Health Consultation

SPRING VALLEY CHEMICAL MUNITIONS

WASHINGTON, DISTRICT OF COLUMBIA

PUBLIC HEALTH EVALUATION
FOR THE
SPRING VALLEY COMMUNITY

WASHINGTON, DC

SEPTEMBER 7, 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.

Please address correspondence and comments regarding this report to the Division of Health Assessment and Consultation, Agency for Toxic Substances and Disease Registry, ATTN: Spring Valley Chemical Munitions, 1600 Clifton Road, NE (E60), Atlanta, Georgia 30333.

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Prepared by:

Federal Facilities Assessment Branch
Division of Health Assessment and Consultation
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Washington, District of Columbia

Public Health Evaluation

for the

Spring Valley Community

Washington, D.C.

August 30, 2005

Prepared by
Federal Facilities Assessment Branch
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry (ATSDR)
Atlanta, Georgia

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ABBREVIATIONS

ALL	Acute Lymphocytic Leukemia
AML	Acute Myelogenous Leukemia
Army	U.S. Army
ATSDR	Agency for Toxic Substances and Disease Registry
AUES	American University Experiment Station
CDC	Child Development Center (American University)
CLL	Chronic Lymphocytic Leukemia
CML	Chronic Myelogenous Leukemia
CREG	cancer risk evaluation guide (ATSDR)
CVAA	2-chlorovinyl arsonous acid
CVAO	Chlorovinyl arsenous oxide (lewisite oxide)
DC DOH	District of Columbia Department of Health
DMA	dimethylarsinate
DNT	dinitrotoluene
EMEG	environmental media evaluation guide (ATSDR)
EPA	U.S. Environmental Protection Agency
ERDEC	Edgewood Research, Development & Engineering Center
FUDS	Formerly Used Defense Sites
LOAEL	lowest-observed-adverse-effect level
MCL	maximum contaminant level (EPA)
mg/kg/day	milligram per kilogram per day
MRL	minimal risk level (ATSDR)
NAS	National Academy of Sciences
NCI	National Cancer Institute
NHL	Non-Hodgkin's lymphoma
NIH	National Institutes of Health
NLM	National Library of Medicine
NOAEL	no-observed-adverse-effect level
ORNL	Oak Ridge National Laboratory
OU	Operable Unit
PAH	polycyclic aromatic hydrocarbon
PEHSU	Pediatric Environmental Health Specialty Units
POI	Point of Interest
ppb	parts per billion

ppm	parts per million
RfD	reference dose (EPA)
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
USABC	U.S. Army Soldier Biological Command
USACE	U.S. Army Corps of Engineers
USACHPPM	U.S. Army Centers for Health Promotion and Preventive Medicine
SVOC	semi-volatile organic compound
TNT	2,4,6-trinitrotoluene
$\mu g/m^3$	micrograms per cubic meter
VOC	volatile organic compound
WWI	World War I

I. Summary

During and after World War I (WWI)—specifically, from 1917 to 1920—the U.S. Army (Army) conducted chemical warfare research and testing at its Washington, D.C. American University Experiment Station (AUES). Following WWI, some of the chemical agents, ordnance, and laboratory wastes generated at the site were disposed of at AUES and in an adjacent area known as Spring Valley. Recent discoveries of those buried munitions and chemical agents have resulted in both the Spring Valley neighborhood and the American University being designated a Formerly Used Defense Site (FUDS). This designation authorizes the U.S. Army Corps of Engineers (USACE) to address environmental contamination resulting from past Department of Defense activities at the American University/Spring Valley site (sometimes collectively referred to in this health consultation as the Spring Valley Community).

Since 1993, the USACE has been investigating the Spring Valley Community to determine where and to what extent the Army disposed of buried ordnance, explosive wastes, and hazardous substances. USACE found several burial pits containing munitions and chemical agents as well as arsenic in soil exceeding background levels. The primary chemical agents found were mustard agent, lewisite, and their degradation products. In 2002, the USACE determined that three artillery shells found at the Glenbrook Road burial pits contained arsine gas.

Some community members believe their health is being adversely affected because of AUES-related activities. In this evaluation, the Agency for Toxic Substances and Disease Registry (ATSDR) considers community health concerns and possible health implications of detected levels of contaminants. This assessment is an analysis of site-specific environmental and health data, exposure investigations, as well as a literature review on reported diseases. We consider exposure to arsenic in soil, indoor dust and air, and drinking water as well as other contaminants according to available data. ATSDR also evaluated possible hazards associated with materials found in burial pits and surface disposal areas and whether buried contaminants could migrate and reach people (e.g., via groundwater or soil gas). *As summarized below, our assessment indicates that most people in Spring Valley have not and will not experience adverse health effects due to AUES activities because exposure point concentrations are not high enough to result in adverse health effects.*

To evaluate possible health implications associated with the levels of contaminants detected in the Spring Valley neighborhood, ATSDR studied exposure conditions and reviewed the epidemiological, toxicological, and medical literature. Site-specific exposure levels were compared with those conditions shown in the literature to be associated with adverse health effects. To address community concerns about the perceived high rates of illness in the neighborhood, ATSDR considered these reported conditions (e.g., anemias and cancers) when reviewing the literature.

- ***Soil.*** USACE has continued its search for the chemical warfare materials and their degradation products at American University and in the surrounding neighborhoods. Principally, USACE has conducted an area-wide soil sampling for arsenic. USACE focused on arsenic because it is the most persistent breakdown product of the chemical warfare agents (Arsenic is also found in pressure treated wood, some pesticides, and is a product of fossil

fuel burning; it is found naturally in soil). To date, approximately 1,484 out of 1,602 Spring Valley properties have been sampled. The majority (90%) of these properties did not have arsenic levels exceeding the clean-up level of 20 parts per million (ppm). Where elevated arsenic levels have been found in soil (locations known as "hot spots"), USACE is removing them through a soil excavation process. Some of the properties were also tested for explosives, chemical warfare agents, and other contaminants. In a limited number of surface or subsurface soil samples, trace levels of a mustard breakdown product and cyanide have been found. USACE, however, only detected these contaminants at non-hazardous levels. Although most metals are found naturally in the Spring Valley area, some metals exceeding background levels, but not of health consequence, were also present. The estimated maximum doses of arsenic (the most prevalent contaminant) and other contaminants measured in Spring Valley soils are below doses shown in the scientific literature to cause any harmful health effects in adults and children who may contact soil during their daily activities. *ATSDR, therefore, concludes that the soil pathway at the American University/Spring Valley site does not represent a public health hazard (excluding disposal areas/burial pits). As such, exposure to the levels of chemical warfare agents or their breakdown products detected in soil is not expected to cause the reported conditions. Precautionary measures are being taken by USACE, however, to remove soils with elevated arsenic levels. Because some uncertainties remain about the presence and levels of non-arsenic contaminants in surface soil, ATSDR recommends that additional surface soil analyses be conducted for residential properties. Specifically, ATSDR recommends surface soil analyses for AUES-related contaminants including explosives and their transformation products, chemical warfare agents and degradation products, and metals such as lead and mercury.*

- ***Buried materials.*** Burial areas discovered within Spring Valley to date have or are in the process of being removed. ATSDR acknowledges that any remaining chemical warfare materials, other chemicals, explosives, etc. in disposal areas (burial pits and surface disposal areas) or newly discovered areas *could pose a chemical or physical hazard if disturbed.* Of particular concern would be munitions or containerized materials that might still contain chemical warfare agents. USACE is still conducting extensive geophysical surveys to help identify burial pits, munitions, and other materials in Spring Valley, and continues to clean up areas believed to be past disposal areas. USACE has provided information to residents on what WWI items could possibly be found in their neighborhoods. Residents are encouraged to contact USACE immediately upon discovery of items such as glassware or other suspect materials; residents should not collect such items. ATSDR recommends that the USACE continue to respond to calls from residents concerning suspicious items in their yards and to identify and remove items possibly relating to AUES activities. ATSDR recommends that the USACE continue rapid intervention to minimize and eliminate potential hazards. Currently, the only known remaining disposal areas are Pit 23 on Glenbrook Road and the surface disposal area at Lot 18. In 2005, a range fan, linked with firing chemical rounds, was identified. The munitions were launched from the Spalding/Captain Rankin Area near American University toward the present-day Dalecarlia Parkway area. The USACE and their partners are determining if further investigations are needed for properties falling within the projected range fan.

ATSDR also evaluated the extent to which buried materials may have posed a threat to the groundwater beneath the site or possibly volatilize and pose indoor air threats. Based on our understanding of the properties of the chemical warfare agents and breakdown products and the results of available sampling, harmful exposures to soil and air are unlikely to occur, though some uncertainty exists. In general, chemical warfare agents in soil rapidly break down to less toxic forms upon contact with water or moisture typically found in soils. While it is possible that some of the chemicals associated with the burials could migrate to groundwater, the groundwater beneath the site is not used for drinking or other purposes and therefore poses no direct threat to people in the area. Nonetheless, the USACE has initiated an investigation to evaluate the condition of the underlying groundwater and determine the nature and extent of any contamination and its possible impact. Of particular interest is whether groundwater is moving in the direction of Dalecarlia Reservoir. ATSDR recommends that USACE continue its groundwater evaluation, focusing on AUES contaminants known to have migration potential. Upon request, ATSDR will evaluate sampling plans and data when they become available.

To date, no data have been presented that suggest harmful exposures to airborne contaminants including indoor air, dust, and soil gas samples taken at Spring Valley residences. Available sampling, however, provides only a snapshot of possible conditions and some uncertainty exists on the nature of past conditions and any remaining buried waste. ATSDR therefore recommends that soil gas samples be taken, prior to excavation, at burial pits or other disposal areas. This may be applicable to Pit 23 on Glenbrook Road, the surface disposal area at Lot 18, or newly discovered disposal areas. In addition, ATSDR recommends that the USACE groundwater investigation include an evaluation of possible volatile constituents, including chemical warfare agent breakdown products.

- ***Exposure investigations.*** In addition to USACE investigations, ATSDR and the District of Columbia Department of Health (DC DOH) have collaboratively conducted several exposure investigations in Spring Valley. These health agencies investigated American University's Child Development Center (CDC) playground in March 2001, and the Spring Valley neighborhood in March 2002 and in the summer of 2002. The purpose of these investigations was to determine whether residents were coming in contact with arsenic by ingesting soil or inhaling dust. The CDC exposure investigation found that arsenic concentrations in hair were not elevated in the 28 children and 4 adults who participated in the investigation. The Spring Valley neighborhood investigations found that biological testing of the hair and urine of residents whose yards had the highest arsenic levels (i.e., up to 202 ppm in composite samples; 613 ppm in discrete samples) did not yield levels that would lead to adverse health effects. The findings of these investigations are detailed in a separate health consultation released by ATSDR in 2001.

- ***Health outcome data evaluations.*** DC DOH completed an epidemiological study of arsenic-related cancers but did not find increased rates in the community. If additional environmental sampling indicates a completed exposure pathway for contaminants with doses sufficient to cause adverse health effects, then ATSDR will consider whether additional public health actions are needed. Following an ATSDR recommendation to follow-up on leukemia, the DC DOH found that the incidence of leukemia in Potomac, Maryland was higher than Spring Valley. Although no widespread occurrence of contamination and exposure to contamination

that would lead to illness or disease has been found, the DC DOH is working on a health study. As a precautionary measure, area residents are being advised to report conditions of concern to their physicians. A section for healthcare providers has been added to ATSDR's Spring Valley Web page to assist physicians in their evaluations.

II. Introduction and Purpose

Since 1997, ATSDR has responded to requests on specific issues concerning the Spring Valley site. The most recent requests have come from the Government of the District of Columbia, Department of Health (DC DOH) and lawyers representing community members.

In March 2001, a citizen petitioned the Agency for Toxic Substances and Disease Registry (ATSDR) to conduct a public health assessment for the Spring Valley site (Williams et al. 2001). In June 2001, DC DOH requested additional biomonitoring for Spring Valley residents and assistance with health education (DC DOH 2001a). ATSDR agreed to these requests (ATSDR 2001b; ATSDR 2001c) and in September 2001, ATSDR assembled a team to fulfill them. In April 2002, ATSDR received a supplemental request for a public health assessment (Cohen et al. 2002). ATSDR responded that it would evaluate the necessity of additional activities (such as an epidemiological study of area residents and dose reconstruction for environmental pathways) as the assessment process proceeded (ATSDR 2002a).

Because data prior to 1999 have been analyzed in previous ATSDR documents, this health consultation focuses primarily on environmental and health data collected after 1999. The earlier documents are available in the Spring Valley repository (Palisades Public Library) and on ATSDR's Spring Valley Web site at www.atsdr.cdc.gov/sites/springvalley. Additionally, Appendix A of this health consultation includes document summaries of ATSDR's documents for the American University/Spring Valley Site. ATSDR also considered USACE and U.S. Environmental Protection Agency (EPA) environmental data and includes health information collected by the DC DOH. While this evaluation focuses largely on possible health impacts of exposure to arsenic levels detected in residential soils, ATSDR also reviewed dust, air, and drinking water sampling data and information related to disposal areas.

In the pages that follow, ATSDR reviews background information, such as site conditions (Section III). We then discuss contaminants of potential concern detected during site investigations (Section IV), followed by the findings of our exposure and health effects assessment (Section V). Lastly, we discuss responses to specific community health concerns (Section VI) and issues related to child health (Section VII).

The appendices to this health consultation contain supplemental information. Appendix A contains summaries of ATSDR reports to date. Appendix B is describes the environmental fate of chemicals associated with past AUES activities. Appendix C summarizes health concerns reported to the DC DOH hotline. Appendix D describes the key characteristics of the illnesses reported by some area residents and summarizes the complex and uncertain etiologies (causes) of these health conditions. Appendix E details the methodology used to research the chemical-specific toxicity and illnesses discussed in this report. ATSDR's gardening brochure *Safe Gardening, Safe Play, and a Safe Home* is included as Appendix F. Appendix G contains ATSDR's glossary of terms. Appendix H presents comments on a draft of this document submitted during our public comment period (February 14 through April 29, 2005) and our responses to those comments.

III. Background

The Spring Valley Community is in northwestern Washington D.C., north of the Potomac River. It is predominately residential, with American University occupying the area near the southeastern part of the site. The approximately 668-acre Spring Valley site includes a hospital, 27 foreign embassy properties, a number of commercial properties, and about 1,500 homes. It is one of the District's most affluent neighborhoods. The total population residing within a 1-mile buffer from the site boundary is 61,977 persons. The total population residing within the FUDs boundary is estimated at 7,105 persons (Figure 1).

Aerial photographs of the Spring Valley area provide evidence of trenches, buildings, and bomb pits associated with activities of the chemical weapons research facility—activities which were ongoing both before and after the area's residential and commercial development.

Because the U.S. Army (Army) buried materials there more than 80 years ago and because the area has undergone many changes since, characterizing and evaluating possible exposures at the Spring Valley site has been challenging. The Army is, however, addressing environmental contamination resulting from past activities in Spring Valley. A detailed summary of findings and other information on the Spring Valley project is accessible at the U.S. Army Corps of Engineers (USACE) Web site:
http://www.nab.usace.army.mil/projects/WashingtonDC/springvalley.htm.

Army Activities

During WWI, the Army conducted chemical warfare research and testing in Washington, DC, at a site that now comprises the Spring Valley neighborhood and American University. From 1917 to 1919, the site was known as the American University Experiment Station (AUES). The Army established AUES to test, produce, and investigate the effects of noxious gases, antidotes, and protective masks (Parsons 2001). During research and training operations chemical weapons were detonated in several areas of the site. Following WWI, the Army disposed of some of the remaining chemical agents, including hazardous substances, ordnance, and explosive wastes, in various locations around the site. Buildings and other structures that were impregnated with mustard or other toxic gases were burned; however, their final disposition is unknown (Parsons 1995). By 1921, the Army had decommissioned and completely vacated AUES, returning the site to American University and to Spring Valley private property owners.

In January 1993, while digging a utility trench, a contractor discovered buried military ordnance. The Army initiated an emergency response action and removed 141 ordnance items, 43 of which were suspected of containing chemical agents. Since then, the USACE has been conducting investigations to identify the extent of chemical contamination and buried ordnance resulting from past AUES operations. Findings of this initial investigation, along with other disposal discoveries highlighted below, are reported in more detail in the Section IV ("Discussion of Contaminants of Potential Concern").

On February 3, 1993, as a result of finding the buried ordnance and chemical agents, the USACE initiated a remedial investigation (RI) of the Spring Valley site. Using historical documentation (reports, maps, and photos), USACE focused its investigation on specific sites found to have the

greatest contamination potential, naming those sites “Points of Interest” (POIs). Eventually, USACE identified 53 POIs (Figure 2). More recently, USACE conducted geophysical surveys on 492 properties to identify possible buried ordnance (USACE 2001d). Over 1,900 metal objects were identified below the ground surface. But USACE found only a few items that were in fact ordnance, and safely removed them. USACE also conducted soil sampling at 260 locations within 17 POIs, where it suspected chemical weapons activity. Both USACE and EPA tested and analyzed the samples. No chemical agents, chemical warfare agent-unique breakdown products, explosives, or explosive breakdown products were found in any of the samples taken. Still, several metals were identified at levels exceeding the EPA's risk-based screening criteria. But a quantitative baseline risk assessment found these metals posed no elevated health risk and therefore required no remedial action. Moreover, because the sampling results for arsenic were not significantly different from background concentrations, the risk assessment excluded arsenic as a chemical of potential concern. A March 1995 Remedial Investigation Report documented these findings (Parsons 1995).

For the Spring Valley investigation the USACE initially created two “Operable Units” (OUs). The American University site-wide RI was designated OU-1. An investigation involving sampling in three underground bunkers associated with AUES research was designated OU-2 (POIs 21and 23 [Captain Rankin Area]; POI 22 [Spaulding Area]—a shell pit incorporated into the foundation of a house) (USACE 1999). The Army used these three bunkers in 1918 to test explosives, smokes, and chemical warfare agents (EPA 1997a). Approximately 70 cubic yards of soil and debris were removed from POIs 21 and 23. No chemical warfare agents or their breakdown products nor explosives and their breakdown products were detected in soil beneath the utility room floor at POI 22. No ordnance was discovered at OU-2. Bunker walls were sprayed and cleaned. USACE released the RI report in March 1995. In June 1995, USACE released a Record of Decision, which concluded the Spring Valley site required “No Further Action” (Parsons 1995; USACE 2001a).

