptions and re-evaluated the potential for people to come into contact with arsenic in the canal or creek sediment at levels that could harm health. Results indicate residents and students of the neighboring high school are not exposed to surface water or sediment run-off from the Magazine Study Area. Seal Creek and another drainage ditch receive run-off from the study area. The creek and drainage ditch run north through the base, away from the residential area and the high school, and empty into Suisan Bay. The Navy is planning to sample Seal Creek as a part of the remedial investigation for this site.

(3) Please clarify the term "nuisance" applied to dust possibly generated during the tilling activity to clearly describe the concern.

The evaluation has been modified to describe that minor short-term health effects could result from exposure to high concentrations of dust that could be present close to the tilling activities and that residents close to the tilling activities may have to clean the settled dust.

(4) Clarify the basis for expressing arsenic detections in surface soil relative to a concentration of 20 mg/kg in the text, consistent with Table 1.

Done.

(5) The last paragraph is the Summary of Measured Data section indicates a small fraction of the arsenic in soil is bioavailable, yet a range of 3 to 77% is presented. Please clarify and modify the text.

The original statement “The bioavailability of arsenic in soil was reported to be approximately 3 - 77% of the total water-soluble fraction of arsenic in soil” was meant to indicate that a portion of the water-soluble arsenic in the soil could be bioavailable. The variation is likely due to differences in test methods used by the different researchers. The water-soluble arsenic is that portion of the total amount of arsenic in the soil that would dissolve into water when the soil is mixed with water. The original statement was removed to eliminate this potential confusion.

(6) Point #2 of ATSDR’s List of Assumptions states “The measured arsenic distribution in the soil profiles and the low accumulation of arsenic in the vegetation indicates the arsenic is strongly attached to the soil particles”. What is the proof that arsenic in soil is strongly attached to the soil particles? Why is this statement made if the potential incidental ingestion and inhalation exposures are said to likely be 100% bioavailable?

Arsenic concentrations were measured in four soil profiles. The reported arsenic concentrations were less than 15 mg/kg for soil samples obtained from depths of 1 - 1 ½ and 2 ½ - 3 ft depths, even when the surface soil concentration was as high as 77.6 mg/kg. Two of the soil profiles had arsenic concentrations within background levels for the study area. The other two samples had concentrations of 72.1 and 77.6 mg/kg in the surface soil, 9.4 and 12.3 mg/kg respectively in the 1 to 1 ½ ft depth, and 9.3 and 6.1 mg/kg respectively in the 2 ½ to 3 ft depth. These results are consistent with other research that indicates arsenic is largely immobile in agricultural soils and tends to remain in the upper soil layers indefinitely (ATSDR 2000). ATSDR interpreted this data as an indication that the arsenic in the surface soil at the study area is not likely to migrate significantly down the soil profile with infiltrating water.

Three vegetation samples were obtained from the study area. Only trace amounts of arsenic were reported in these samples (less than 0.33 mg/kg) even though the arsenic concentrations in the host soil varied from 8.7 - 137 mg/kg. These results are also consistent with other research that indicates the majority of plant species that have been tested do not accumulate significant amounts of arsenic from soil (ATSDR 2000).

Given the consistency of the measured data with that reported by other researchers, ATSDR assumed that for this area the arsenic measured in the surface soil would tend to remain in the surface soil and not be significantly bioavailable for people who incidentally ingest the soil.

ATSDR conservatively assumed that 40% of the arsenic in the soil would be bioavailable to people who incidentally ingest the soil. Several studies have shown that arsenic is not absorbed into the body when ingested from contaminated soil. Research using animal models has reported 0.2 to 24.7% of the arsenic measured in soil is assimilated by the animal, the remaining portion of the soil arsenic passes through the animal's digestive system (ATSDR 2000, Groen et al 1994, Roberts et al 2002).

ATSDR conservatively assumed that 100% of the arsenic present in the air could be bioavailable. The assumption was made because most studies describing the accumulation of arsenic in the body from inhalation are complicated by potential exposure to other metals and uncertainties in the actual exposure concentration (ATSDR 2000).