Since the release of the RI report and the Record of Decision, several incidents have required USACE to initiate additional investigations and remedial actions. In 1996, after unearthing broken bottles containing chemical agents in a Spring Valley residential yard, a landscaper complained of burning eyes (Jaffe 2000; Wengrover 2001). In late 1997, USACE identified two chemical weapons disposal pits on Glenbrook Road, across from the American University property line. Following a geophysical survey, USACE excavated a variety of buried military debris from underneath the private property (e.g., mortar shells, smoke bombs, chemical-filled bottles, and metal drums). USACE and its private contractors found the actual pits containing mustard agents in an unoccupied adjacent property (Wengrover 2001; USACE 2001a).

In addition to the 1996/1997 discoveries, other concurrent events persuaded USACE to continue its search for buried chemical agents. In 1997, DC DOH provided USACE with the results of its independent review of Spring Valley, which indicated that some POI locations had been in error. In 1998, USACE conducted its own review and found that POI 24 was incorrectly located by about 150 feet. During this review, USACE verified that all the other POIs had been properly identified.

Because the location of POI 24 had not been properly located, USACE initiated extensive field investigations of this general area, focusing on Glenbrook Road. In 1998, a geophysical survey

identified two areas with high metallic signatures, indicative of possible burial pits below the ground surface. In March 1999, an investigation of this area located two large burial pits. Over 600 items were recovered, including 288 ordnance-related items, of which 14 contained chemical warfare agents—predominantly mustard agent. After the excavation, USACE collected soil samples that revealed elevated levels of arsenic. USACE removed the top 2 feet of soil in the affected areas, and replaced it with clean fill. USACE then designated this area Operable Unit 3 (OU-3). It is centered at properties on Glenbrook Road, the location of several chemical warfare burial sites (USACE 2001a).

By January 2000, these findings had convinced USACE to expand its investigation area (OU-4). It developed an arsenic sampling plan for 61 private residences and for the southern portion of American University—areas near the disposal pits. As part of the USACE OU-4 RI investigation, sampling was completed at 42 of the 61 properties. USACE recommended more comprehensive sampling for nine residential properties and for several vacant lots on the American University campus. This sampling was completed in January 2001. Because of elevated arsenic levels on some properties, USACE planned soil removals for any yards in which arsenic levels exceeded 20 parts per million (ppm)—a health protective remediation level. ATSDR's soil comparison value, which is used to determine if further evaluation is needed, is also 20 ppm (environmental media evaluation guide (EMEG) for children).

Various units of measure or exposure are presented throughout this document. Soil concentrations are generally reported in parts per million (ppm). Air and soil gas concentrations are reported in micrograms per cubic meter ($\mu g/m^3$) or parts per billion (ppb). Hair and urine measurements are generally reported in ppm and ppb, respectively. When human exposure doses are calculated later on, the unit of measure is milligrams per kilogram per day (mg/kg/day). See *Glossary* in Appendix G for a definition of dose.

Around the American University Child Development Center (CDC) the soil composite for arsenic was 31 ppm. Because of parental and university concerns, USACE expedited further soil sampling and provided the results to the university. After relocating the CDC to another area in the summer of 2001, the soil was removed. At the same time, the DC DOH and ATSDR conducted an exposure investigation of the children attending the CDC. In the 28 children and 4 adults who participated in the exposure investigation, hair and urine arsenic concentrations were not elevated. Further information on the exposure investigations is contained in the Discussion of Contaminants of Potential Concern section (Section IV) under the title "What arsenic levels were found in hair and urine?" and in Appendix A.

In January 2001, USACE completed clean up of a small disposal area located on and adjacent to American University. USACE removed soil, glass, and metal debris from the general vicinity of Lot 18, enough to fill 160 55-gallon barrels. Testing detected no chemical warfare agents in the soil or metal debris. Following confirmation of sampling data for the excavated area, USACE filled the excavated areas with clean soil and restored the site.

At a public meeting in February 2001, community members urged testing of the entire Spring Valley neighborhood. In consultation with EPA and DC DOH, USACE responded with a comprehensive soil sampling plan that proposed sampling for arsenic on every property in Spring Valley (designated as OU-5), with more intensive sampling in selected areas. In May 2001, as part of the OU-5 area-wide soil sampling effort, the USACE began collecting soil

samples from all 1,200 residential and 400 non-residential properties (Tucker 2001; USACE 2001a). In 2002, a more detailed grid sampling procedure was conducted for all properties found to have composite arsenic levels greater than 12.6 ppm—the typical background concentration for arsenic in the general area (Parsons 2003d).

Background refers to the level normally found in soils in the region.

Testing of residential surface soils in the Spring Valley neighborhood has shown composite soil levels of arsenic ranging from background to approximately 202 ppm. USACE identified 17 properties with one or more grid (discrete) sampling results exceeding 150 ppm. The maximum background level of arsenic in Spring Valley soil is approximately 17 ppm, well within background levels for arsenic in U.S. soils. Because Spring Valley residents expressed concern about possible arsenic exposure they might have received from soils on their properties, USACE worked with local citizens and regulators to identify a Spring Valley clean-up level of 20 ppm—again, a health protective value. In July 2002, USACE began removal of arsenic-contaminated soil from residential yards, completing the first seven time-critical removals (and adding two more) by September 2002. USACE then removed soil at grids (discrete sampling locations) with arsenic levels of 150 ppm or higher.

In May 2003, the USACE destroyed the chemical munitions found in the Glenbrook Road burial pits at the Spring Valley site. The emergency removal of contaminated soils at the CDC was completed in 2003. Also in 2003, the USACE discovered approximately 6 milliliters of a 0.3% solution of lewisite in a sealed glass container in a surface disposal area in American University's Lot 18 (USACE 2003). They are currently sampling and defining the extent of this surface disposal area.

Over the next several years, USACE plans to continue removals of arsenic-contaminated soil at locations exceeding 20 ppm and to continue geophysical investigations for ordnance buried in residential properties. Arsenic concentrations up to 43 ppm have been and may be left in place when the homeowner requests that large tree or other impediments (patios etc.) not be disturbed. The USACE plans to have arsenic soil remediation completed on all residential properties by September 2008 and on the federal property in 2009 (USACE 2005).

In 2005, a range fan, linked with firing chemical rounds, was identified. The munitions were launched from the Spalding/Captain Rankin Area near American University toward the present-day Dalecarlia Parkway area. The USACE and their partners are determining if further investigations are needed for properties falling within the projected range fan (USACE 2005).

Reported Community Health Concerns

- Community members have voiced repeated concerns regarding the possible impact of the chemical munitions found buried in their neighborhood. Specific concerns expressed by residents include reluctance to use their yards for recreation and gardening, both in terms of contact with soils and eating homegrown produce. Some residents perceive an excess of illness and disease in the Spring Valley neighborhood. In response to these concerns, the DC DOH established a phone line for community-reported illnesses and health concerns in March 2001. In 2002, following a recommendation by the Mayor's Scientific Advisory Panel, the DC DOH contacted over 200 physicians in the D.C. area and Montgomery County,

Maryland, who serve Spring Valley residents and asked them to report any health problems possibly associated with arsenic exposures. The DC DOH received several reports.

- After review of the initial finding that the 1999 leukemia mortality rate for Ward 3, where Spring Valley is located, is more than twice as high as the mortality rate for DC and nearly twice that of the national leukemia mortality rate, ATSDR suggested that the District of Columbia Department of Health could evaluate the incidence and mortality rates for leukemia by census tract, and compare them with an area of similar demographics to determine any excess rates of disease. The DC DOH evaluated the incidence of leukemia in Potomac, Maryland and determined it was higher than Spring Valley (DC DOH 2005). No widespread occurrence of contamination and exposure to contamination that would lead to leukemia or other adverse health effects has been found. Even so, the DC DOH is working on a health study (DC DOH 2005).

The remainder of this health consultation evaluates the health implications of possible Spring Valley exposures and addresses community health concerns. It describes what is and is not known about health effects associated with exposure to the detected levels of contaminants, based on a comprehensive review of available site-specific environmental and exposure investigation results, and the scientific literature. Section VII of this health consultation ("Discussion of Community Health Concerns") responds to specific questions and concerns raised by community members.

IV. Discussion of Contaminants of Potential Concern

ATSDR critically reviewed the available environmental data (soil, dust, air, and water) to identify locations and levels of contamination detected in the Spring Valley neighborhood. This process enabled ATSDR to focus its health effects assessment (see Section V) primarily on those substances detected at elevated levels and in accessible areas (e.g., surface soils in residential yards). ATSDR also reviewed the findings of its biological monitoring (hair and urine testing conducted during our exposure investigations) in the context of available environmental sampling data.

After identifying the locations, concentrations, and frequency of detection of contaminants, ATSDR compared detected concentrations with health-based screening values or comparison values. The health-based comparison values used in this evaluation are concentrations of contaminants that the current public health literature suggests are "safe" or "harmless." These comparison values are quite conservative because they include ample safety factors that account for the most sensitive populations. If a contaminant has not been reported at levels greater than its comparison value, ATSDR concludes that no harmful exposure is expected to occur. If, however, a contaminant is found at levels greater than its comparison value, ATSDR examines that contaminant more closely (see Section V). Because comparison values tend to be based on very conservative assumptions, the presence of a contaminant at levels above its comparison value does not mean that exposure will result in adverse health effects, simply that further evaluation is needed.

ATSDR uses health-based comparison values to help identify contaminants that require further evaluation.

In the following subsections, ATSDR provides an overview of the environmental and biological sampling results at the Spring Valley site. Sampling results for surface soil, subsurface soil, buried materials, and indoor air and dust are summarized. We also examined the quality of the public drinking water supply serving Spring Valley residents to confirm the absence of harmful arsenic levels. We present our overall understanding of site contamination and possible exposure levels, as well as the adequacy and representativeness of available data sets for assessing public health. Overall, ATSDR determined that available environmental data were sufficient to evaluate the exposure pathways of primary interest—that is, soil and air pathways. Some uncertainties exist regarding possible soil gas releases. However, as discussed in the sections below, our understanding of the behavior of materials known to be present on site suggest limited potential for such releases. Ongoing or planned groundwater sampling and recommended soil gas sampling (see Section VIII) will help answer any remaining questions.

What are the general characteristics of AUES-related contaminants and what does that tell us about exposure potential?

Chemical warfare agents used or tested during past operations include organoarsenic-based agents (e.g., lewisite and adamsite), mustard agents, irritants, and "smokes," used as obscurants. To better understand the possibility of exposure to these substances, ATSDR examined their basic behavior in the environment. For example, ATSDR asked

- How do these chemicals degrade or break down?
- Do they persist (last a long time)?
- Are they likely to migrate (travel) from the point of disposal (i.e., soil) to other environmental media, such as groundwater or air?

Such an understanding, along with the results of the various sampling efforts, was critical in focusing ATSDR's evaluation—in terms of understanding what chemicals people could possibly be exposed to and how.

With the exception of sulfur mustards, various degradation mechanisms cause most chemical warfare agents to break down relatively quickly in the environment (Henriksson et al. 1996; Munro et al. 1999). Even the sulfur mustards break down over time (i.e., weeks to years). The more degradable arsenic-containing warfare agents generally break down to inorganic forms of arsenic, which can persist indefinitely in the environment. Environmental sampling in the Spring Valley neighborhood indicates that arsenic is one of the most prevalent substances related to chemical warfare agents found in area soils. Historical chemical lists for the Spring Valley site indicate that many of the compounds used or developed at AUES contained arsenic (Parsons 1998; Smart 1993). Additional information on arsenic-containing chemicals associated with the site is summarized in Appendix B, Environmental Fate of Chemicals Associated with the Spring Valley Formerly Used Defense Site (FUDS).

Investigators also found some chemical warfare agents in buried containers or glassware that had not degraded. Containerized materials and materials found in bulk are slower to break down, so this finding is not surprising. Some other chemical warfare agent breakdown products were detected in soils tested within burial areas, but generally in trace amounts (see discussion below). So what does this mean in terms of potential exposures? For example, what contaminants, if any, could have migrated to groundwater? Could chemicals from buried wastes have volatilized and migrated through soil gas? Though only a limited amount of sampling data are currently available to answer such questions, our understanding of AUES-related contaminants provides some insights.

The movement and fate of a chemical within the subsurface depends largely on its form, water solubility, and volatility. As mentioned above, inorganic substances such as arsenic tend to persist and are relatively immobile. Other contaminants may be more mobile once released into the environment. Of the AUES-related compounds, sulfur mustard, thiodiglycol, and other mustard breakdown products have been shown to migrate to water. Mustard breakdown products 1,4-dithiane and 1,4-oxathiane, for example, are relatively mobile and volatile. Lewisite and its degradation products, on the other hand, are not likely to migrate to groundwater, nor are they considered volatile (USACHPPM 1999; Munro et al. 1999).

Sulfur mustard degrades naturally through "hydrolysis" (or reaction with water) or biodegradation. In soils of sufficient moisture (greater than 50%) such as in Spring Valley, rapid hydrolysis would be expected. The major product of this process is thiodiglycol, which is far less toxic than sulfur mustard. Unlike its parent, thiodiglycol can persist in soils for weeks to years, and in some cases decades (ATSDR 2003a; Munro et al. 1999); this may be the case in Spring

Valley, as evidenced by small amounts still detected in some soil samples. Similarly, arsine degrades naturally through hydrolysis, yielding arsenic acids and hydrides (WHO 2002).

Sulfur mustard also can theoretically be biodegraded in soil, but this has not been successfully demonstrated. The thioether "oxidation" pathway could produce mustard sulfoxide, mustard sulfone, and divinyl sulfone. These compounds are moderately water soluble, likely limiting their environmental persistence. "Dehalogenation" and "dehydrohalogenation" processes can produce vinyl sulfide, vinyl sulfone, and vinyl sulfoxide. The extent to which these processes occur in soils is not fully known and are more relevant in situations when chemicals are used to decontaminate sulfur mustard. For example, hydrogen peroxide can oxidize sulfur mustard, and hypochlorite solutions (e.g., bleach) can dechlorinate it (ATSDR 2003a; Morrill et al. 1985; Munro et al. 1999; NLM 2004a; Watson and Griffin 1992). It is unknown if such decontamination practices occurred at AUES; some historic data indicate the detection of these breakdown products, though quantities and form are not specified (ERDEC 1993).

Volatilization of buried chemicals, past or present, would also be dependent on the characteristics of the individual chemical, and when and where it was deposited. Neither sulfur mustard nor its degradation products are likely to move into soil-pore air because of sulfur mustard's rapid hydrolysis and formation of aggregates, which prevent volatilization (USCHPPM 1999). Further, based on *estimates* of vapor pressure and other factors, it is predicted that thiodiglycol, vinyl sulfoxide, and vinyl sulfone are essentially non-volatile (ATSDR 2003a; NLM 2004 a, b, c). However, some mustard breakdown products, such as 1,4-dithiane, 1,4-oxathiane, and divinyl sulfide are believed to have enough volatility to allow some vapor transport (Munro et al. 1999). Little site data have be collected to document the presence or absence of contaminants in soil gas, though several volatile organic contaminants were detected in the past within vapor containment systems established over disposal areas during removal actions.

Because available data provide only a snapshot in time and place, further soil gas sampling of remaining or newly discovered burials would support a more definitive conclusion on the soil gas pathway, though it will not necessarily answer questions regarding past conditions. Groundwater sampling currently being planned by USACE will provide information on whether any contaminants of potential concern are present in groundwater, including potentially volatile substances. A host of factors, however, influence the extent to which subsurface gases, if present, might migrate through soil and into indoor air, such as proximity to a given source, soil characteristics, foundation condition, etc. (EPA 2002). Lastly, the concentration of a particular contaminant and its toxicity ultimately determine whether harmful effects would be expected.

A more detailed overview of the environmental fate of some individual agents and other chemicals used at the Spring Valley site is presented in Appendix B.

What were the results of the area-wide investigation for arsenic on Spring Valley properties?

As described above, several Spring Valley neighborhood contamination investigations have been completed, which have focused largely on arsenic. These investigations included soil sampling (surface and subsurface) and sampling indoor air and dust, as well as urine and hair from a subset

of area residents. An overview of the results of the arsenic soil investigations is presented below. Table 1 summarizes arsenic concentrations found in surface and subsurface soils. Figure 4 summarizes the maximum arsenic levels (discrete samples) in surface soils of Spring Valley residential properties and vacant lots prior to time-critical soil removals.

- Through September 2003, 1,484 of the 1,602 residential properties and vacant lots within the Spring Valley study area have been sampled. Of these, approximately 172 required follow-on grid sampling. One or more grids above the arsenic clean-up goal of 20 ppm for residential properties were found in 150 properties (10%) (USACE 2004a). Accordingly, the majority (90%) of Spring Valley properties do not contain arsenic levels exceeding 20 ppm.

- Testing of residential soils in the Spring Valley neighborhood has shown composite soil levels of arsenic ranging from 1 ppm—which is within background levels—up to 202 ppm in one residential yard (Figure 3). Discrete samples collected through September 2002, indicate arsenic concentrations ranging from 2.1 to 613 ppm (USACE 2002).

Table 1. Arsenic in Spring Valley Soils

Composite or Discrete Sample	Surface or subsurface	Maximum value (ppm)*	Mean value (ppm)*	Frequency of Detection (Detects/Samples)	Comparison Value (ppm)**	Comparison Value Source
Composite	Surface	202	6.2	3,971/3,978	200 20	EMEG-Adult EMEG-Child
Discrete	Surface	613	14.5	7,210/7,215		
Discrete	Subsurface	124	3.1	4,337/4,574		

Sources: Parsons 2002 a, b, c; Parsons 2003d

Composite: A group of samples taken from multiple locations, mixed together, and given one chemical analysis.
Discrete: A sample taken from only one location for chemical analysis.

* Spring Valley partners (US EPA, USACE, and DC DOH) have established a clean-up goal of 20 ppm for Spring Valley residential surface soils. The analytical detection limit for soil arsenic was usually below 0.5 ppm.

** ATSDR's comparison values, such as the EMEG: Environmental Media Evaluation Guide, are screening levels used to determine if further evaluation is needed.

What other chemicals were tested and detected in Spring Valley soils?

Specialty Parameter Results

In a subset of the *subsurface* soil samples collected at Spring Valley, USACE's specialty parameter sampling program tested for chemical contaminants typically associated with breakdown products from explosives and chemical warfare agents. The USACE collected soil borings (i.e., subsurface samples) at each of the properties within the central testing area—the portion of Spring Valley where AUES testing activities were most likely to have occurred. Soil

boring samples were also collected at 15% of the residential properties in the comprehensive site area, outside of the central testing area and from properties within Operable Unit 4 (USACE 2001b; Parsons 2001, 2002a and 2003d).

The program included analyses of approximately 250 samples for mustard, some mustard agent breakdown products, lewisite, and some lewisite agent breakdown products. Of these, only thiodiglycol, a sulfur mustard breakdown product was detected. Thiodiglycol is not a unique degradation product of sulfur mustard degradation—it has been used as a solvent in antifreeze solutions, in dyestuffs for printing, and in the production of polyvinyl chloride (Munro et al. 1999). Thiodiglycol was detected in 9 out of 249 subsurface samples at a maximum concentration of 2.1 ppm, and at two locations: American University president's residence (4835 Glenbrook Road) (OU-3) and American University property at 4400 Massachusetts Avenue (OU-4) (Parsons 2003d). It is interesting to note that, in addition to thiodiglycol, high levels of arsenic were detected at 4835 Glenbrook Road [reported up to 1,200 ppm in the subsurface prior to removal actions] (Apex 1996). Although ATSDR does not have a comparison value for thiodiglycol, it has low toxicity to people and most people have limited to no contact with these deeper soils.

Approximately 30 subsurface soil samples were collected in the central testing area and analyzed for selected explosives and their transformation products (e.g., trinitrotoluene [TNT], dinitrotolunene [DNT] and tetryl) (Parsons 2001; USACE 2002). No explosives or their transformation products were detected. Total cyanide was analyzed in 254 samples with 5 detections of 0.2 ppm, near the method detection limit and far below ATSDR's health-based comparison value of 1,000 ppm for children.

AUES List Sampling Results: Selected OU-4 Residences, Sedgwick Trench, the CDC, and American University Lot 12

USACE conducted several additional "specialty samplings" for four OU-4 properties (Parsons 2002a), for four properties on Sedgwick Street on the former trench area (Parsons 2002b), and for the CDC and Lot 12 on American University property (Parsons 2002c). Most of these specialty samplings contain a more comprehensive suite of chemical analyses than the area-wide samples. These investigations involved analysis of approximately 200 compounds, including

- EPA's target list for VOCs and semi-volatile organic compounds (SVOCs)
- Metals and elements
- Several chemical warfare agents and their breakdown products
- Other parameters such as ammonia and cyanide.

Samples tested as part of these investigations reported only a few substances at elevated levels and those substances were detected below levels of health concern. Specifically, of the 13 samples collected from four OU-4 properties, in addition to arsenic, two other substances were detected above ATSDR comparison values and site background levels: benzo(a)pyrene and phosphorus (Table 2). Benzo(a)pyrene concentrations were slightly elevated but well below

levels known to result in harmful health effects (ATSDR 1997; Brenniman and Levy 1984; Freeland-Graves et al. 1987; NRC 1989; WHO 1973; Wones et al. 1990). The form of phosphorus detected in site soils is not specified; even assuming it is the most toxic form, levels are lower than those expected to cause harmful effects. A discussion of phosphorus toxicity is presented in Appendix E. Elevated arsenic concentrations were found on two properties: a property on Quebec Street and a property on Rockwood Parkway. ATSDR's evaluation of arsenic exposures is discussed in Section V (Health Effects Assessment) of this health consultation.

Table 2. Selected AUES List Sampling Results of Surface Soil at OU-4 Residences

Contaminant*	Maximum Value (ppm)	Frequency of Detection (Detects/samples)	Comparison Value (ppm)	Comparison Value Source
Arsenic	133	13/13	200 20	EMEG-Adult EMEG-Child
Benzo(a)pyrene	0.720J	9/13	0.1	CREG
Phosphorous	1,530	13/13	100 10	EMEG-Adult EMEG-Child
Thiodiglycol**	0.813J	3/13*	None. USACE standard is 39.1 ppm.	

Source: Parsons 2003d

ATSDR's comparison values are screening levels used to determine if further evaluation is needed.

CREG: cancer risk evaluation guide
EMEG: environmental media evaluation guide
J: estimated value
ppm: parts per million

*This list does not include all detected contaminants, but those fitting the general AUES fingerprint. Other polycyclic aromatic hydrocarbons (PAHs) were detected in addition to benzo(a)pyrene, but none at levels exceeding the comparison value for benzo(a)pyrene.
**Thiodiglycol was detected at two residences: Rockwood Parkway (0.813J ppm) and Quebec Street (at 0.257J and 0.411J ppm).

The Sedgwick trench was also sampled for AUES list contaminants. Five soil samples from the Sedgwick trench area were taken at trench bottom or other subsurface areas—locations with limited potential for human contact. No chemical warfare agents or their degradation products were detected in the samples collected from this area. Further, detected metals (including arsenic) and polycyclic aromatic hydrocarbons (PAHs) were detected at or below ATSDR health-based comparison values or background concentrations. Even if people were to contact soils with the detected concentrations, no adverse health effects would be expected. In February 2001, soil samples were collected from American University Lot 12, at the CDC and on Lot 12 outside of the CDC property boundary (Table 3). Sixteen samples received full AUES list chemical analysis. Traces of the mustard breakdown product thiodiglycol (estimated maximum 0.732 ppm) were found in the surface soil of one American University lot and in the surface soil

of one property near American University. Arsenic was detected at concentrations ranging from below background to 498 ppm in composite surface soil. PAHs were detected at concentrations ranging from 0.12 to 2.3 ppm, about 2 to 3 times higher than ATSDR's comparison values. Phosphorus was detected above ATSDR's comparison values for white phosphorus, the most toxic form. However, the form is not specified and is unlikely to be predominantly white phosphorus in surface soils. It is below harmful levels of phosphorus (less toxic forms from phosphate-bearing minerals and rocks) based on comparisons to safe dietary levels (Institute of Medicine 1999).

In 2003, contaminated soil was removed at and surrounding the CDC (Parsons 2003a). Soil samples taken during the removal process showed many elevated arsenic levels (four samples exceeding 1,000 ppm; maximum 3,550 ppm in the subsurface). The site was remediated to levels of arsenic less than 20 ppm in surface soil and less than 26 ppm in subsurface soils. Two feet of clean fill was added to the entire fenced-in area of the CDC as well as a 2-foot buffer zone outside the entire fence line (ATSDR 2003b).

Table 3. Selected Sampling Results for the CDC and American University Lot 12

Contaminant*	Maximum Value (ppm)	Frequency of Detection (Detects/Samples)	Comparison Value (ppm)	Comparison Value Source
Arsenic	3,550*		200 20	EMEG-Adult EMEG-Child
Benzo(a)pyrene	1.1J	29/32	0.1	CREG
Phosphorous	678	26/26	100 10	EMEG-Adult EMEG-Child
Thiodiglycol	0.732J**	11/16	None. USACE standard is 39.1 ppm.	

Source: Parsons 2003d

ATSDR's comparison values are screening levels used to determine if further evaluation is needed.

CREG: cancer risk evaluation guide
EMEG: environmental media evaluation guide
J: estimated value
ppm: parts per million

* The maximum reported concentration is from a *subsurface* soil sample analyzed during removal operations conducted in 2003. In 2001, the surface soil (0–6") arsenic maximum was 399 ppm. The composite surface soil maximum was 498 ppm.

** Thiodiglycol was detected in surface and subsurface soils at the CDC. Detections ranged from 0.235 ppm to an estimate of 0.732 ppm (surface thiodiglycol concentrations were higher than subsurface). The samples in which thiodiglycol was not detected had high detection limits, in the 1,000's of ppm—apparent interference.

What was found in burial pits and other disposal areas?

Burial Pits

Within the Spring Valley FUDS boundary, four burial pits and several other disposal areas have been uncovered. The four pits—the only four thus far discovered—held hundreds of munitions, including munitions containing sulfur mustard, lewisite, fuming sulfuric acid, and other chemicals. Other disposal areas have contained barrels, contaminated soil, glass including laboratory glassware, metal debris, and other items.

The first burial pit was discovered at 52nd Court Street (POI 14) in January 1993, during the digging of a utility trench. It held 141 intact munitions, 43 of which contained some form of chemical warfare agent. The samples removed during Operation Safe Removal consisted of soil and various solids, crystals, fibers, liquids, the contents of laboratory glassware and equipment, household items, munitions, and metal pellets (ERDEC 1993). Thirty-four of the chemical ordnance items were sent to Pine Bluff Arsenal in Pine Bluff, Arkansas for destruction. The remaining nine chemical munitions were sent to ERDEC at Edgewood Arsenal, Maryland, for additional analysis (Parsons 1995). One of the nine munitions contained at least 60% pure intact sulfur mustard and two munitions contained fuming sulfuric acid (ERDEC 1993). Residues of lewisite breakdown products were found on broken glassware. Adamsite (diphenyl chloroarsine) was found inside a test tube in soil with an arsenic concentration of 250 ppm. A vial and solid samples contained chloroacetophenone (a component of tear gas, a colorless to gray crystalline solid with a sharp irritating odor that slowly corrodes metals) and its degradation products. TNT was identified in soil adhering to glassware as well as high concentrations in yellow powder form. Other identified contaminants were tetryl, red phosphorous, metals (elevated calcium and magnesium in water solutions of inorganic salts or chlorides; elevated cadmium, lead, and zinc in powders of munitions or soil near munitions), and sulfur mustard degradation products. The complete list of 33 compounds found to be present in soil/debris and the contents of munitions is listed in reference ERDEC 1993. Follow-on screening of arsenic in surface soil did not detect arsenic at levels above background on properties in this immediate area.

In May 1992, during excavation activities of homes being constructed at 4825 and 4835 Glenbrook Road, a rotten and acrid odor was detected coming from the soil. Glassware (mostly at 2 feet below the surface) including laboratory jars; a closed, rusted, empty 55-gallon drum; pieces of lab equipment; and ceramic materials were encountered. Construction workers experienced irritation to their eyes and face. White granular layers were encountered throughout one of the excavations (Apex 1996). In June 1996, landscapers intended to plant a tree at 4835 Glenbrook Road, the American University president's residence. When they dug the hole, they encountered buried chemical wastes (VOCs and SVOCs, but no analyses for chemical warfare agents were done) and glassware. A contaminated area 12 feet in diameter was defined (Apex 1996).

Later, authorities discovered three burial pits on Glenbrook Road, near American University (Figure 2, POI 24-R). Two of the pits were remediated, with the third pending completion. The two large burial pits on the personal residence of the South Korean Ambassador at 4801 Glenbrook Road, held 299 ordnance and explosive items (Parsons 2003c), including fifteen 75 mm projectiles with some chemical warfare agents (smokes, chlorine, sulfur mustard, etc.)

(USACE 2004a). Soils removed from the pits were sampled for a wide range of contaminants. A relatively small subset of samples contained elevated detections of sulfur mustard or lewisite, and some reported dithiane or thiodiglycol. Some VOCs and SVOCs also were reported in soil, but generally below health-based screening levels (Parsons 2003c). Similarly, air samples collected in June 1999 within a vapor containment system set up during Pit 2 excavation detected approximately 17 VOCs. Benzene, carbon tetrachloride, chlorobenzene, chloroform, tetrachloroethylene, and toluene were detected above health-based screening values (Parsons 2003c).

USACE also found chemical warfare agents in glass vials and bottles in Glenbrook Road burial pit 23, partially on 4801 Glenbrook Road (the property of the South Korean Ambassador) and partially on 4825 Glenbrook Road. In July 2001, during excavation activities, USACE collected samples of powder and liquid from some of these containers. A total of 12 samples were analyzed for sulfur mustard agent and lewisite derivatives. Sulfur mustard was detected in two of the samples (maximum concentration = 2,600 ppm) and lewisite derivatives were detected in five samples (maximum concentration = 50,000 ppm) (USABC 2001). In August 2001, USACE collected samples of glass vials and jars identified during the environmental investigations of Glenbrook Road pit 23. A total of 19 samples were analyzed for sulfur mustard, lewisite, and selected agent breakdown products. Most of the samples did not contain mustard and lewisite analytes. Sulfur mustard was detected in one sample at a maximum concentration of 890,000 ppm, but at much lower concentrations in three other samples (less than 50 ppm). A lewisite agent breakdown product (tris-[2-chlorovinyl]arsine) was detected in one sample at a maximum concentration of 148,220 ppm, but detected at lower concentrations in four other samples (USABC 2001). Additionally, three shells containing arsine gas were removed from Glenbrook Road burial pit 23. Until 2002, when the shells were prepared for their destruction, the contents of these shells had been misidentified.

An EPA Baseline Risk Assessment addressed arsenic contamination of the Glenbrook Road properties (EPA 1999) and a non-time critical removal action was performed at 4825 and 4801 Glenbrook Road from December 2000 to August 2002 (Parsons 2003d). USACE plans further soil removal at 4825 and 4835 Glenbrook Road (Parsons 2003d).

All known burial pits—excluding one that was partially remediated—have been excavated and closed. Thus, any future hazards to the Spring Valley community from chemical warfare agents and other contaminants in pits have been reduced. The USACE continues to conduct geophysical surveys to help identify burial pits, munitions, and other materials in Spring Valley. Also, USACE has provided information to residents on what AUES-related materials could conceivably be found in their neighborhoods.

Ongoing USACE investigations are intended to further evaluate burial pit impact. Groundwater investigations being conducted by USACE will serve to identify whether any buried materials affected area groundwater. ATSDR also recommends taking pre-excavation soil gas samples in the remaining portion of the Glenbrook Road burial pit and any newly identified burial areas to determine whether any potential exists for exposure from a soil-gas migration pathway.

Surface Disposal Areas

In addition to the burial pits, two surface disposal areas were found on American University property, on and west of Lot 18. One area, the Small Disposal Area (SDA), was located north of Rockwood Parkway residences and adjacent to the Kreeger Theater Building. The SDA was also on the banks of a small stream, designated the Upper Rockwood Stream, which flows onto the property of the South Korean Ambassador's residence (Parsons 2004c). In January 2001, USACE completed the initial clean up of this area. USACE removed 160 55-gallon barrels filled with soil, glass including lab glassware, and metal debris. Although testing detected no chemical warfare agents in the soil or in the metal debris, soil contaminated with elevated (above background) levels of arsenic, lead, and mercury was encountered (Parsons 2003d). The high lead levels were attributed to lead batteries, which had been found in the excavation (Parsons 2004c). The high mercury levels may have been associated with the laboratory wastes. Based on sampling results, USACE performed an over-excavation of the SDA going to rock at 4 to 5 feet below ground surface. Following over-excavation, USACE filled the areas with clean soil and restored the site. Hazardous soil, glassware, metal debris, and PPE were shipped to ChemMet in Brownstown, Michigan for disposal and non-hazardous soil and debris was sent to the King and Queen Landfill in Plymouth, Virginia (Parsons 2004c).

The other surface disposal area was discovered on American University Lot 18 with potential extension onto American University rental properties on Rockwood Parkway. In 2003, a bottle containing six milliliters of a 0.3% solution of chemical warfare agent lewisite was found on Lot 18. Mustard breakdown products, dithiane and oxathiane (thioxane), were discovered in a glass container removed from the Lot 18 burial in November 2004. A munition containing white phosphorus was also removed. Removals and investigations on and near Lot 18 are continuing, with completion anticipated in 2006.

Additionally, a subsurface burn layer, containing elevated levels of PAHs, lead, and arsenic, was found at one residence on Woodway Lane (Parsons 2004a). The layer was removed and confirmation soil sampling was performed for the elevated contaminants. The maximum confirmation results were 27.6 ppm arsenic, 135 ppm lead, and total PAHs of 0.542 ppm (benzo(a)pyrene was 0.086 ppm). SCRA action levels for lead and PAHs were not exceeded and the soil containing (two samples) arsenic over 20 ppm were not excavated further (Parsons 2004a).

What did indoor air samples show?

To determine the presence of any mustard agent, lewisite, or their breakdown products in airborne residential dust, USACE collected indoor airborne dust samples from one home on the Sedgwick trench. The September 20–26, 2001, sampling round also tested for arsenic-related compounds (Parsons 2002d). Although no samples were found to contain chemical warfare materials, their related products, or arsine, arsenic was detected at levels above ATSDR's comparison value for arsenic in air. Reported arsenic air concentrations ranged from 0.05–0.64 micrograms per cubic meter ($\mu g/m^3$). ATSDR's comparison value is 0.0002 $\mu g/m^3$. The minimal detectable concentration for this study was 0.05 $\mu g/m^3$. No adverse health effects are anticipated from these air concentrations—as explained in Section V, Health Effects Assessment, under the subtitle "Exposure to arsenic in dust and air." The average arsenic concentration was higher on

the main floor than other areas of the residence. Because the main floor is also the main entrance, arsenic dust from soil is a suspect source. However, the soil-arsenic concentration in the yard did not exceed 20 ppm.

This home on Sedgwick Street was re-sampled in July 2003, using a different method—one that collects the particles that penetrate deeply into the lung, or particulate matter less than 10 microns in diameter (PM10), rather than total suspended particulates. The PM10 level of arsenic was 0.0003 to 0.0007 $\mu g/m^3$. The outdoor PM10 concentration was slightly higher at 0.0008 $\mu g/m^3$ (Parsons 2003b). These airborne arsenic levels show the respirable fraction to be low and not of health concern.