(7) The cancer risk for children and students shown in Tables 2 and 7 are suspect due to the choice of averaging times (did not use 70 years).

ATSDR removed those comparisons and added two new tables to summarize toxicologic and epidemiologic studies showing the potential health effects of arsenic exposure at the estimated ingestion rates and estimated downwind concentration during the annual tilling operation. Results indicate that health effects are not likely for these exposures.

(8) Please provide the reference for the EPA National Emission Inventory method used to estimate particulate emissions from the tilling operation used in Table 4.

The method used is described in Roe and Hemmer 2004, Section VI Agricultural Tilling. The complete reference including a web-site link is in the reference section of this document.

(9) Please provide a reference for the National Ambient Air Quality Standards (NAAQS).

A summary of the NAAQS is available on EPA's web-site: http://www.epa.gov/air/criteria.html

(10) Please provide references to the values used in Table 4.

Done.

(11) The document states that unvalidated soil sampling data was reviewed. What does "unvalidated" mean and how is it different from "validated" soil samples?

The Navy originally supplied their initial sampling results that had not been through the entire quality assurance/quality control process used to ensure the accuracy of the results. Since the release of the initial draft, ATSDR was notified that the results have been validated without any changes to the original data values.

(12) Explain how EPA determines if the risk for the arsenic exposure is at an acceptable level by the equation in Appendix A.

Descriptions of EPA risk assessment methods are available on the EPA web-site. ATSDR conservatively estimated the amount of arsenic that residents, children and student athletes might ingest due to their activities in their yards or school grounds and compared that to the ingestion rates that have been associated with health effects. In addition ATSDR conservatively estimated the downwind concentration of arsenic that could result from the annual tilling operation and compared that to ambient concentrations that have been associated with health effects. For both conditions, the estimated exposure is safely below the exposures shown to cause health effects.

(13) What is ATSDR's MRL for arsenic? Include the value to show the estimated arsenic ingestion is below the MRL.

Table 2 was revised to more clearly show this relationship.

Authors, Technical Advisors

Susan Neurath, Ph.D.
Environmental Health Scientist
Federal Facilities Assessment Branch
Division of Health Assessment and Consultation

Scott Sudweeks, M.S.P.H.
Toxicologist
Federal Facilities Assessment Branch
Division of Health Assessment and Consultation

Aimee Treffiletti, M.P.H.
Environmental Health Scientist
Federal Facilities Assessment Branch
Division of Health Assessment and Consultation

Gary Campbell, Ph.D.
Environmental Health Scientist
Federal Facilities Assessment Branch
Division of Health Assessment and Consultation

References

Agency for Toxic Substances Disease Registry. 2000. Toxicological Profile for Arsenic. Atlanta: US Department of Health and Human Services.

Case IH. No Date. Disk Harrows: Offset; product information.
Available at: http://www.caseih.com/products
Accessed on: September 7, 2004

[EPA] US Environmental Protection Agency. 1989. Risk Assessment Guidance for Superfund. Volume 1 Human Health Evaluation Manual (Part A) Interim Final. EPA/540/1-89/002.

EPA. 1995. Compilation of Air Pollutant Emission Factors, AP-42, Fifth Edition, Volume 1: Stationary Point and Area Sources, Chapter 13.2.3.3.
Available at: http://www.epa.gov/ttn/chief/ap42/
Accessed on: September 2, 2004

EPA. 2004. National Ambient Air Quality Standards (NAAQS).
Available at: http://www.epa.gov/air/criteria.html
Accessed on: December 8, 2004

Gomex SR, Parker RA, Dosman JA, McDuffie HH. 1992. Respiratory health effects of alkali dust in residents near desiccated Old Wives Lake. Arch Environ Health 47: 364-369.

Groen K, Vaessen AMG, Kliest JJG, de Boer JLM, van Ooik T, Timmerman A, et al. 1994. Bioavailability of inorganic arsenic from bog ore-containing soil in the dog. Environmental Health Perspectives 102. February 1994.

Mengesha YA and Bekele A. 1998. Relative chronic effects of different occupational dusts on respiratory indices and health of workers in three Ethiopia factories. American Journal of Industrial Medicine 34: 373-380.