In June 2003, an independent contractor analyzed indoor air at 4625 Rockwood Parkway. ATSDR was asked to evaluate those data and provided a separate health consultation for that property (ATSDR 2003c). Although there were elevated levels of carbon monoxide (a suspected furnace problem), the other identified indoor air contaminants were not considered to be a health threat. In March/April 2004, sub-slab soil gas was sampled at two Rockwood Parkway properties (including 4625 Rockwood Parkway), near the American University Lot 18 disposal area (Parsons 2004c). Samples were analyzed for VOCs, SVOCs, and chemical warfare agent breakdown products, including lewisite degradation products; the mustard degradation products thiodiglycol, 1,4-dithiane, and 1,4-oxathiane; phosgene; and arsine. Low levels of VOCs and SVOCs (generally below 1 ppb) were detected and are not at levels of health concern; all were generally detected below health-based screening values. The source of these trace VOC and SVOC levels, however, is not known. The chemical warfare agent breakdown products analyzed were not detected.

What arsenic levels were found in hair and urine?

As described above, several investigations have been initiated to determine the extent of arsenic contamination in surface soils, along with some limited testing of indoor environments. Other investigations involved the analysis of hair and urine for arsenic to further evaluate the extent of arsenic exposures, particularly in those areas with the highest soil concentrations. Sampling soil and other environmental media helps to identify exposure *potential*, but hair and urine sampling helps determine whether arsenic is present in the body at levels of health concern. As described below, no harmful levels of arsenic were measured in the hair or urine of study participants.

In December 2000, contaminated soil was identified at American University's CDC. Surface soil samples collected from the center's playground were contaminated with arsenic at an average concentration of 57 ppm and at a maximum concentration of 498 ppm (ATSDR 2001a). However, remedial actions at the CDC have reduced arsenic levels in the soil (ATSDR 2001a).

On February 1–2, 2001, ATSDR conducted an exposure investigation (hair analyses for arsenic) at the CDC. Hair samples from 28 children and from four adults indicated no elevated arsenic exposure in children or in workers at the center. Detectable levels of arsenic were measured in hair samples from eight of the investigation participants at concentrations ranging from 0.10 to 0.14 ppm—within the range reported for unexposed populations.

On February 10 and 15, 2001, Washington Occupational Health Associates, Inc. collected hair and urine samples at American University (WOHA 2001). The target population for this exposure investigation included CDC staff and children who attended the center during the prior 12 months, maintenance and grounds workers, and university athletes who use the intramural athletic fields near the center. Sixty-six persons (39 adults and 27 children) provided hair samples. Four adults provided urine samples. Washington Occupational Health Associates, Inc. also concluded the sample results indicated no elevated levels of arsenic in the population tested (WOHA 2001).

In March 2002, ATSDR conducted an exposure investigation for those households with the highest arsenic levels, as determined by composite soil samples. ATSDR collected and analyzed settled household dust for arsenic in 13 homes (vacuum samples from the floor). Concentrations of arsenic in dust ranged from not detected to 63 ppm (ATSDR 2002b). ATSDR also collected urine and hair samples from 32 individuals living in these households (23 adults and 9 children). Urine was analyzed for inorganic arsenic and total arsenic. Only four of the individuals tested had detectable inorganic arsenic in their urine, with levels ranging from 10 parts per billion (ppb) to 15 ppb. Levels below 20 ppb of inorganic arsenic usually indicate no clinically significant exposure. These low inorganic arsenic levels are therefore not expected to cause any health problems (ATSDR 2002b). In all individuals tested, total arsenic ranged from not detected to 210 ppb. Such a total arsenic range in urine is what one might expect in the general population. ATSDR concluded that the total urinary arsenic is mostly organic arsenic—the virtually non-toxic form of arsenic (ATSDR 2002b). Hair-arsenic levels ranged from not detected to 0.73 ppm. The average concentration was 0.1 ppm. Levels below 1 ppm usually indicate no statistically significant arsenic exposure in hair (ATSDR 2002b).

In response to requests from the Scientific Advisory Panel and others to sample residents during summer months—when the potential for exposure to soil arsenic should be higher—ATSDR and DC DOH conducted the Summer 2002 Exposure Investigation (ATSDR 2003d). The agencies offered urine-arsenic testing to those individuals who participated in the March 2002 Exposure Investigation, to individuals who were living on or adjacent to property undergoing remediation, and to individuals whose yards had the highest grid sample results. Urine samples were collected from July to November 2002. Urine-arsenic levels were tested in 40 individuals (34 adults and 6 children). Three individuals had mild elevations (>10 ppb but <30 ppb) of inorganic arsenic in their urine. Most participants (92%) had urine arsenic values of less than 10 ppb, indicating no significant exposure. Levels below 20 ppb of inorganic arsenic usually indicate no clinically significant exposure. Accordingly, adverse health effects are not expected, even in those adults whose urinary arsenic is mildly elevated.

Indoor dust samples (wipe samples) were analyzed in one home on Sedgwick Street. The data were collected by USACE and provided qualitative results. The purpose of the wipe samples was to help identify any potential arsenic sources in the home. The results indicated undetectable to low levels of arsenic in easily accessible and cleaned places and higher arsenic levels in more remote locations. ATSDR drew no health conclusions from these samples because of their non-quantitative nature.

What arsenic levels were found in the public drinking water?

On November 14, 2001, at the Washington Aqueduct, some ATSDR team members visited with Mr. Lloyd Stowe a representative of the USACE. ATSDR's purpose was to collect information on arsenic monitoring for the municipal water supply that serves Spring Valley residents. The Washington Aqueduct is a federally owned and operated public water system which draws its raw water from two locations on the Potomac River: Great Falls and Little Falls, Maryland. The intakes are upstream of the Spring Valley site. At two treatment plants located in the District of Columbia—the Dalecarlia Treatment Plant and the MacMillan Treatment Plant—the Washington Aqueduct processes millions of gallons of water from the Potomac River. Municipal water for Spring Valley is drawn primarily from the Dalecarlia Reservoir on a regular basis. The Dalecarlia Reservoir is located west of the Spring Valley site. The USACE is conducting groundwater monitoring at the Spring Valley site near the Reservoir and American University Lot 18 with initial results anticipated in September 2005.

ATSDR reviewed arsenic monitoring results listed in a monthly report from January 1975 through July 2001 (USACE 2001c). These data indicate nondetectable to trace amounts of arsenic (0.004 ppm or below) in finished water for all months except January and February 1981, when slightly higher values were found for Dalecarlia finished water (0.009 and 0.018 ppm respectively). Except for the February 1981 result, reported values are below EPA's maximum contaminant level (MCL) for arsenic (0.010 ppm). These arsenic levels in drinking water pose no health concern and present no notable additional source of arsenic exposure for Spring Valley residents.

V. Health Effects Assessment

This section focuses primarily on the public health implications of possible exposures to the detected levels of arsenic described in the previous section. The discussion focuses on surface soil exposures, but also addresses indoor air/dust exposures. ATSDR focuses on arsenic in surface soil because, as discussed earlier, inorganic arsenic is the most persistent degradation product of the organic arsenicals (e.g., lewisite), arsenic has been detected in some Spring Valley soils at elevated concentrations, and area residents may come in direct contact with surface soils. ATSDR also considers the findings of hair and urine testing of area residents. We also briefly discuss possible hazards associated with some of the buried materials identified during site investigations, though people would not be expected to come in contact with subsurface soil or buried waste.

To evaluate whether environmental exposures in the Spring Valley neighborhood could result in adverse health effects, ATSDR evaluated the following factors:

- *Exposure conditions*. To what extent might people come in contact with (i.e., be exposed to) arsenic found in soils or dust in the Spring Valley neighborhood? Under what conditions might people have been exposed (e.g., what is the exposure route, the duration, and the magnitude of any exposure)? To what extent is the arsenic detected in soils or dust available for uptake in the human body?

- *Possible health effects*. What are the documented associations (or lack of associations) between detected contaminants and harmful effects? How do documented adverse effect levels compare with estimated exposure levels at the Spring Valley site?

The methods used to estimate site-specific exposure doses and the information used to help answer these questions are presented in Appendix E. Appendix E also provides some additional toxicity information for the chemical warfare agents.

ATSDR's evaluation indicates that exposure to detected arsenic levels in soil and indoor dust/air is not expected to result in adverse health effects. Contact with the pure product found in some buried containers is a hazard, as is evidenced by reported irritant effects experienced in the past by those accidentally encountering these materials. Health hazards are likely to exist should wastes be uncovered or disturbed. ATSDR recommends that USACE continue rapid intervention in these areas.

The basis for these conclusions is discussed below.

Exposure to Arsenic Detected in Spring Valley Surface Soil

The most studied exposure pathway at the Spring Valley site is exposure via direct or indirect contact with soils containing arsenic—primarily surface soils. During normal activities, people can accidentally ingest soil and dust generated from soils. In fact, everyone ingests some soil or dust every day. Small children (especially those of preschool age) tend to swallow more soil or dust than any other age group. They tend to have more contact with soil because of play activities and because of a tendency toward hand-to-mouth activity. Some children have a much

greater tendency to place non-food items in their mouths, such as soil; this is referred to as pica behavior (see also Section VII). Older children, teenagers, and adults tend to swallow much smaller amounts of soil. The amount of grass cover in an area, the amount of time spent outdoors and indoors, and weather conditions also all influence how much soil and dust contact people might have.

To study possible health effects one needs to understand the amount of arsenic that people might have come in contact with or might have been exposed to. This is done by looking at detected arsenic concentrations and applying various "exposure factors" (e.g., intake rate, exposure duration, etc.) and estimating "exposure doses." Many of the studies in the scientific literature relate exposure doses to observed health effects. Evaluating exposure doses under site-specific but conservative (protective) exposure conditions allows comparisons between site doses and doses reported in the scientific literature that are associated with harmful effects.

ATSDR used available soil sampling data from Spring Valley yards to estimate site-specific exposure doses. Both adults and children were considered. ATSDR made several conservative assumptions when estimating site exposure doses. In doing so, we evaluated what is considered a reasonable worst-case exposure situation. We focused on the possible ingestion of soil, since dermal (skin) uptake of arsenic from soils is considered negligible (ATSDR 2000a). Our general assumptions and findings are discussed below. Appendix E describes the methodology in more detail.

- *Arsenic concentration.* We considered arsenic detections in the most contaminated yard—that is, the yard with the highest overall detected arsenic concentrations. In this yard, arsenic concentrations measured from 35 discrete surface soil samples ranged from 14.9 to 529 ppm. The highest composite reading was 202 ppm.[1]

- *Soil intake.* We assumed soil ingestion rates of 100 and 200 mg/day for adults and children, respectively. These rates are standard defaults used by health scientists and represent the amount of soil that might be incidentally ingested on a daily basis (EPA 1997b); 200 mg/day equates to ingesting approximately 1/16 of a teaspoon. Additionally, we considered pica behavior for children, which results in higher than normal soil consumption rates (we assumed an ingestion rate of 5,000 mg/day or approximately one teaspoon/day).

- *Exposure duration and frequency.* ATSDR estimated site-specific exposure doses assuming daily exposure to detected arsenic concentrations, regardless of where or how long a person may have lived in the Spring Valley neighborhood. Assuming this type of continuous chronic exposure may lead to an overestimation of exposure potential.

- *Bioavailability.* We assumed that 50% of the arsenic in soil would actually be absorbed in the body once ingested. The selected value represents the high end of the range of

[1] Note that arsenic concentrations detected in surface soils at residences where health conditions were reported to the DC DOH information line did not exceed 85 ppm. At some of these residences, arsenic was not detected at elevated levels at all. See the Discussion of Community Health Concerns (Section VI) and Appendix E for ATSDR's evaluation of illnesses of reported concern in the Spring Valley neighborhood.

"bioavailability factors" reported in the scientific literature and from site-specific studies (ATSDR 2000b; Oomen et al. 2002; Parsons 2002e; Ruby et al. 1999; WHO 2001). Using the high end of this range could overestimate exposures. See the text box for more information on the bioavailability of arsenic in soils.

Understanding Bioavailability

Arsenic in water has been shown to be very well absorbed across the gastrointestinal tract (ATSDR 2000b). However, this is not so with arsenic in soil. Fairly extensive studies of arsenic bioavailability reveal that the human body absorbs only a portion of the arsenic that is present in a soil matrix. Bioavailability is dependent on arsenic form and soil type. The best measure of bioavailability, therefore, is testing designed to quantify uptake under site-specific conditions (Battelle and Exponent 2000). Such testing occurred at Spring Valley. USACE tested 11 soil samples and reported bioavailability factors ranging from 3% to 50% (Parsons 2002e). To be conservative, ATSDR chose the highest reported factor when calculating exposure doses (see Appendix E). Recognize, however, that only one Spring Valley sample yielded bioavailability as high as 50%. The bioavailability in the remaining samples was considerably lower, ranging from 3% to 22%, with a mean of 10%. Therefore, our dose estimates could be overestimated by a factor of approximately 2 to 16. Knowing that site-specific doses are probably lower than those used in our analysis lends support to our conclusions.

ATSDR evaluated possible non-cancer and cancer effects. As shown in Table 4, no adverse health effects would be expected or have been demonstrated at doses estimated for the range of exposure conditions studied at Spring Valley. In all cases, *estimated arsenic doses fall below the lowest dose shown to be associated with adverse health effects*. The lowest-observed-adverse-effect level (LOAEL) represents the lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects. The LOAEL reported in the literature for arsenic is associated with skin lesions observed in people drinking arsenic-contaminated water. Cancer outcomes have been reported at comparable and higher levels. The margin of exposure shows the ratio between site doses and doses at which adverse health effects have been documented in human epidemiologic studies. Because estimated doses are at least 14 times lower than the most sensitive endpoint under our worst-case exposure situation (child exposure in the most contaminated yard), we conclude that harmful effects of any kind would not be expected for people contacting these soils.

Table 4. Estimated Spring Valley Arsenic Doses Compared to the LOAEL

Soil Concentration Arsenic (ppm)	Exposure Situation	Estimated Dose (mg/kg/day)		LOAEL (mg/kg/day)	Margin of Exposure
		Child	Adult		
529	Acute ingestion	0.003	0.0004	0.05	17
202	Chronic ingestion	0.001	0.0001	0.014	14
20	Chronic ingestion	0.0001	0.00001	0.014	140

See Appendix E for dose equation and further discussion. These worst-case residential exposure scenarios were used to evaluate the potential for harm (202 ppm and 529 ppm); however, these soil concentrations, as well as the highest concentrations in other yards, have been removed. The arsenic soil cleanup level of 20 ppm is shown for comparison purposes.

ATSDR estimated doses for chronic (long-term) and acute (short-term) exposures. ATSDR considered the highest composite arsenic concentration (202 ppm) detected in the most contaminated residential yard and assumed that children and adults could have had regular contact with these soils over a long period of time (an exposure situation of chronic ingestion). For acute exposures, ATSDR assumed exposure to the highest detected concentration (529 ppm) in a single spot (discrete sample) in that same yard. Both standard child soil intakes and those associated with possible pica behavior were evaluated.[2] As shown in Table 4 (and also Table E-1), the estimated chronic doses are more than 14 times lower than the most sensitive endpoint related to chronic arsenic exposure (skin lesions and skin cancer). In fact, for adults, chronic dose estimates are lower than the chronic MRL and doses at which no adverse effects have been reported. Acute doses generally fall below the acute MRL, clearly indicating that no observable adverse effects are expected (e.g., gastrointestinal disturbance). For the hypothetical pica child, however, estimated doses associated with exposures to the highest arsenic levels detected at the site would be in the range at which symptoms characteristic of acute arsenic "poisoning" (e.g., facial swelling, nausea, vomiting, and diarrhea) have been reported. This would only happen if relatively *large* amounts of the *most* contaminated soil were ingested in a short amount of time. The highest levels of soil arsenic in yards were removed during the time critical removal actions; remaining concentrations are not expected to result in harmful doses, even to a pica child. ATSDR's evaluation of possible health effects related to arsenic is discussed further in Appendix E.

An understanding of how arsenic behaves once it is ingested provides additional perspective on the estimated arsenic exposure doses. Once a substance enters the body, it is absorbed, metabolized (i.e., changed or broken down), distributed through the body, and then excreted. Various studies indicate that at low-level exposures, arsenic compounds are detoxified (or metabolized)—that is, changed into less harmful forms—and then excreted in the urine. More specifically, once arsenic is absorbed into the bloodstream, it eventually passes through the liver where some of the inorganic arsenic is changed into organic forms of arsenic (a process known as methylation). When the body's capacity to detoxify is exceeded, blood levels of arsenic increase and adverse health effects can occur. Limited data suggest that the dose at which this happens is somewhere between 0.003–0.015 mg/kg/day (ATSDR 2000b). All of the estimated site-specific exposure doses fall below this range, indicating that effective breakdown and excretion of arsenic should occur at the exposure levels documented in Spring Valley.

[2] Some children have a much higher tendency to ingest soil and other non-food items. This is known as pica behavior. Pica children could conceivably consume a teaspoon or more of contaminated soil each day. No documentation of this type of exposure has been identified at Spring Valley, so its consideration is purely hypothetical.

The Body's Ability to Detoxify Arsenic

As noted in the text, our bodies have the ability to change inorganic arsenic into less harmful forms and excrete it. This occurs through a process known as "methylation." Recent data suggest that arsenic affects some people more than others. This could be due to genetic differences related to methylation capacities. Differences in individual sensitivities, however, have not been quantified (Chung et al. 2002). While capacity questions clearly remain, the available data indicate that the body can safely handle exposures to the levels of arsenic measured in Spring Valley soils.

The findings of available urine and hair testing lend further support to the conclusion that harmful exposures to arsenic in soil are not occurring. Neither the urine nor hair samples taken from residents with yards known to contain the highest arsenic concentrations showed elevated levels. This observation further supports our understanding of the relatively low bioavailability of arsenic in soil. While the interpretation of such testing must be done with caution, these results indicate that body burdens of arsenic are low and not of health concern. ATSDR recognizes that these tests represent only a snapshot in time and historical exposure data are not available. Nonetheless, these data provide reasonable evidence that Spring Valley residents are not currently being exposed to harmful levels of soil arsenic.

Exposure to Arsenic in Dust and Air

Although indoor air and dust samples are limited, detected arsenic levels do not appear to be of health concern. Most of what we know about inhaled inorganic arsenic comes from occupational settings such as smelters and chemical plants, where exposure has been primarily to arsenic trioxide. But limited quantitative information is available regarding exposure levels in these studies. For example, persons exposed to arsenic dusts have been shown to experience upper respiratory system irritation. In fact, inorganic arsenic is the irritant-effect component in lewisite (see below). Reported longer-term effects of inhaled inorganic arsenic include some skin effects, cardiovascular effects, and lung cancer. Available effect levels range from 0.007 mg/m^3 (dermatitis) to approximately 0.05–0.4 mg/m^3 (lung cancer) (ATSDR 2000b).