Pan Z, Molhave L, Kjaergaard SK. 2000. Effects on eyes and nose in humans after experimental exposure to airborne office dust. Indoor Air 10: 237-245.

Roberts SM, Weimar WR, Vinson JRT, Munson JW, Bergeron RJ. 2002. Measurement of arsenic bioavailability in soil using a primate model. Toxicological Sciences 67: 303-310. June 2002.

Roe SM and Hemmer P. 2004. Summary of approaches available for fugitive dust sources, Technical Memorandum. Mid-Atlantic Regional Air Management Association, Baltimore, MD.
Available at: http://www.marama.org/visibility/AreaandPoint/TM_FugitiveDustFinal.doc
Accessed on: September 6, 2004.

Sharma S, Datta R, Sarkar D. 2004. Effect of equilibrium time on arsenic bioavailability in two Florida soils contaminated with arsenical pesticide. Geological Society of Armerica Abstracts with Programs 36. November 10, 2004.

Tetra Tech. 2003. Draft Supplemental Remedial Investigation Site 22 Naval Weapons Station Seal Beach Detachment Concord. San Francisco, CA. February 12. Prepared for Department of the Navy.

Available at:
http://www.sbeach.navy.mil/Programs/Environmental/IR/Reading_Room/Read_CO/Site%2022/CO_Site22_RI-S-D_2003-2.pdf Accessed on: September 3, 2004.

Tu C, Ma LQ, Bondada B. 2002. Arsenic accumulation in the hyperaccumulator Chinese Brake and its utilization potential for phytoremediation. Journal of Environmental Quality 31: 1671-1675.

Turpeinen R, Virta M, Haggblom MM. 2003. Analysis of arsenic bioavailabilty in contaminated ssoils. Environmental Toxicology and Chemistry 22: 1-6. January 2003.

Wallerstein M and Tyahla S. 2004. Personal Communication. Re: Arsenic concentrations in soil. August 31, 2004.

Appendix A - Exposure Calculations

Potential Arsenic Exposure from Incidental Soil Ingestion

Estimates of Arsenic Intake by Incidental Soil Ingestion

$$\text{Intake (mg/kg-d)} = (C \times IR \times B \times EF \times ED)/(BW \times AT)$$

Where

Intake = estimated amount of arsenic available to the body daily (mg arsenic/kg/d)

C = concentration of arsenic in the soil (mg/kg)

IR = soil ingestion rate; amount of soil incidentally consumed during activities (mg soil/d)

B = bioavailability; fraction of arsenic in the soil that is absorbed by the body (unitless)

EF = exposure frequency (days/yr)

ED = exposure duration (years)

BW = body weight (kg)

AT = averaging time (days)

Table 1. Summary of Arsenic Intake Estimation

	Adult ** max conc.	**Adult** †† ave conc.	**High School Athlete** max conc.	**High School Athlete** ave conc.	**Child** max conc.	**Child** ave conc.
Arsenic Concentration in Soil (mg/kg) *	199	72	199	72	199	72
Ingestion Rate (mg soil/d) †	33	33	200	200	67	67
Bioavailability (unitless)	0.4	0.4	0.4	0.4	0.4	0.4
Exposure Frequency (days/yr) ‡	312	312	200	200	312	312
Exposure Duration (yr) §	70	70	4	4	6	6
Body Weight (kg) ¶	70	70	70	70	16	16
Averaging Time (ED × 365 d/yr) (d)	25550	25550	1460	1460	2190	2190
Estimated Intake (mg arsenic/kg-d)	3.21E-05	1.16E-05	1.25E-4	4.51E-05	2.85E-04	1.03E-4

* Intake was calculated assuming the maximum measured concentration (199 mg/kg) and the average of the 26 samples having a concentration > 20 mg/kg (72 mg/kg), 20 mg/kg was chosen as the lower bound because it represents the lowest concentration of arsenic that was likely a result of arsenical pesticide use, the intent was to calculate an average concentration of samples obviously impacted by arsenical pesticide use.

† Basic ingestion rates were from EPA guidance (EPA 1989). This represents the incidental ingestion that occurs during daily (24-hr) activities; ATSDR assumed children and adults would only be in their yards for a few hours/per day and that incidental soil ingestion from the yard would represent approximately 1/3 of their total ingestion.

‡ Athlete value was based on 5 d/wk × 40 wk/yr; values for adults and children were based on 6 d/wk all year.

§ Adult and child value based on EPA guidance (EPA 1989), athlete based on 4-yr school program.

¶ Based on EPA guidance (EPA 1989).

** Estimated arsenic intake for adults based on the maximum measured arsenic concentration in the soil

†† Estimated arsenic intake for adults based on the average concentration of arsenic from the 26 samples having a concentration > 20 mg/kg (72 mg/kg).

Table 2. Estimated Arsenic Intake and ATSDR's Health-Based Comparison Values

	Adult max conc.	**Adult** ave conc.	**High School Athlete** max conc.	**High School Athlete** ave conc.	**Child** max conc.	**Child** ave conc.
Arsenic Concentration * (mg/kg)	199	72	199	72	199	72
Estimated Arsenic Intake † (mg arsenic/kg-d)	3.21E-05	1.16E-05	1.25E-04	4.51E-05	2.85E-04	1.03E-04
Chronic Oral MRL ‡ (mg/kg-d)	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
Intake/ MRL §	0.107	0.039	0.417	0.150	0.950	0.343

* Maximum value of the arsenic concentration measured in the soil or average arsenic concentration estimated from the 26 samples having a concentration > 20 mg/kg (72 mg/kg).

† Estimated arsenic ingestion is from Table 1

‡ ATSDR's Chronic Oral MRL is a conservative health-based comparison value set below the daily arsenic ingestion rate that is anticipated to result in adverse health effects. Daily arsenic ingestion at this rate, even over a lifetime, is not expected to result in any adverse health effects.

§ An Intake/MRL ratio less than one indicates the estimated daily arsenic ingestion would not be expected to result in any adverse health effects.

Table 3.

Summary of Studies Describing Health Effects from Arsenic Exposure by Ingestion

Study Type	Potential Health Effects from Arsenic Ingestion
Human Environmental Exposure	Various forms of cancer have been associated with ingestion of arsenic contaminated drinking water. The reported ingestion rates ranged from 0.0011 to 3.67 mg/kg/d. However, in many of these studies, other factors such as poor nutrition, smoking, and exposure to additional chemicals may have also contributed to the development of the cancer. *The maximum estimated arsenic ingestion (Table 1) is ten to ten thousand times below levels associated with an increase in cancer.*
	Increased incidence of Raynaud's disease and cyanosis of fingers and toes occurred with ingestion of arsenic in water of 0.02 to 0.06 mg/kg/d (Borgono and Greiber 1972, Zaldivar 1974 and 1977, Zaldivar and Guillier 1977, in ATSDR 2000). Blackfoot disease typically corresponds to arsenic ingestions of 0.014 to 0.065 mg/kg/d from drinking water (Abernathy et al 1989, in ATSDR 2000). Anemia and leucopenia have been reported for long-term ingestions of 0.05 mg/kg/d or more (Glazener et al 1968, Guha Mazumder et al 1988, Kyle and Pease 1965, Tay and Seah 1975; in ATSDR 2000). However, this effect has not been observed in all cases, even with higher ingestion rates (Harrington et al 1978, Huang et al 1985, Silver and Wainman 1952, Southwick et al 1981; in ATSDR 2000). Gastrointestinal irritation has been reported following long-term ingestion of 0.03 to 0.05 mg/kg/d; however, they are generally not detectable for ingestions less than 0.01 mg/kg/d (ATSDR 2000). Minor respiratory symptoms; cough, sputum, runny nose, and sore throat, have been reported following repeated ingestion of 0.03 to 0.05 mg/kg/d (Ahmad et al 1997 and Mizuta et al 1956; in ATSDR 2000). Dermal effects, generalized hyperkeratosis, hyperkeratotic warts or corns on palms and soles, and hyperpigmentation/hypopigmentation, commonly result following repeated ingestion at 0.01 to 0.1 mg/kg/d (usually from water) and appears to be the most sensitive indication of effect. Dermal effects were not detected following long-term ingestion of less than 0.01 mg/kg/d in drinking water (ATSDR 2000). Neurological effects noted following long-term ingestion of 0.03 mg/kg/d or higher did not occur with long-term ingestion of 0.004 mg/kg/d (Lianfang and Jianzhong 1994; in ATSDR 2000). Elevated levels of hepatic enzymes in blood were reported following long-term ingestions of 0.0006 mg/kg/d (Hernandez-Zavala et al 1998, in ATSDR 2000). Several studies have detected no health effects following long-term ingestion of 0.0004 to 0.01 mg/kg/d from water (Cebrain et al 1983, Guha Mazumder et al 1988, Harrington et al 1978, Southwick et al 1981, Valentine et al 1985; in ATSDR 2000). *In general, no health effects (including cancer) have been detected following arsenic ingestion of 0.0004 mg/kg/d. The maximum estimated arsenic ingestion calculated in Table 1 are well below this value.*