The maximum indoor air arsenic sample detected in Spring Valley homes was 0.64 $\mu g/m^3$ (or 0.00064 mg/m^3). Therefore, the highest measured arsenic concentration in Spring Valley air is approximately 10–600 times lower than effect levels reported in the literature (ATSDR 2000b).

As noted earlier, detected levels of arsenic in dust ranged from not detected up to 63 ppm. Incidental ingestion of arsenic at the detected concentrations is not expected to result in adverse health effects (see previous discussion on soil exposures). Therefore, indoor dust at these levels is not considered a hazard.

Exposure to Buried Waste

As described in Section IV, the USACE identified some chemical warfare agents and/or associated breakdown products in some of the buried containers removed from the Spring Valley site. These substances were not prevalent in area soils, however. Three of the four known burial pits have been remediated with the remaining one needing some additional remediation. There is

also one remaining known surface disposal area at American University Lot 18. Thus, the potential for exposure to harmful levels of contaminants, although limited, still exists.

The extent to which people might have been directly exposed to chemical warfare agents (e.g., during past excavations or contact with broken containers) and some of the breakdown products is not fully known. No question remains, however, that these agents in concentrated forms can be highly toxic upon direct contact. Individuals involved in soil excavations might have had some short-term exposures resulting in immediate effects, consistent with some reports of burning eyes and respiratory system reaction. Some future potential remains for workers digging up soil in yet undiscovered burial pits to become exposed to agents in broken or degraded containers. Further, there are anecdotal reports of residents collecting glassware from their yards. Should a resident find suspect materials, notify the USACE to investigate. USACE can be contacted at 410-962-0157 or 202-360-3762. USACE has provided and distributed fact sheets on what objects are suspected of being from WWI and related to the AUES wastes to area residents.

As mentioned in earlier discussions, some question remains whether soil gas migration may have occurred near the burial pits (i.e., movement of volatilized materials through soil pores to the surface or into homes). This potential merits further examination, though based on our understanding of the type of buried waste the potential for exposure to contaminants at levels of health consequence appears to be small. Measuring soil gas for newly discovered burials or those currently under investigations is therefore recommended to help complete this story. Similarly, planned groundwater sampling by USACE will evaluate whether buried waste affected groundwater.

VI. Discussion of Community Health Concerns

In this section, ATSDR provides answers to specific questions and concerns raised by residents in the Spring Valley neighborhood.

Is it safe to use yards in the Spring Valley Neighborhood for gardening and recreation?

Residents have expressed concerns about using their yards for gardening and recreation, as well as consumption of garden produce. To address these concerns ATSDR has prepared a separate brochure entitled *Safe Gardening, Safe Play, and a Safe Home*. The brochure states that persons with contaminated properties can safely use their yards and gardens—particularly if the recommended precautionary measures are used. A copy of this brochure is included as Appendix F of this Health Consultation (ATSDR 2003e).

Are diseases and symptoms occurring at elevated rates in the Spring Valley Neighborhood? Could illnesses reported by some residents be related to site contamination?

Some Spring Valley residents have expressed concerns about perceived high rates of various diseases or illnesses in their neighborhood. The residents are especially concerned about the Sedgwick Street area, in which homes were built over trenches where chemical weapons were tested (Tucker 2001). They are also concerned about the number of illnesses in the Rockwood and Glenbrook Road areas (Cohen et al. 2002).

In response to health concerns, DC DOH conducted a health study of selected cancers, the findings of which are summarized below. DC DOH also received reports of health concerns through an information hotline. ATSDR examined these concerns in the context of our understanding of environmental exposures. Our findings are presented below.

DC DOH Cancer Incidence and Mortality Reviews

Evaluation of arsenic-related cancer incidence and mortality data shows no excess cancers or deaths from cancer in Spring Valley.

In May 2001, ATSDR received the DC DOH incidence and mortality review (DC DOH 2001b). The study, titled *Descriptive Epidemiological Study of Cancers Associated with Arsenic in the Spring Valley Area of Washington, D.C.*, stated its purpose as an assessment, through record reviews, of the potential excesses of arsenic-related cancer incidence and mortality (e.g., urinary bladder cancer, melanoma skin cancer, lung cancer, liver cancer, and kidney cancer) in two census tracts. One tract (Tract 9.1) included the Spring Valley area. The other tract included an adjacent reference area (Tract 8.1). DC DOH concluded that, when compared to the U.S. white population in general, the results indicated no excesses of arsenic-associated cancer incidence and mortality in the Spring Valley Neighborhood during the 1987–1998 study period. Additionally, DC DOH concluded that for many of the cancers examined, the reference tract actually showed higher rates than did the Spring Valley tract.

DC DOH also compared its data with a reference tract in Potomac, Maryland (DC DOH 2002). Again, as compared to the U.S. white population in general, no excesses of arsenic-related cancer

incidence and mortality occurred in the Spring Valley neighborhood during the 1987–1998 study period.

ATSDR's Evaluation of DC DOH Hotline Records

ATSDR's evaluation indicates that exposure to contaminants at Spring Valley residences are below levels reported in the literature to lead to adverse health effects. None the less, self-reported illnesses and diseases collected through the DC DOH hotline are reported in this section.

Through the DC DOH hotline, individuals from residences and businesses in the area have reported a number of illnesses or symptoms (Figure 2). During an approximate 1-year period the hotline recorded one or more reported illnesses or health conditions from 46 separate residences. In many cases, multiple health concerns were reported from a single address. The list of illnesses and health conditions were self-reported; they were not confirmed by reviewing patient medical records or through consulting with a diagnosing physician. The hotline also recorded conditions related to students, employees, and children who had spent time on American University property. Illness and symptoms were reported in greater numbers from several areas: the Sedgwick/Tilden Street area and the American University CDC area, and along Warren Street (Figure 2). These areas also have the greatest number and density of POIs and anomalies (Figure 2).

Reports to the DC DOH hotline included a wide range of conditions as summarized in Appendix C. In reviewing the hotline information, ATSDR made several observations. More than one third of the reported conditions are disorders of the blood and bone marrow, as listed below (with the number of reported cases noted parenthetically).[3] Brain tumors (reported from 3 residences) and brain cancer (reported from 5 households) from 46 residences were also reported at seemingly elevated rates.

- anemia (4)
- aplastic anemia (1 in 1966 and 1 in a non-related child who later lived in the same house)
- leukemia/bone marrow cancer (2)
- multiple myeloma (2)
- myelofibrosis (1)
- Hodgkin's lymphoma (1)
- lymphoma (large-cell lymphoma, lymphatic, non-Hodgkin's) (4)

[3] Several other health conditions were reported to the DCDOH information line, including allergies, asthma, benign liver growths, bone cancer, brain tumors/cancer, breast cancer, chronic autoimmune disease, chronic fatigue, fibrosarcoma, lung cancer, lupus, neuropathy, Parkinson's disease, prostate cancer, rashes, and skin cancer.

As described above, ATSDR's evaluation of site-related exposures demonstrated that people are not coming in contact with harmful levels of contaminants in the soil. In our analysis, we showed that estimated exposures to arsenic and other measured contaminants are lower than those associated with the most sensitive health endpoints. Recognizing, however, that associations are known to exist between some contaminants (such as arsenicals [lewisite], sulfur mustard, and TNT) and various disorders, ATSDR conducted a comprehensive review of the scientific literature to study exposure doses associated with such disorders more closely. Appendix E details the findings of the literature review. Our evaluation demonstrated that estimated Spring Valley exposures to arsenic and the trace amounts of warfare agents detected in soils are indeed lower than those shown to be associated with these types of illnesses.[4]

Evaluation of possible environmental links to these conditions is complicated by the fact that most of the reported conditions (e.g., anemia, leukemia, and lymphoma), as well as peripheral neuropathy have multiple causes, including pre-existing disease, genetic predisposition, and lifestyle (e.g., diet and other exposures). Therefore, without a more complete evaluation of each patient's medical and risk factor history, other contributing factors cannot be ruled out. Further, some conditions were not explicitly described in the log, making interpretation more difficult. Some incomplete information was provided, such as reports of "many problems compatible with arsenic/mustard exposure," "skin rashes," "other problems," or "cancer." Without clinician verification and specification of reported conditions, some uncertainty exists regarding the specific nature and magnitude of the health conditions in the Spring Valley neighborhood. To provide some additional perspective, Appendix D presents a general overview of the multiple causes and prevalence of these disorders, independent of site-specific considerations.

ATSDR's Evaluation of Community-Health Surveys, the DC DOH Cancer Atlas, and Selected Health Outcome Data

In addition to the health concerns reported through the DC DOH hotline, ATSDR reviewed community concerns gathered by the *Current* and provided to ATSDR in February 2004 (*The Northwest Current* 2004). Additional noteworthy conditions, based on information from 61 residences, were seven leukemia cases, seven cases of peripheral neuropathy, and three deaths associated with leukemias (*The Northwest Current* 2004). Diseases of the thyroid were also reported (*The Northwest Current* 2004). Some of these cases were also reported to the DC DOH hotline and by another community health survey, suggesting some possible overlap.

Based on health survey reports indicating potential brain cancer and leukemia elevations, ATSDR reviewed the 1999 DC Cancer Atlas for further cancer information. According to the Cancer Atlas of the District of Columbia, cancer is the second leading cause of death in the United States and the District of Columbia (DC DOH 1999). In the District, more than 3,000 new cancer cases are reported each year, translating into one of the highest incidence and mortality rates for cancer in the nation (DC DOH 1999). The Atlas reports the highest mortality rate for brain cancers [2.9- 4 per 100,000] and leukemia [12.1- 13.1 per 100,000] within the District for Ward 3, where Spring Valley is located (DC DOH 1999).

[4] This was a qualitative analysis only and is not intended to evaluate any causal relationship between exposure to certain chemicals and any of the reported conditions.

ATSDR evaluated brain cancer and leukemia mortality rates further by comparing DC statistics with national rates as shown in Tables 5 and 6. Table 5 shows that in 1999 the U.S. age-adjusted mortality rate for brain cancer (4.5 per 100,000) was almost twice as high as the mortality rate reported for DC (2.5 per 100,000). Although in 1999 the range of brain cancer mortality rates for Ward 3 (2.9 to 4 deaths per 100,000) is higher than the entire DC area, it is actually a little lower than the national brain cancer mortality rate. Additionally, when looking at the three-year period from 1999 through 2001, the mortality rate for brain cancer in the entire DC area is 3.2 per 100,000, which is within the range reported for Ward 3. Since there are relatively few cases of brain cancer diagnosed in DC for any one year period the rate is likely to fluctuate considerably from year to year because even a difference of one or two cases can produce a significant change in the rate. Therefore, the 1999-2001 mortality rate is a more reliable comparison than the 1999 mortality rate.

Table 6 shows that in 1999 the U.S. age-adjusted mortality rate for all subgroups of leukemia (7.7 per 100,000) was slightly higher than the mortality rate reported for DC (5.8 per 100,000). The 1999 leukemia mortality rate range reported for Ward 3 (12.1- 13.1 per 100,000) is more than twice as high as the mortality rate for DC. It is also higher than the national leukemia mortality rate, although the difference is not as large.

There is no known association between site contaminants and brain cancers. Additionally, no widespread occurrence of contamination and exposure to contamination that would lead to leukemia or other adverse health effects has been found (See Appendix D for further descriptions of leukemia.). Based on the initial finding that the 1999 leukemia mortality rate for Ward 3, where Spring Valley is located, is more than twice as high as the mortality rate for DC and nearly twice that of the national leukemia mortality rate, ATSDR suggested that the District of Columbia Department of Health could evaluate the incidence and mortality rates for leukemia by census tract, and compare them with an area of similar demographics to determine any excess rates of disease. The DC DOH evaluated the incidence of leukemia in Potomac, Maryland and determined it was higher than Spring Valley (DC DOH 2005). No widespread occurrence of contamination and exposure to contamination that would lead to leukemia or other adverse health effects has been found. Even so, the DC DOH is working on a health study (DC DOH 2005). If additional environmental sampling indicates a completed exposure pathway for contaminants with doses sufficient to cause adverse health effects, then ATSDR will recommend investigations related to those contaminants.

Table 5. Brain Cancer Mortality Comparison – U.S. versus D.C.

U.S Mortality			District of Columbia	
Year	Death Count	AAR	Death Count	AAR
1999	12,484	4.5	14	2.5*
2000	12,412	4.5	18	3.2*
2001	12,372	4.4	21	3.8
1999-2001	NA	NA	53	3.2

ICD-10 code C71 is listed as malignant neoplasm of the brain and was used to produce the rates presented above.
*Unreliable rate due to small number of cases
AAR = Age-adjusted rate based on 2000 Census data; rates are per 100,000
NA = Not Available
Brain cancer mortality rate range for Ward 3 (which includes Spring Valley) is 2.9 – 4 deaths per 100,000[5]

Source: [CDC] Centers for Disease Control and Prevention. National Center for Health Statistics. CDC WONDER. Compressed Mortality File, Underlying Cause of Death. http://wonder.cdc.gov.

Table 6. Leukemia Mortality Comparison – U.S. versus D.C.

U.S Mortality			District of Columbia	
Year	Death Count	AAR	Death Count	AAR
1999	21,014	7.7	32	5.8
2000	21,339	7.7	38	6.8
2001	21,451	7.6	34	6.0
1999-2001	NA	NA	104	6.2

ICD-10 codes C91-C95 are listed as all leukemias and were used to produce the rates presented above.
AAR = Age-adjusted rate based on 2000 Census data; rates are per 100,000
NA = Not Available
Leukemia mortality rate range for Ward 3 (which includes Spring Valley) is 12.1 – 13.1 deaths per 100,000[1]

Source: [CDC] Centers for Disease Control and Prevention. National Center for Health Statistics. CDC WONDER. Compressed Mortality File, Underlying Cause of Death. http://wonder.cdc.gov.

[5] ICD-10 codes used within the Cancer Atlas of the District of Columbia 1999 need to be verified to ensure same as national statistics.

VII. Child Health Considerations

ATSDR recognizes that in communities faced with contamination of their water, soil, air, or food, infants and children can be more sensitive to environmental exposures than adults. This sensitivity results from the facts that (1) children are more likely to be exposed to certain media (for example, soil or surface water) because they play and eat outdoors; (2) children are shorter than adults, which means that they can breath dust, soil, and vapors close to the ground; and (3) children are smaller than adults; therefore, childhood exposure results in higher doses of chemical exposure per body weight. Children can sustain permanent damage if these factors lead to toxic exposure during critical growth stages. ATSDR is committed to evaluating the special interests of children at sites containing potentially hazardous materials.

Ingestion or inhalation of contaminated soils or dusts is a plausible exposure route for Spring Valley children. However, based on the evaluation described in the previous section, the levels of arsenic in Spring Valley soils are unlikely to cause harm to children during typical play activities. At the levels detected in soil samples the body can usually eliminate arsenic before damage occurs or, if damage does occur, the body can repair itself. See Section V and Appendix E for further discussion.

Occasionally, some children have a much higher tendency to ingest soil and other non-food items (known as pica behavior). Pica children—who could conceivably consume a teaspoon or more of contaminated soil each day—could be at higher risk if they come in contact with the highest arsenic levels detected at the site. In such a case, symptoms characteristic of acute arsenic "poisoning" (e.g., facial swelling, nausea, vomiting, and diarrhea) might be possible. This only would happen if relatively large amounts of the most contaminated soil were ingested in a short amount of time. No documentation of this type of exposure has been identified at Spring Valley, so its consideration is purely hypothetical. Because the highest levels of soil arsenic in yards was removed during the time critical removal actions, the remaining concentrations should not be sufficient to lead to adverse health effects.

VIII. Conclusions

After evaluating environmental contamination data for the Spring Valley FUDS site, and how people might come into contact with that contamination, ATSDR has reached the following conclusions. (Refer to the Glossary [Appendix G] for definitions of the hazard categories that ATSDR uses in these conclusions.)

1. ATSDR evaluated arsenic levels in the soil around Spring Valley in relation to ways in which people could ingest or inhale them. ATSDR concludes that the expected levels of exposure would **not result in adverse health effects**. Because, however, incidental exposure could occur, ATSDR categorizes this pathway as a **No Apparent Public Health Hazard**. This evaluation is supported by exposure investigations in which ATSDR and DC DOH measured arsenic levels in hair and urine from community members residing on or near properties with the highest arsenic levels. Reported levels were below those known to be associated with arsenic-related adverse health effects. As a preventive measure, USACE continues to remove soils found to contain elevated arsenic levels as appropriate (arsenic concentrations greater than 20 ppm are removed unless a property owner requests that trees, patios, etc. not be disturbed; in those cases, an upper level of 43 ppm may remain).

2. ATSDR also evaluated levels of other contaminants (including chemical warfare agents, explosives, and other substances) detected in Spring Valley soil samples. Environmental information indicates that substances tested were not detected or were at levels that would not cause adverse health effects. Therefore, ATSDR categorizes the soil pathway with respect to these chemicals as a **No Apparent Public Health Hazard**. ATSDR acknowledges that only a subset of surface soil samples were analyzed for substances other than arsenic; however, the likelihood of the more toxic chemical warfare agent parent compounds being present or persisting in surface soil is low.

3. The USACE has identified and remediated burial pits containing chemicals and other materials, including chemical warfare agents. Although the USACE has a continuing program for locating and removing other buried materials and items in surface disposal areas, the possibility remains that some hazardous material could still pose a health hazard to the public if it is tampered with or disturbed. Because of the unknown nature of any possible remaining disposal areas, ATSDR considers them to be an **Indeterminate Public Health Hazard.**

4. ATSDR recognizes that past and possible remaining burials could serve as a potential source of groundwater and soil gas contamination. Although the extent of groundwater and soil gas contamination is not fully known, contaminants in these pathways are unlikely to pose an indoor air threat. Additional groundwater and soil gas sampling would help to more fully evaluate this potential exposure pathway. [Because nobody is using the groundwater beneath the site for drinking water or other household purposes, it poses no direct threat to public health. The planned USACE groundwater investigation will evaluate the nature and extent of any groundwater contamination and whether nearby drinking water supplies could be affected.]

5. The environmental and exposure data collected to date do not suggest that widespread adverse health effects would be occurring in the community. ATSDR's exposure investigations have not indicated any significant exposure to arsenic, one of the most persistent and widespread contaminants in Spring Valley. ATSDR evaluated the health conditions reported in March 2001 to the DC DOH as well as those conditions provided to us in February 2004 through The Northwest Current. We evaluated these conditions with respect to known associations with arsenic exposures, as well as to other chemical exposures. Some of the reported conditions do have a biologically plausible relationship to exposure to arsenic and other chemicals. Nevertheless, the arsenic and other chemical levels detected in surface soil in Spring Valley are not high enough to be the cause of these illnesses. In addition, the DC DOH completed an epidemiological study of cancers that could be arsenic-related. They did not find increased rates of these cancers in the community.

   If additional environmental sampling indicates a completed exposure pathway for contaminants with doses sufficient to cause adverse health effects, then ATSDR will consider recommending further investigations related to those contaminants. Although no widespread occurrence of contamination and exposure to contamination that would lead to leukemia or other adverse health effects has been found, ATSDR suggested follow-up on the leukemia rates based on the 1999 leukemia mortality rate reported for Ward 3, where Spring Valley is located.

IX. Recommendations

As detailed below, ATSDR recommends additional, but targeted, environmental sampling—most of which is already ongoing. ATSDR also recommends continued community activities as well as some health activities as discussed below.

Environmental Sampling

- *Surface Soil Sampling of Residential Yards.* Because some uncertainties remain about the presence and levels of non-arsenic contaminants in surface soil, ATSDR recommends that additional surface soil analyses be conducted for a limited number of residential properties—selected based on their potential for AUES contamination or health concerns. Specifically, ATSDR recommends surface soil analyses for AUES-related contaminants including explosives and their transformation products, chemical warfare agents and degradation products, and metals such as lead and mercury.

- *Soil Gas Sampling Near Burial Pits/Disposal Areas*. ATSDR recommends that soil gas samples be taken at disposal areas, preferably prior to excavation, to evaluate the potential for exposure by a soil gas migration pathway. This includes existing disposal areas such as the Glenbrook Road area where there are some AUES remnants in a burial pit (Pit 23) and in a surface disposal area at Lot 18, if still applicable. Soil gas sampling should also be considered for any additional burial pits or other disposal areas that are found. The existing suite of AUES chemicals and VOCs should be considered. Collected data would provide additional insights to currently available indoor air and sub-slab soil gas data, and the potential need for additional indoor air sampling.

- *Groundwater Monitoring Near Burial Pits/Disposal Areas.* ATSDR recommends that USACE continue with its plan to conduct groundwater sampling, particularly in the area of the burials. This sampling will provide data regarding the possible nature and extent, if any, of groundwater contamination near burial pits and other disposal areas and should target site-related contaminants and their degradation products that are mobile and could persist in groundwater. Although there are no known private wells in the area used for drinking water, the data collected can be used to determine whether groundwater contains any contaminants that could be reaching people (e.g., through releases to soil or air).

Community Activities

- ATSDR concurs with the USACE activities to continue pursuing the identification and rapid removal of any remaining burial pits or surface disposal areas and recommends that existing practices continue. Because of such remaining areas and the potential for others to be discovered in the Spring Valley area, residents should call USACE at 410-962-0157 or 202-360-3762, if they find any suspicious objects. Community members should not collect or otherwise handle glassware or other objects. Instead, they should await USACE response. In addition, community members should remove any such items currently stored in their homes and are encouraged not to bring such items into their homes in the future.

- If community members want to further reduce their exposure to soils potentially containing hazardous substances, they are encouraged to follow the precautionary measures outlined in ATSDR's interim guide *Safe Gardening, Safe Play, and a Safe Home*, which is provided in Appendix F of this health consultation.

- Residents are encouraged to report illnesses that they believe may be site-related to their physicians. A healthcare provider's page has been placed on ATSDR's Spring Valley Web site to assist physicians in their diagnoses of patients.

Health Activities

- After review of the initial finding that the 1999 leukemia mortality rate for Ward 3, where Spring Valley is located, is more than twice as high as the mortality rate for DC and nearly twice that of the national leukemia mortality rate, ATSDR suggested that the District of Columbia Department of Health could evaluate the incidence and mortality rates for leukemia by census tract, and compare them with an area of similar demographics to determine any excess rates of disease. The DC DOH evaluated the incidence of leukemia in Potomac, Maryland and determined it was higher than Spring Valley. No widespread occurrence of contamination and exposure to contamination that would lead to leukemia or other adverse health effects has been found. Even so, the DC DOH is working on a health study.

- If additional environmental sampling indicates a completed exposure pathway for contaminants with doses sufficient to cause adverse health effects, then ATSDR will recommend investigations related to those contaminants.

X. Public Health Action Plan

Completed ATSDR Actions

1. Approximately every 6 months a Spring Valley Newsletter outlining ATSDR activities and information was developed and produced.

2. A site-specific Spring Valley Web site was developed and can be accessed at http://www.atsdr.cdc.gov/sites/springvalley. The Web site contains past ATSDR documents and other relevant materials and information.

3. A repository of ATSDR documents was established at the Palisades Public Library in Spring Valley. The repository contains ATSDR's past documents produced for Spring Valley/American University as well as information on contaminants of concern.

4. In collaboration with the DC DOH, ATSDR completed three exposure investigations in the Spring Valley community.

5. Some recommendations for prevention of soil-arsenic exposure were provided to residents in ATSDR's interim guide *Safe Gardening, Safe Play, and a Safe Home*. Residents are encouraged to follow these precautionary measures.

6. ATSDR completed several specific requests from members of the Spring Valley Partnering Meeting group for evaluation of private properties. We provided a health consultation on Rockwood Parkway that evaluated indoor air. We also evaluated the CDC post remedial report results and indoor air and other samples taken at a Sedgwick Street residence.

7. ATSDR developed a site-specific fact sheet on arsenic for distribution to area residents.

Planned ATSDR Actions

1. Through the Mid-Atlantic Pediatric Environmental Health Specialty Units (PEHSU) located in D.C, ATSDR will provide medical consultative services to physicians with Spring Valley patients. Local residents with health concerns can have their physician contact the PEHSU with specific environmental health-related questions. The summer 2002 ATSDR Spring Valley Newsletter listed local PEHSU clinic contacts.

2. ATSDR will continue contact with the DC DOH and the community to provide public health input as needed. We will review additional environmental or health data as they become available. If new data alter our conclusions and recommendations, ATSDR will revise this health consultation.

3. A healthcare provider's Web page has been developed and placed on ATSDR's Spring Valley Web site to assist physicians in their diagnoses of patients. Residents could assist by providing the Web site address to their physicians. DCDOH could assist by providing this information to physicians caring for Spring Valley patients.

Actions Completed by DC DOH and USACE

1. DC DOH assisted ATSDR with the exposure investigations related to the Spring Valley site.

2. Following a recommendation by the Mayor's Scientific Advisory Panel, the DC DOH contacted over 200 physicians in the D.C. area and Montgomery County, Maryland, who serve Spring Valley residents and asked them to report any health problems possibly associated with arsenic exposures. The DC DOH received several reports.

3. DC DOH completed an epidemiological study of cancers that could be arsenic-related. They did not find increased rates of these cancers in the community.

4. Following an ATSDR recommendation to follow-up on leukemia, the DC DOH found the incidence of leukemia in Potomac, Maryland was higher than Spring Valley.

5. USACE has completed most of their area-wide soil sampling and has begun removal of residential soils containing arsenic concentrations above the established clean-up goal of 20 ppm for Spring Valley.

6. USACE completed removal of three burial pits. Removal of the last known burial pit and surface disposal area in Spring Valley are pending completion.

7. USACE completed indoor air sampling at a Sedgwick Street property.

8. USACE conducted several specialty investigations, analyzing about 206 compounds (those believed to have been used or tested at AUES). These investigations were conducted at four selected private properties, at four properties on Sedgwick Street on the former trench area, and at the American University's CDC and Lot 12.

9. Using a closed unit called an Explosives Destruction System, USACE destroyed chemical munitions found in the Spring Valley burial pits.

10. USACE has developed and provided residents with fact sheets on what objects are suspected of being from WWI and related to the AUES wastes. The fact sheets also provide information about where to call if suspicious items are found.

11. USACE sampled soil gas at two Rockwood Parkway residences in March 2004.

Planned Actions by DC DOH and USACE

1. Although no widespread occurrence of contamination and exposure to contamination that would lead to illness or disease has been found, the DC DOH is working on a health study.

2. USACE plans to continue soil removals in the Spring Valley community as well as to conduct additional environmental sampling and geophysical surveys to identify any remaining buried hazardous materials. Further soil removal at 4825 and 4835 Glenbrook

Road is planned over the next several years. Soil gas sampling is planned for 4825 Glenbrook Road in 2006. American University Lot18 removals are continuing, with completion anticipated in 2006. The USACE plans to have arsenic soil remediation completed on all residential properties by September 2008 and on the federal property in 2009.

3. USACE in collaboration with their partners is also conducting groundwater monitoring for contaminants in the Spring Valley area with results anticipated in September 2005.

4. In 2005, a range fan, linked with firing chemical rounds, was identified. The munitions were launched from the Spalding/Captain Rankin Area near American University toward the present-day Dalecarlia Parkway area. The USACE and their partners are determining if further investigations are needed for properties falling within the projected range fan.

XI. Preparers of Report

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Figures

Figure 1. Demographics and Statistics Map

Figure 2. Points of Interest and DC DOH Hotline Results

Figure 3. Graph of Arsenic Composite Results Prior to Soil Removals

Figure 4. Arsenic in Surface Soil Prior to Removals

Appendices: A-G

Appendix A. Abstracts of ATSDR Documents for the American University/ Spring Valley Site, Washington, D.C.

The complete documents, abstracted in this section, can be found at the Palisades Library in Spring Valley or on ATSDR's Spring Valley Web site at www.atsdr.cdc.gov/sites/springvalley.

Health Consultation, Evaluation of Indoor Air Sampling, 4625 Rockwood Parkway, American University Experiment Station/Spring Valley, Washington, D.C.

December 2003

The U.S. Environmental Protection Agency (EPA) asked the Agency for Toxic Substances and Disease Registry (ATSDR) to review indoor air and soil gas sampling data to determine if exposure to chemical substances detected in indoor air posed an immediate or long-term health hazard to residents occupying a home at 4625 Rockwood Parkway, Spring Valley. EPA asked ATSDR to recommend actions necessary to protect the health of building occupants. The house was occupied at the time of sampling, but vacated at the time ATSDR received the data. The building occupants lived in the house for less than 1 year. They reportedly found laboratory glassware and other debris on the property and believed that it came from former AUES activities. The property is in an area adjacent to a debris field on American University Lot 18 and has the potential to be leased to another tenant. In June 2003, W. L. Gore and Associates, Inc. performed soil gas and indoor air sampling at the property. From a review and evaluation of the indoor air sampling data and available toxicological and medical information relevant to the substances of interest, ATSDR concludes that the presence of low levels of volatile and semivolatile substances in indoor air at 4625 Rockwood Parkway poses no apparent public health hazard to adult or child occupants. However, past detection of elevated carbon monoxide concentrations in the home indicate that carbon monoxide levels were elevated and may have contributed to reported health symptoms. ATSDR recommended that confirmatory sampling be conducted and that carbon monoxide levels be within a safe level prior to leasing.

Health Consultation, Exposure Investigation of Summer 2002 (Phase II), Arsenic Biomonitoring, Spring Valley Neighborhood

February 2003

Due to requests (from the Scientific Advisory Panel and others) to sample residents during summer months when the potential for exposure to soil arsenic should be higher, ATSDR and DC DOH conducted the Summer 2002 Exposure Investigation. Testing was offered to those individuals who participated in the March 2002 Exposure Investigation, individuals who were living on, or adjacent to, property which was being remediated, and individuals whose yards had the highest grid samples. Urine samples were collected from July to November 2002. Urine arsenic levels were tested in 40 individuals, 34 adults and 6 children. Three individuals had mild elevations (> 10 but <30 ug/L) of inorganic arsenic in their urine. Most participants (92%) had urine arsenic values less than 10 ug/L, indicating no significant exposures. Health effects are not expected in the adults with the mild elevations of urinary arsenic.

Health Consultation, Exposure Investigation of March 2002 (Phase I), Arsenic Biomonitoring, Spring Valley Neighborhood

June 28, 2002

In 2001, the DC DOH requested that additional biomonitoring be conducted in Spring Valley.

As a response to their request, ATSDR conducted an exposure investigation in March 2002 which included sampling hair, urine, and dust in homes. Participants were those individuals with yards having the highest composite soil samples of arsenic. A total of 32 individuals were tested; 23 adults and 9 children. Three individuals had levels of inorganic arsenic exceeding 10 ug/l.

Health Consultation, The Public Health Significance of Arsenic in Soil at the American University Child Development Center

March 14, 2001

The Army requested ATSDR to review new environmental sampling data from the American University Child Development Center (CDC) playground, to determine whether there is an increased risk of adverse health effects for the children and staff who worked and played at the CDC. The Army took 67 surface soil samples from the playground of the CDC, and analyzed them for arsenic. The average arsenic concentration in the samples was slightly less than 60 ppm, and the maximum was 498 ppm. ATSDR concluded that children and staff at the Child Development Center should not experience any adverse health effects from previous exposure to arsenic in soils at the playground. ATSDR concurred with the Army that the soil arsenic levels in the affected areas of the CDC playground be reduced to normal background levels.

Exposure Investigation, Spring Valley (a/k/a American University Child Development Center)

March 8, 2001

The Army reported that elevated concentrations of arsenic were detected in surface soil samples collected from some locations in the playground at the Child Development Center (CDC) at the American University in Washington, D.C. Parents of the children who attended the CDC expressed concern that their children may have been exposed to this contamination. In response to this concern, ATSDR collected hair samples from children who were attending the CDC and adult staff at the CDC and tested the samples for arsenic. Hair arsenic concentrations were not elevated in the 28 children and 4 adults who participated in this exposure investigation.

Health Consultation, Assessment of Soil Sampling Results at the American University Child Development Center

December 14, 2000

The Army Corps of Engineers requested that ATSDR review the environmental sampling data from the daycare playground, to determine whether there is an increased risk of adverse health effects to the children, their families, and the teachers. The Army sampled six areas within the

playground, and mixed all six into a single soil sample. This sample was analyzed, and found to contain 31 ppm arsenic. We concluded that children attending the daycare, their families, and teachers, should not experience any adverse health effects from exposure to arsenic in soils at the level found by the Army. Nevertheless, should children eat large amounts of soils (a handful a day), they could experience gastrointestinal distress. Also, if this behavior continues over a period of a few weeks, children could begin developing pigmentation changes on their palms and the soles of their feet. ATSDR concurred with the Army's plan for additional sampling of the play area over 20 foot grids.

Health Consultation, Assessment of Arsenic in Creek Sediment at Four Residences in Spring Valley

March 2, 2000

EPA Region III requested that the Agency for Toxic Substances and Disease Registry (ATSDR) evaluate the public health significance of arsenic in creek sediments. Four sediment samples were taken from four residences on Glenbrook Road, near American University. The levels of arsenic in these samples were 4.0, 9.5, 9.6, and 9.7 ppm. We considered that children have ready access to the creek, and that a child might play in this creek every day. For this exposure scenario, ATSDR has derived a health protective comparison value for arsenic of 20 ppm. For arsenic, this level is based upon epidemiological studies of humans, including children, who were inadvertently exposed to arsenic. No adverse health effects were observed in these people at a dose which is higher than would occur from the creek sediments at this site. For this reason, no adverse health effects are expected to result from this exposure.

Technical Assistance to the District of Columbia Department of Health, Potential Contaminants in Soils at American University

January 8, 1998

The Agency for Toxic Substances and Disease Registry (ATSDR) was requested to consider whether suspected chemical warfare agents, laboratory reagents, and associated degradation products in soils at the American University in Washington, DC, could pose a concern to public health. This question came about because many of these substances were not on the target compound list for the soil sampling analysis. After discussing the list of potential contaminants supplied by the DC government with the Army Corps of Engineer's contractor, Parsons Engineering, ATSDR was assured that the majority of substances in the list would have been tentatively identified during the sample analysis, since they were included in the reference library for the gas chromatograph/mass spectrograph during analysis. Contamination by other substances or their degradation products would have been observed as increased levels of inorganic substances, particularly arsenic. Remaining substances are chemical warfare agents, which are volatile and reactive in nature, making it unlikely that any of these substances would remain to contaminate soils in the area. ATSDR concluded that the potential for these substances to contaminate soils at the American University has been appropriately addressed during the analyses of soil samples.

Health Consultation, Assessment of Soil Sampling Results at the American University

August 26, 1997

The District of Columbia Public Health Commissioner requested ATSDR to review the EPA environmental data, to determine whether there is an increased risk of adverse health effects at the American University and vicinity. Several areas were sampled by the Army from December, 1993 through March, 1994. These areas are suspected to have been used as shell pits, storage areas, and testing fields and trenches. These samples were analyzed by the Army for chemical warfare agents and degradation products: mustard gas, oxathiane, dithiane, lewisite, and thiodiglycol. In addition, the samples were analyzed for explosives and metals. No chemical agents, degradation products, or explosives were detected. The same (split) samples were analyzed by the EPA for metals, volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), pesticides, and metals. With the exception of one sample, the only substances which exceeded ATSDR comparison values are antimony, arsenic and manganese. This sampling information from the Army and the EPA do not indicate that adverse health effects might occur as a result of exposure to these soils. Still, arsenic was elevated above background in a few locations.

Chemical and conventional ordnance may remain buried at the American University or in the vicinity. In addition, laboratory or storage vessels may also be buried in these areas. These discarded weapons and glassware may hold explosives or noxious agents, and could pose serious health threats if they are unearthed.