Potential Arsenic Exposure From Inhalation of Dust During Tilling Operations

Estimates of Particulate Matter Released by Tilling Operations

$$\text{PM10 Emissions (lbs)} = c \times k \times s^{0.6} \times p \times a$$

Where

c = emission constant for tilling (4.8 lb/acre-pass)

k = constant to adjust for particle size (0.21 for PM10) (unitless)

s = silt content of surface soil (estimated to be 0.33 for a sandy loam) (unitless)

p = number of tilling passes per year (assumed to be 1; tilled once per year) (pass)

a = acres of land tilled (50 ft x 5,400 ft = 6.2 acres) (6.2 acres)

Table 4. Summary of Estimated PM10 Emissions from Annual Tilling *

Parameter	PM10 † Sandy Loam	PM10 Silty Loam	PM10 Loamy Sand
Emission Constant (c) ‡	4.8	4.8	4.8
Particle Size Const (k) ‡	0.21	0.21	0.21
Silt Content (s) ‡	0.33	0.52	0.12
Annual Tilling Passes (p) §	1	1	1
Acres Tilled (a) ¶	6.2	6.2	6.2
Estimated PM10 Emissions (lbs) **	3.2	4.2	1.2

* Emissions calculations based on EPA's National Emission Inventory methods as described in Roe and Hemmer 2004.

† PM10 = Particulate matter with an aerodynamic diameter less than 10 μm released during tilling operation.

‡ Values from Roe and Hemmer 2004, Section VI Agricultural Tilling.

§ The area is tilled annually, ATSDR assumed one pass with the tilling equipment.

¶ ATSDR assumed the area between the fences near the boundary next to the residential community was tilled; distances were approximated from a base map (50 feet width between the fences, 5,400 feet length between the fences).

** Estimated PM10 emissions for sandy loam, silty loam, or loamy sand soils.

Estimation of Emission Rate

Emission Rate = (Emissions)/(Total Area × Time)

Where

Emissions = Estimated PM10 emissions released during tilling operation (lbs) (see Table 4)

Total Area = Total area tilled (length × width of fenced area) (ft^2)

Time = Time of tilling = (Total Distance Tilled)/(Tractor Velocity) (seconds) *

Assumptions

Total Area = 5,400 ft × 50 ft = 270,000 ft^2

Time = (5,400 ft/section)(2 sections)/(10 miles/hr) = 12.3 min = 736 seconds

Table 5. Summary of Estimated PM10 Emission Rates

Parameter	PM10 † Sandy Loam	PM10 Silty Loam	PM10 Loamy Sand
Estimated PM10 Emissions (lbs)	3.2	4.2	1.2
Total Area (ft^2)	270,000	270,000	270,000
Time (seconds) *	736	736	736
Emission Rate (lbs/ft^2-s) ‡	1.6E-8	2.1E-8	6.0E-9
Emission Rate (g/m^2-s) ‡, §	8E-5	1E-4	3E-5

* To calculate the time required to till the area, ATSDR assumed the area was tilled in two sections and that each section was 25 ft wide. This was based on product information about tillage equipment (chisel plows) available from Case IH which indicated their plows had a minimum working width of 25 ft.

† PM10 = Particulate matter with an aerodynamic diameter less than 10 μm released during tilling operation in sandy loam, silty loam, or loamy sand type soils.

‡ Emission rate represents the amount of PM10 released to the air during the tilling operation; this amount depends on the area tilled and the time spent tilling.

§ Conversion: (lbs/ft^2-s)(1 g/0.00225 lb)(10.7584 ft^2/m^2) = (g/m^2-s)

Estimation of Downwind PM10 and Arsenic Concentrations

Based on analysis using the SCREEN-3 air dispersion model

Table 6. Summary of Input Values and Results of the SCREEN-3 Model

Parameter	PM10 ¶ Sandy Loam	PM10 Silty Loam	PM10 Loamy Sand
Estimated PM10 Emissions (lb) *	4.2	3.2	1.2
Emission Rate (g/m^2-s) †	0.0001	0.00008	0.00003
Source Height (m) ‡	0.1	0.1	0.1
Source Length (m) ‡	4.2	4.2	4.2
Source Width (m) ‡	0.7	0.7	0.7
PM10 @ 10 m (ug/m^3) §	500	400	150
PM10 @ 100 m (ug/m^3) §	10	7.9	3.0

* Calculated in Table 4
† Calculated in Table 5
‡ Estimated from off-set disk harrows from Case IH, Model 770 Deep Tillage
§ Results from SCREEN-3 model; represents the PM10 concentration predicted at 10 and 100 m from the tilling equipment.
¶ PM10 = Particulate matter with an aerodynamic diameter less than 10 µm released during tilling operation in sandy loam, silty loam, or loamy sand type soils.

Table 7. Summary of Estimated Downwind Arsenic Concentrations

	Estimated Downwind Concentration at 10 m	Estimated Downwind Concentration at 100 m
Estimated Downwind Arsenic Concentration ($\mu g/m^3$) *	***0.1***§	***0.002***§
Maximum Estimated PM10 Concentration ($\mu g/m^3$)	500 5	10
Max Measured Arsenic Concentration in Soil (mg/kg)	199	199
Estimated Downwind Arsenic Concentration ($\mu g/m^3$) †	***0.03***§	***0.0005***§
Maximum Estimated PM10 Concentration ($\mu g/m^3$)	400 ¶	7.9
Ave Measured Arsenic Concentration in Soil (mg/kg)	64	64
Estimated Downwind Arsenic Concentration ($\mu g/m^3$) ‡	***0.003*** §	***0.00006***
Maximum Estimated PM10 Concentration ($\mu g/m^3$)	150	3.0
Low Measured Arsenic Concentration in Soil (mg/kg)	18.8	18.8

* Assumes SCREEN-3 estimated concentration of PM10 based on silty loam soil and highest measured arsenic concentration.
† Assumes SCREEN-3 estimated concentration of PM10 based on sandy loam soil and arsenic concentration is equal to the average of the concentrations greater than 20 mg/kg measured along the fence.
‡ Assumes SCREEN-3 estimated concentration of PM10 based on loamy sand and the lowest measured arsenic concentration along the fence.
§ Arsenic concentrations greater than ATSDR's CREG (0.0002 $\mu g/m^3$)
¶ PM10 concentrations greater than the 24-hr NAAQS (150 $\mu g/m^3$). The NAAQS are available on the EPA web-site: http://www.epa.gov/air/criteria.html

Estimates of Arsenic Intake by Inhalation

Intake (mg/kg-d) = (C × IR × ET × EF × ED)/(BW × AT)

Where

Intake = estimated amount of arsenic available to the body on a daily basis

C = concentration of arsenic in the air

IR = inhalation rate (amount of air inhaled during daily activities)

ET = exposure time (duration of the event)

EF = exposure frequency (days/yr)

ED = exposure duration (number of years)