Health Consultation, Spring Valley/ American University Experiment Station

June 3, 1997

This health consultation was sent to the D.C. Public Health Commissioner. It is a review of Remedial Investigations and other environmental reports for the American University Experiment Station (AUES) Formerly Used Defense Site. The purpose was to identify public health hazards resulting from chemical warfare research activities conducted at the site during World War I and recommend initial public health activities to mitigate or prevent human exposure to hazardous substances released into the environment from the site. Although previous remedial investigations have concluded that the AUES site poses no further public health hazards and that no additional actions are recommended, the subsequent unexpected encounter with hazardous substances by landscapers at the Presidents residence and evidence of open air dispersion testing mentioned in the Operation Safe Removal RI indicate that the full range of potential hazards posed by releases of hazardous substances from the site may not yet have been identified and addressed. We recommended a focused health education program to inform residents, construction workers, emergency responders and health care providers about potential hazards related to the site, and to prepare them to respond to unexpected encounters with residual ordnance and contaminants. Other specific recommendations are also provided.

Appendix B. Environmental Fate of Chemicals Associated with the Spring Valley Formerly Utilized Defense Site

ATSDR also considered the fate and transport of potential contaminants in Spring Valley. Unless containerized or trapped, most chemicals used at American University Experiment Station (AUES), including warfare agents, are not persistent, especially after 80 years of being in the environment. However, breakdown products of organoarsenicals, such as lewisite and adamsite, can leave residual arsenic in soil. Some residual metals remain in soil as well. Additionally, explosives can be environmentally persistent but explosives have not been found in tested Spring Valley soils. The chemicals presented in this section have been selected based on detections in Spring Valley soils and an association with past AUES activities.

Generally, only chemicals with low vapor pressures (i.e., that tend not to volatilize), low water solubility (i.e., that tend not to dissolve well in water), and low rates of natural degradation are likely to persist in the environment. The main degradation processes include

- Photolysis—decomposition by the action of radiant energy,
- Hydrolysis—decomposition of a substance by reaction with the elements of water to form one or more new substances,
- Oxidation—oxygen combining with other elements, and
- Microbial degradation—the process of decomposition by microbes (tiny plants and animals).

Persistence in soils also depends on the form of the chemical (solids including crystalline forms, liquids, etc.), soil composition (organic matter content, cation exchange capacity, etc.), and environmental conditions (temperature, pH, etc.). These properties also influence the likelihood of chemicals moving from one environmental medium to another. Volatilization can be an important mechanism for the transfer of some chemical warfare agents from soil and water to air (Munro et al. 1999).

The specific properties of persistent chemicals or breakdown products of those chemicals associated with past AUES activities are described in the following sections. Toxicity of these chemicals and breakdown products is discussed in Appendix E.

Arsenic from Lewisite

Lewisite (Agent L), classified as an organic arsenical, is a complex mixture of several compounds, with dichloro(2-chlorovinyl)arsine predominating. Other compounds and impurities include bis(2-chlorovinyl)chloroarsine, tris(2-chlorovinyl)arsine, and arsenic trichloride. Lewisite (L) is considered nonvolatile, although with a vapor pressure of 0.58 mmHg at 25^{o}C, it is more volatile than sulfur mustard agent (Munro et al. 1999; ORNL 1997).

Lewisite is easily broken down in soil via hydrolysis. As such, its persistence is considered "intermediate" (i.e., it can persist for days, as opposed to hours or years) (USACHPPM 1999). Depending on the moisture content, it produces two hydrolysis products, 2-chlorovinyl arsonous acid or chlorovinylarsenious acid (CVAA) and lewisite oxide (chlorovinyl arsenous oxide or CVAO). Although lewisite is basically insoluble in water, its breakdown products, CVAA and CVAO, are soluble. Lewisite oxide can be converted (oxidized) to 2-chlorovinyl arsonic acid. The trivalent arsenic (As^{3+}) in lewisite oxide is generally oxidized to pentavalent arsenic (As^{5+}) (Munro et al. 1999). Generally, As^{5+} is more stable and more commonly found in the environment (Winski and Carter 1998).

Regardless of the degradation pathway, arsenical compounds will ultimately be formed. Depending on environmental conditions, various inorganic arsenic compounds can be formed in the course of complete lewisite mineralization as demonstrated by the presence of inorganic arsenic compounds in areas of past lewisite releases, such as Spring Valley. Some inorganic arsenic can be lost to the atmosphere via volatilization as a result of the production of methylarsines (ATSDR 2000; Kohler et al. 2001; Munro et al. 1999).

Other Potential Sources of Arsenic

Other potential sources of arsenic include liquid arsine and arsenic-containing compounds such as: arsenic trifluoride; arsenic trichloride; arsenic trioxide; acetylene-arsenic trichloride; dimethylarsine, methyl dichlorarsine; ethyl dichloroarsine; diphenylcyanoarsine; phenyldichloroarsine; sodium arsenite; and aluminum, calcium, magnesium, and zinc arsenides (Parsons 1998; Smart 1993).

Arsenic from Adamsite

Adamsite (Agent DM) is the trade name for another organic arsenical, known as 10-chloro-9-10-dihydrophenarsazine, diphenylarsenious acid, or diphenylamine chloroarsine. It was first produced during World War I, but determined not to be toxic enough for the battlefield (USACHPPM 1998). Not being readily soluble or volatile, it is considered relatively persistent in the environment. Adamsite degradation products can leave residual arsenic in soil. Although it is basically insoluble in water, it can persist in water by forming an insoluble film.

Sulfur Mustard

Sulfur mustard[6] has been used in chemical warfare as early as World War I and as late as the Iran-Iraq War in 1980–1988. It has not been produced in the United States since 1968 (ATSDR 2001). The active ingredient in sulfur mustard is bis(2-chlorethyl)sulfide. Unlike other chemical warfare agents, sulfur mustard is considered to be somewhat persistent (can last for months under very cold conditions and can persist for years in bulk quantities or if trapped or containerized) (Munro et al. 1999). In military testing areas and land dumps, where large or bulk quantities of sulfur mustard had been deposited, persistence for weeks to decades has been reported (Munro et al. 1999).

Little information exists regarding the specific fate of sulfur mustard in soil, although it is considered relatively stable. Volatilization would be the main route of sulfur mustard loss expected in dry surface soil. Bulk quantities of sulfur mustard spilled or splashed on soils could persist for years depending on soil and weather conditions. Generally, sulfur mustard persists longer under cold wet conditions (Watson and Griffin 1992).

The primary fate of buried sulfur mustard is hydrolysis, leading to the production of thiodiglycol and hydrochloric acid. Thiodiglycol is the most persistent of the sulfur mustard degradation products. Thiodiglycol is not a unique degradation product of sulfur mustard degradation—it has been used as a solvent in antifreeze solutions, in dyestuffs for printing, and in the production of polyvinyl chloride (Munro et al. 1999). Other degradation products include 1,4-dithiane and 1,4-oxathiane; these are considered thermal degradation and dehydrohalogenation products, respectively. Sulfur mustard is not normally found in groundwater because of its low solubility and rapid hydrolysis when dissolved. However, its hydrolysis product, thiodiglycol, has been reported to leach into groundwater or surface water. In addition, 1,4-dithiane and 1,4-oxathiane have been reported in groundwater beneath other chemical warfare agent burial sites. Dithiane can be transported from surface soil and water to air, where it readily *photo*oxidizes to sulfoxides and sulfones (Munro et al. 1999).

In the presence of insufficient water to dissolve sulfur mustard (e.g., bulk mustard), sulfonium ion aggregates (mustard and hemimustard-thiodiglycol aggregates) can be formed. The H-thiodiglycol (undistilled mustard-thiodigylcol) aggregate has considerable toxicity when applied dermally (Munro et al. 1999). Theoretically, oxidation products can be formed, including mustard sulfoxide, mustard sulfone, and divinyl sulfone (ATSDR 2003, Munro et al. 1999; Watson and Griffin 1992). Again, hydrolysis is the primary degradation pathway for sulfur mustard, especially in the relatively moist soil in the Spring Valley area.

Sulfur mustard can also contain a variety of impurities or by-products formed during manufacturing as well as stabilizers and starters. Sulfur mustard can form metal complexes with the metal in the containers in which it is stored (e.g., with iron) or with metal sulfides present in the soil (Munro et al. 1999).

Trinitrotoluene (TNT) and Dinitrotoluene (DNT)

[6] Sulfur mustard is also referred to as "mustard gas," but the term can be a little misleading because it is stored as a liquid and is not likely to change into a gas at ordinary temperatures.

2,4,6-Trinitrotoluene (TNT) and dinitrotoluene (DNT), which were detected at trace amounts (0.1 parts per million (ppm)) in only a few soil samples (less than 7%) are composed of a mixture of nitric and sulfuric acid. TNT and DNT are water soluble and do not tend to bind or sorb strongly with soil, increasing the likelihood that these substances would be carried from soil to groundwater. The estimated half-life of TNT in soil ranges from 1 to 6 months. But it could persist for decades in a crystalline form or in bulk quantities. DNT tends not to stay in the environment for a long time because it is broken down by sunlight and bacteria into substances such as carbon dioxide, water, and nitric acid. However, little information is available regarding the specific behavior of DNT in soil (ATSDR 1995, 1998).

DNT comes in several forms, including 2,4-dinitrotoluene and 2,6-dinitrotoluene.

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Appendix C. DC DOH Hotline Summary of Health Conditions

The District of Columbia Department of Health set up a Health Hotline in March 2001, for Spring Valley community members to report concerns and health problems. The following is a summary of health conditions that were reported to the Hotline:

Cancers

- Bone marrow
- Bone non-specific
- Brain
- Breast
- Fibro sarcoma
- Leukemia
- Lung **-**
- Skin **-**
- Prostate/Testicular
- Lymphoma
- Multiple myeloma
- Prostate
- Testicular

Blood and Bone Marrow Disorders

- Aplastic anemia
- Blood disorder, non-specific **-**
- Lymphoma/Hodgkins lymphoma
- Multiple myeloma
- Myelofibrosis
- Pernicious anemia

General

- Asthma
- Allergies
- Benign liver growth
- Bone condition **?**
- Chronic fatigue **?**
- Chronic infections
- Chronic auto-immune disease **?**
- Hair loss
- Lupus
- Neuropathy **-**
- Parkinson=s disease
- Skin rashes **?**

Birth Defects

- Hydrocephalus
- Club feet

√ Disease known to be associated with arsenic exposures, but also associated with many other causes as well.

? Disease that could have a possible arsenic relation, but are associated with many other causes as well.

Appendix D. Descriptions of Reported Diseases and Health Conditions

This appendix describes the general characteristics of the *blood-related disorders* of reported concern in the Spring Valley neighborhood, as well as a general overview of *peripheral neuropathy* (final sections of Appendix D).

The primary purpose of this appendix is to help the reader understand the complexity of the systems in the body related to blood and the many factors that can lead to changes in and dysfunction of these systems. For example, many of the conditions reported by Spring Valley residents (e.g., anemia) come in many forms and may be non-specific in their etiology (i.e., they may be caused by multiple factors).

An overview of the general biology of the blood (hematological), blood-forming (hematopoietic), and lymphatic systems is presented first to provide some context for subsequent discussions. Next, a brief description of the specific blood-related disorders reported by Spring Valley residents is presented. Although not a blood-related disorder, peripheral neuropathy has been included in these discussions because of its association with arsenic ingestion. The known causes or risk factors, symptoms, incidence (i.e., the number of new cases diagnosed during a predetermined time period), prevalence (i.e., the total number of cases that are present in a given time period), and typical age of onset are detailed where possible. It is very important to understand the complexity of these disorders and the uncertainties regarding their cause(s) as one begins to evaluate the possible role of particular chemical substances in their development. Such data provide added perspective on the extent to which the described diseases or conditions might or might not be ordinarily expected to occur in a given population.

General Biology of the Blood and Lymphatic Systems

The human blood and lymphatic systems are complex systems responsible for specific and multiple functions that help maintain our bodies. Blood carries oxygen to our tissues from our lungs and carries carbon dioxide from our tissues to our lungs. Blood also carries nutrients from the food we eat to our tissues, transports waste products generated in our bodies, and helps fight disease. The lymphatic system is closely linked with the blood system. It is a drainage and filtration system that helps remove excess fluids and filters out disease-causing agents from the body. Scientists continue to study how these systems work and factors that can disrupt the normal functioning of these systems.

Blood and Bone Marrow

Whole blood consists of three primary types of cells: red corpuscles (erythrocytes), white corpuscles (leukocytes), and platelets (thrombocytes). The main function of the red blood cells is to transport oxygen to all parts of the body. The primary function of white blood cells is to protect and help the body heal wounds and fight against infection and harmful agents. A deficiency in red blood cells, that carry oxygen from the lungs to all parts of the body, results in oxygen deficits and fatigue. A shortage of white blood cells challenges your ability to fight infections and a shortage of platelets makes clotting of the blood more difficult. Several types of white blood cells exist, including lymphocytes, monocytes, eosinophils, and basophils, each with

a specific function in fighting infection. Platelets are needed for normal blood clotting. Increases and decreases in the number and quality of our blood cells can be a sign of disease; physicians therefore study the number and condition of our blood cells as a diagnostic tool.

Throughout life, blood cells are continuously being replaced. The average life span of a red cell, for example, is 120 days (Brobeck 1979). A healthy person produces about 1 million red blood cells and about 200,000 white blood cells every second of their life (Rich 2002). "Stem cells" or hemoatopoietic cells are the precursor cells that produce blood cells. This occurs in the bone marrow—the soft, spongy part of the bone. Inability of marrow to produce hematopoietic cells is a common feature of many hematologic diseases (Young 1994).

Bone marrow dysfunction can lead to various blood-related disorders (e.g., anemia, leukopenia [i.e., abnormally low number of white blood cells]). Factors that can injure bone marrow include:

- High-dose radiation and chemotherapy treatments
- Exposure to toxic chemicals such as hair dyes, benzene, herbicides, insecticides
- Use of certain drugs (e.g., those used to treat rheumatoid arthritis)
- Autoimmune disorders (e.g., lupus)
- Viral infection
- Pregnancy (on occasion)
- Bone marrow diseases (e.g., leukemia)

In general, however, it is important to remember that the extent to which chemical exposures could or could not result in illness is related to the amount and duration of exposure. This concept is addressed in Section IV of this report (Toxicological Assessment).

Lymphatic System

The lymphatic system is an extensive drainage system that returns water and proteins from various tissues back to the bloodstream. It consists of a network of ducts, called lymph vessels or lymphatics, and carries lymph, a clear, watery fluid that resembles the plasma of blood. If there were no way for excess fluid to return to the blood, our body tissues would become swollen. The lymph vessels collect that excess fluid and carry it to the veins through the lymphatic system.

The lymphatic system also acts as a filter and helps defend the body against invasion by disease-causing agents such as viruses or bacteria. Harmful foreign materials are filtered out by small masses of tissue called lymph nodes that lie along the network of lymphatic vessels. Because the lymphatic system extends throughout most of the body, disorders or diseases of the lymphatic system may affect multiple organ systems. The spleen, also considered part of the lymphatic system, filters the blood similar to the way lymph nodes serve as a major filter for the lymph (Amdur et al. 1991; Brobeck 1979).

Diseases of the Blood and Bone Marrow

Anemia

Anemia is the general name for the condition characterized by a decreased number of red blood cells and a decreased amount of hemoglobin (the substance in red blood cells which transports oxygen). Causes may include nutritional deficiencies, an underlying disease, or exposure to certain chemical agents (e.g, anti-cancer drugs, benzene, ionizing radiation) (A.D.A.M., Inc., 2001a; NCHS 2002).

A description of the specific types of anemia reported by Spring Valley residents follows:

Hemolytic Anemia

Hemolytic anemia occurs when red blood cells are being destroyed prematurely and the bone marrow simply cannot keep up with the demand for new cells. Hemolytic anemia can occur for many reasons, including heat stroke, parasites, viral infections, bacteriological and chemical toxins, and other non-specific conditions. Hemolytic anemia is typically classified by the location of the defect (i.e., intrinsic or extrinsic). Intrinsic hemolytic anemia involves the destruction of the red blood cells due to a defect within the red blood cells themselves. Intrinsic hemolytic anemias are often inherited, such as sickle cell anemia and thalassemia (thalassemia occurs as a result of a genetically determined defect in hemoglobin synthesis). These conditions produce abnormal red blood cells that do not live as long as normal red blood cells. Extrinsic hemolytic anemia (also referred to as autoimmune hemolytic anemia) occurs when healthy red blood cells are destroyed by becoming trapped in the spleen, destroyed by infection, or destroyed from drugs that can affect red blood cells (University of Maryland Medical System 2001a). The overall incidence of all types of hemolytic anemia in the United States is reported to be around 4 cases in 100,000 people.

How common is anemia?

The National Center for Health Statistics (NCHS) has collected national data on the prevalence of anemia in the United States. According to NCHS, approximately 3.4 million Americans have anemia. Over 2 million of these cases affect Americans under age 45. Anemia is far more prevalent among women than among men and more people in the southern portion of the United States have reported anemia than in any other region (based on 1996 statistics) (A.D.A.M., Inc., 2001a; NCHS 2002).

Aplastic Anemia

Aplastic anemia is a rare and serious bone marrow disorder. This form of anemia occurs when the bone marrow is unable to produce sufficient numbers of blood cells. The aplastic patient typically exhibits pancytopenia (a deficiency of all three major blood cells: red blood cells, white blood cells, and platelets) with bone marrow hypoplasia (or “empty” bone marrow) (NLM 2001; Foucar 1995; Young 1994, 1997).

Aplastic anemia can be inherited or acquired. Inherited or congenital aplastic anemia is a genetic disorder characterized by chronic bone marrow failure along with various congenital anomalies (physical abnormalities present at birth) (Young 1994). Acquired (also referred to as secondary) aplastic anemia refers to bone marrow failure which appears to be triggered by certain

environmental factors and physical conditions. The majority of cases of aplastic anemia, however, are of unknown cause.

Based on clinical reports and epidemiologic studies, drug or chemical exposures are the most frequently cited cause for aplastic anemia. An international study of aplastic anemia published in 1991, however, found that only about 25% of cases overall had a likely drug etiology (Kaufman et al. 1991 and 1997). The major drug associations were with gold salts and anti-thyroid drugs. Even in cases where the association is strong, the estimated risk of aplastic anemia remains extremely small relative to the use of the drug (Young 1994).