BW = body weight

AT = averaging time

Table 8. Summary of Annual Arsenic Intake from Tilling by Inhalation

	Adult §§ @ 10 m	**Adult @ 100 m**	**Athlete @ 10 m**	**Athlete @ 100 m**	**Child @ 10 m**	**Child @ 100 m**
Max PM10 Concentration (ug/m^3) *	500	10	500	10	500	10
Max Arsenic Concentration (ug/m^3) †	0.1	0.002	0.1	0.002	0.1	0.002
Inhalation Rate (m^3/d) ‡	30	30	40	40	20	20
Exposure Time (hr/d) §	0.5	3	0.5	3	0.5	3
Exposure Frequency (days/yr) ¶	1	1	1	1	1	1
Exposure Duration (yr) **	70	70	4	4	6	6
Body Weight (kg) ††	70	70	70	70	16	16
Averaging Time (ED × 365 d/yr) (d)	25550	25550	1460	1460	2190	2190
Estimated Intake (mg arsenic/kg-d) ‡‡	**2.45E-09**	**2.94E-10**	**3.26E-09**	**3.91E-10**	**7.13E-09**	**8.56E-10**

* Maximum PM10 concentration estimated from the SCREEN-3 model.
† Assumes that all of the dust emitted while tilling contains the maximum measured concentration of arsenic and assumes dust transport from tilling operation is not impeded by trees, bushes, fences, or buildings.
‡ Based on EPA guidance (EPA 1989) for the upper bound adult value, assumed child value was approximately equal to the average adult value, and assumed the athlete was approximately equal to twice the average adult value.
§ Assumed tilling process is relatively short for this small area. The dust would settle or disperse quickly near the source and slightly slower with distance
¶ Operation occurred once per year
** Adult and child value based on EPA guidance (EPA 1989), athlete value based on 4-yr school program
† † Based on EPA guidance (EPA 1989)
‡‡ All values are well below the chronic and acute MRLS shown in Table 3
§§ Estimated arsenic intake for adults continuously present 10 m from the tilling operation

Table 9.

Summary of Studies Describing Health Effects From Arsenic Exposure by Inhalation

Study Type	Potential Health Effects From Arsenic Inhalation
Animal Studies	No respiratory symptoms were observed in mice exposed to arsenic in air at concentrations of 2,000 µg/m^3 (Holson et al 1999, in ATSDR 2000).
Human Occupational Exposure	The NOAEL for respiratory effects from arsenic concentrations in air is 613 µg/m^3 (ATSDR 2000). Workers with a long-term exposure to an arsenic concentration of 360 µg/m^3 had increased incidences of Raynaud's phenomenon and increased vasopasticity (Lagerkvist et al 1986, ATSDR 2000). There was no effect of blood values for workers exposed to 130 µg/m^3 of arsenic in air (Watrous and McCaughey 1945, in ATSDR 2000). Increased incidence of dermal effects were reported in workers exposed to 78 - 7 µg/m^3 of arsenic in air (Perry et al 1948 and Mohamed 1998; in ATSDR 2000). No chromosomal aberrations were found in livers of fetuses from pregnant mice exposed to 2,200 µg/m^3 (Nagymajtenyi et al 1985, in ATSDR 2000). *The arsenic concentrations estimated by SCREEN-3 are hundreds to thousands of times below levels where no or mild health effects were reported. In addition, residents would be exposed to arsenic from the tilling operation one day per year; occupational exposures were 5 days per week.*
	A small to moderate increased incidence of lung cancer was reported for smelter workers with occupational exposure of 50 µg/m^3 arsenic in air (Welch et al 1982 and Jarup et al 1989, in ATSDR 2000). *The arsenic concentrations estimated by SCREEN-3 are hundreds to thousands of times below this level. In addition, residents would be exposed to arsenic from the tilling operation one day per year; occupational exposures were 5 days per week.*
Human Environmental Exposure	No increased risk of stillbirth was noted for arsenic concentrations below 0.7 µg/m^3 (Ihrig et al 1998, in ATSDR 2000). *The arsenic concentrations estimated by SCREEN-3 are well below this level. In addition, residents would be exposed to arsenic from the tilling operation one day per year.*
Maximum concentrations of arsenic in air estimated by SCREEN-3 (Table 6) were C = 0.1 µg/m^3 at 10 m downwind from tilling operation C= 0.002 µg/m^3 at 100 m downwind from tilling operation	