Several chemicals have been associated with aplastic anemia, with some more strongly linked than others. For example, a definitive association has been established between benzene and aplastic anemia, based on clinical and epidemiologic data, as well as animal and in vitro studies (Al Khouri and Ericson 1999). Researchers continue to examine benzene-exposed workers, however, to better understand the strength of the link between low-level benzene exposures and aplastic anemia (Hayes et al. 2000; Yin et al. 1996). Certain types of explosives, most notably trinitrotoluene (TNT), have also been linked to aplastic anemia. Numerous cases of aplastic anemia were observed in production workers during World War I as a result of inhalation and skin contact with TNT, but the levels and duration of exposure were not well documented for these workers (DOE 1998; ATSDR 1995). More recent occupational studies and animal studies suggest that blood effects, not necessarily aplastic anemia, represent a major sign of TNT toxicity (DOE 1998; ATSDR 1995). Documented effect levels, however, are more than 1 million times higher than estimated exposure doses at the Spring Valley site. As discussed in Appendix E, Toxicologic Assessment Methodology, TNT levels in Spring Valley soils would result in estimated exposure doses of approximately one million times lower than levels at which no effects were observed.

While research has shown that arsenic is associated with a variety of blood-related disorders (see Section V of the main text), no study data were identified that show a direct relationship between arsenic and aplastic anemia. Inorganic arsenic suppresses the hematopoietic system which may result in hypoplastic anemia (a low red blood cell count that results from the underproduction of red blood cells by the bone marrow). In severe cases of arsenic poisoning, agranulocytosis (characterized by a significant decrease in the number of a certain type of white blood cells referred to as neutrophils) may develop. However, most of the chemical agents that appear to contribute to the development of agranulocytosis are not linked to the development of aplastic anemia (Young 1994; WHO 2000).

Some infectious agents (especially those causing viral hepatitis, as well as Epstein-Barr virus and HIV, the virus which can cause AIDS) are also associated with aplastic anemia. The link between hepatitis and Epstein-Barr virus is relatively well established, however, associations with other viruses such as HIV are less clear (Young 1994, Al Khouri and Ericson 1999).

Aplastic anemia affects approximately 2 to 6 in 1,000,000 people in the United States; approximately 500 to 1,000 new cases are reported each year. It affects males and females in equal numbers (Bakhshi et al. 2002). Incidence rates have been shown to vary depending on study location, gender, and age group. For example, the incidence of aplastic anemia in metropolitan Baltimore, Maryland, was reported to be as high as 7.1 per million among males

and 5.4 per million among females between 1970 and 1978 (Szklo et al. 1985). A large difference in incidence rates has been observed among different age groups. Specifically, the incidence rate for individuals less than 60 years old has been observed to be approximately three cases per million compared with an incidence of 26 cases per million among those 60 years or greater (Bakhshi et al. 2002; Rawson et al. 1998). Acquired aplastic anemia affects children slightly less frequently than adults. However, children may also develop the disease from the less frequent inherited causes of bone marrow failure. In the United States and Europe, most cases occur in either the 15–24 year age group, or in the older than 60 age group (Bakhshi et al. 2002).

Pernicious Anemia (Commonly Referred to as Megaloblastic Anemia)

Pernicious anemia is a rare disorder in which the body does not absorb enough vitamin B12 from the digestive tract, resulting in an inadequate amount of red blood cells being produced (Conrad 2002; University of Maryland Medical System 2001b). Pernicious anemia may be associated with Type 1 diabetes, thyroid disease, and a family history of the disease. Other causes may include leukemia, myelofibrosis, multiple myeloma, certain hereditary disorders, chemotherapeutic agents, and excessive alcohol consumption. It is a disorder in which the incidence typically increases with age. Its frequency of occurrence has been estimated at about 0.1% of the population (Conrad 2002).

Pernicious anemia is more common in individuals of northern European descent and in the elderly. The adult form of pernicious anemia is most prevalent among individuals of either Celtic (i.e., English, Irish, Scottish) or Scandinavian origin. In these groups, 10 to 20 cases per 100,000 people occur per year (Conrad 2002). Pernicious anemia is reported less commonly in people of other racial backgrounds. Pernicious anemia from B12 deficiency tends to be an inherited tendency and is commonly seen in those over 60 years old. Researchers involved in a study done in California in 1996 used their results to estimate that as many as 800,000 elderly people in the United States have undiagnosed and untreated pernicious anemia (Carmel 1996).

Leukemia

Leukemia is a cancer that originates in the bone marrow. It is characterized by the uncontrolled growth of developing marrow cells. Leukemia actually consists of a group of different cancers of white blood cells. Leukemias are typically categorized based on their cellular origin, myeloid (i.e., myelogenous) or lymphoid (i.e., lymphocytic), and their stage of progression based on the course of the disease if left untreated (i.e., acute or chronic). Acute leukemias (e.g., acute lymphocytic leukemia [ALL] and acute myelogenous leukemia [AML]) often result in internal bleeding, anemia, or infection. Many patients with chronic leukemias (e.g., chronic lymphocytic leukemia [CLL] and chronic myelogenous leukemia [CML]) do not exhibit clinical symptoms (Landis et al. 1999; Wu and Martinez 2000).

The cause of the different forms of leukemia appears to be multi-factorial. Genetic, viral, environmental factors (e.g., ionizing radiation), drugs, and chemicals (e.g., benzene, trichloroethylene) all have been implicated in the development of leukemia. It is believed that the final common pathway is damage to the DNA in one way or another. Patients with an abnormal number of chromosomes (e.g., trisomy 21) and chromosomal translocations are at an increased risk of developing ALL. Of those patients diagnosed with CML, 90% have an acquired

chromosomal abnormality (Wu and Martinez 2000). A review conducted by the Environment Committee of the Armed Forces Epidemiological Board suggested that *perhaps* an association exists between sulfur mustard and leukemia (Perrotta 1996), though no exposure data were available to support the existence or strength of the association. A more recent study of combatants in the Iran-Iraq war reports a possible link between exposures to mustard gas and CML, but authors acknowledge that previous studies have not shown such links and that further study is needed (Ghanei and Vosoghi 2002).

In 1999, 30,200 newly diagnosed cases of leukemia were reported in the United States. The incidence rates for each of the four primary types of leukemia ranges between 1 and 2.3 cases per 100,000 people per year. Of the leukemias diagnosed in the United States, approximately one-third were classified as AML (incidence = 2.3 cases per 100,000); About 26% were classified as CLL (Incidence rate = 2 cases per 100,000); about 15% were classified as CML (incidence rate = 1.3 cases per year); and about 10% were classified as ALL (incidence rate = 1 case per year). In general, males are diagnosed more often with each of the sub categories of leukemia (i.e., AML, CLL, CML, ALL) than females (Landis et al. 1999; Wu and Martinez 2000).

Multiple Myeloma

Multiple myeloma is a cancer of the plasma cells. Plasma cells are a type of white blood cell normally present in the bone marrow and responsible for producing antibodies to help fight infection. In multiple myeloma, uncontrolled growth of defective plasma cells (or myeloma cells) occurs. This disrupts the normal immune system as well as displacing normal bone marrow cells. Myeloma cells invade and damage bone and soft tissues such as nerves and muscles and can travel through the blood stream to other bone marrow sites (Grethlein 2002; Sorenson et al. 2001; Medifocus.com 2002; NCI 2002a).

Multiple myeloma can lead to a wide variety of problems. The disease may interfere with the normal production of blood cells, resulting in leukopenia (decreased number of white blood cells), anemia (i.e., decreased number of red blood cells) and thrombocytopenia (i.e., decreased number of platelets). The defective cells may cause lesions in the skeleton or in soft tissue masses and result in a high incidence of infection in patients (Grethlein 2002).

In most cases, people who develop multiple myeloma have no clear risk factors. Multiple myeloma, like most diseases, may be the result of several factors (known and/or unknown) acting together. Some research suggests, however, that certain risk factors may increase a person's chance of getting multiple myeloma. For example, a person’s family background appears to affect the risk of developing multiple myeloma; children and brothers and sisters of patients who have this disease have a slightly increased risk. Farmers and petroleum workers exposed to certain chemicals (e.g., some pesticides, benzene) also seem to have a higher-than-average chance of getting multiple myeloma. In addition, people exposed to large amounts of radiation (such as survivors of the atomic bomb explosions in Japan) have an increased risk for this disease. Scientists have some concern that smaller amounts of radiation (such as those radiologists and workers in nuclear plants are exposed to) also may increase the risk (Grethlein 2002; NCI 2002a; Eriksson and Karlsson 1992). One study was identified that investigated a possible link between arsenic and multiple myeloma; this study reported no statistically significant associations between arsenic and multiple myeloma (Eriksson and Karlsson 1992).

The overall incidence of multiple myeloma is approximately 3 to 4 cases per 100,000 persons (Grethlein 2002; Sorenson et al. 2001). In the United States, approximately 10,000 persons per year die from the disease. Without treatment, most patients die in less than 1 year; with treatment, life expectancy may be extended 2–3 years (Sorenson et al. 2001). Multiple myeloma is generally a disease of older people. Most patients who receive the diagnosis are aged 60–65 years. Only 3–5% of patients with multiple myeloma are younger than 45 years. The disease is rare in children. Reported frequencies by age, sex, and race indicate that black males are at highest risk to develop multiple myeloma and the condition is very rare among Asian Americans. The age-adjusted annual incidence in the general U.S. population is 4.3 cases per 100,000 white men, 3 cases per 100,000 white women, 9.6 cases per 100,000 black men, and 6.7 cases per 100,000 black women (Grethlein 2002; Sorenson et al. 2001).

Myelofibrosis

Myelofibrosis, or fibrosis of the bone marrow, is another type of bone marrow disease in which fibrous scar tissue builds up inside the bone marrow cavity. The normal bone marrow has a very fine network of fibers supporting the blood-forming tissues. In myelofibrosis this network is coarsened and thickened so that normal blood cell production is blocked. It is generally triggered by a disturbance of the immune system. The disease results in the generation of poor quality blood made by the marrow. Although symptoms may not appear for a year or more, an enlarged spleen discovered at an annual medical examination may be the first clue. Eventually, symptoms become more prevalent (A.D.A.M., Inc., 2001b; The Thompson Corporation 2001).

The cause of myelofibrosis is unknown. Most cases arise secondarily to other diseases. The disorder is frequently associated, for example, with certain cancers of the hematologic system and may be seen prior to a clear diagnosis of acute leukemia, at the time of diagnosis with leukemia, or as a late event in patients previously treated for leukemia. Numerous nonmalignant diseases also have been reported in association with myelofibrosis (The Thompson Corporation 2001).

Myelofibrosis is an uncommon condition, and is especially rare in children. Most patients are over 50 years old, but it can occur at any age. Fewer than 100 cases in children have been described in the medical literature (The Thompson Corporation 2001; Johnston 2002).

Diseases of the Lymphatic System

Diseases may affect the lymph nodes, the spleen, or the collections of lymphoid tissue that occur in certain areas of the body. Lymphoma broadly describes cancers of the lymphatic system. Lymphoma occurs when a lymphocyte (a type of white blood cell) undergoes malignant changes—multiplies, grows, and creates tumors. The two main types of lymphoma in people are Hodgkin's and non-Hodgkin's lymphomas. These two types of lymphomas are described in greater detail below (The Nemours Foundation 2001a, 2001b).

Hodgkin's Lymphoma

Hodgkin's lymphoma is a malignant disorder of the lymph node that is highly treatable. It is characterized by progressive enlargement of the lymph nodes, spleen, and liver and by progressive anemia. Since lymph tissues all over the body are connected, abnormal (cancerous) lymphocytes can circulate in the lymphatic vessels. As a result, Hodgkin's lymphoma often spreads from one lymph node to another throughout the body. Hodgkin's lymphoma can also spread to other areas and organs outside the lymph system (Lymphoma Research Foundation 2002).

The exact cause of Hodgkin's lymphoma is unknown. However, various triggers are suspected. For example, Epstein-Barr virus genes have been identified in tissue samples of approximately 20–50% of individuals with Hodgkin's lymphoma. The Epstein-Barr virus is a herpes virus that causes infectious mononucleosis. Workers who are exposed to benzene and other organic solvents may be at an increased risk of chromosome damage which may result in Hodgkin's lymphoma. However, strong evidence linking chemicals to Hodgkin's lymphoma is sparse. Hodgkin's lymphoma also is associated with a number of rare immune disorders. These include Wiskott-Aldrich syndrome (an immune deficiency disease), Klinefelter's syndrome (a chromosomal disorder) and ataxia telangiectasia (a progressive childhood disease that affects the nervous system and other body systems). Chronic inflammatory disorders such as rheumatoid arthritis and systemic lupus have also been associated with Hodgkin's lymphoma (Argiris and Kaklamani 2001; Hanson Centre for Cancer Research 1997). Recipients of heart, kidney, and other organ transplants have also been found to be at an increased risk of developing the illness. Also, Hodgkin's lymphoma is more common in western societies and in higher socio-economic groups. It is important to note, however, that most people with these possible risk factors never develop the disease and many who are diagnosed have no identifiable risk factors (Lymphoma Research Foundation 2002).

The age-adjusted incidence rate for Hodgkin's lymphoma is 2.9 cases per 100,000 individuals. In the United States, 7,400 new cases were diagnosed during 2000 (Argiris and Kaklamani 2001). In the United States and northern Europe, Hodgkin's lymphoma is rare before the age of five, with a gradual rise in incidence until adolescence. After adolescence, there is a striking increase in incidence until age 30. Boys are more likely than girls to develop Hodgkin's lymphoma. Siblings of patients have a slightly increased risk of developing the disease (St. Jude Children's Research Hospital 2002; Argiris and Kaklamani 2001).

Non-Hodgkin's Lymphoma

Non-Hodgkin's lymphoma (NHL) is cancer that starts in lymphoid tissue (also called lymphatic tissue). NHL is a collection of more than a dozen different cancers of the lymphatic system. Cancers originating in other organs (e.g., the lung or colon) that then spread to lymphoid tissue are not considered lymphomas. Lymphomas starting in the lymphoid tissue can spread to other organs. Because NHL can develop in the body wherever lymphocytes are found, the cancer can develop nearly anywhere in the body. Symptoms can vary widely, depending on the cancer site. The most common symptom is a noticeable, usually painless swelling of a lymph node (NCI 2002b; Patlak 1996).

Little is known about exactly what causes NHL. Certain risk factors appear to exist. The likelihood of getting NHL increases with age and is more common in men than in women. NHL is more common among people with inherited immune deficiencies, autoimmune diseases, or HIV/AIDS, and among people taking immunosuppressant drugs following organ transplants. Human T-lymphotropic virus type I (HTLV-1) and Epstein-Barr virus are two infectious agents that may increase the chance of developing NHL. People who work extensively with or are otherwise exposed to certain chemicals, such as pesticides, solvents, or fertilizers, may have a greater chance of developing NHL (NCI 2002b; Patlak 1996). However, most people with these risk factors do not get NHL, and many who do get this disease have none of the suspected risk factors (NCI 2002b).

The incidence of NHL has increased dramatically over the last couple of decades. This disease, which was historically relatively rare, is now the fifth most common cancer in the United States. According to the National Cancer Institute, NHL has increased by 75% over the last 20 years, making it the most rapidly rising cancer after lung cancer and melanoma. Nationwide, the incidence of NHL increased from 8.5 per 100,000 people in 1973 to 15.1 per 100,000 in 1991, and mortality from the disease increased from 4.8 per 100,000 people in 1973 to 6.5 per 100,000 in 1991 (Patlak 1996).The increase is a result of both better methods of detection and an actual increase in the number of new cases. Although some types of NHL are among the most common childhood cancers, more than 95% of NHL cases occur in adults. The average age at diagnosis is the early 40s. Whites are affected more often than African Americans or Asian Americans (Patlak 1996).

General Information About Peripheral Neuropathy

Peripheral neuropathy is a general term referring to disorders of peripheral nerves. The peripheral nervous system relays information back and forth from the central nervous system (brain and spinal cord) to muscles and other organs. Peripheral neuropathy is a clinical syndrome affecting a variety of peripheral nerve cells and fibers. The syndrome is characterized by pain, loss of sensation, muscle weakness and atrophy, decreased deep tendon reflexes, and vasomotor symptoms (singly or in combination). Effects may result from disease of a single nerve or many nerves simultaneously (Merck 1992; NIH/NLM 2002).

Peripheral neuropathy is a very common disorder. However, incidence rates are difficult to determine and vary depending on geographic region and other factors such as the specific type of neuropathy and the precise case definition. The population prevalence of non-specific peripheral neuropathy reported by one investigator has been estimated to be 2,400 per 100,000 people (2.4%), with prevalence increasing with age to 8,000 per 100,000 people (8.0%) (Hughes 2002). One Web site reports that peripheral neuropathy affects at least 20 million people in the United States (Neurologychannel 2004).

Common Causes of Peripheral Neuropathy

Many diseases and conditions can cause or increase the risk of peripheral neuropathy. In some cases, the cause is unknown. The most common risk factors are summarized below (Merck 1992; Hughes 2002; NIH/NLM 2002):

- Systemic or metabolic disorders (e.g., diabetes). [Diabetes is considered the most common cause of neuropathy.]
- Heavy alcohol use.
- Infectious or inflammatory conditions (e.g., AIDS, HIV infection, rheumatoid arthritis).
- Nutritional deficiencies and metabolic disorders.
- Trauma or localized injury.
- Certain medicines or toxic substances (e.g., chemotherapeutic agents, lead, mercury, organic solvents, carbon monoxide, and arsenic).
- Hereditary disorders/predisposition.

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Appendix E. Estimates of Human Exposure Doses and Determination of Health Effects

ATSDR focused its health effects evaluation on exposures to *arsenic* levels detected in surface soil in the Spring Valley neighborhood because it was a completed exposure pathway (elevated arsenic levels were present in surface soil of some residential yards). This appendix presents the methods and findings of ATSDR's health effects assessment. It describes how ATSDR estimated exposure doses for Spring Valley residents contacting soils with detected levels of arsenic and then discusses what estimated doses mean—that is, how do the doses compare to those shown in the scientific literature to result in adverse health effects? *As is detailed below, doses associated with exposure to the detected levels of arsenic in Spring Valley soils are lower than those expected to result in illness, including the symptoms and diseases of concern reported by some area residents.*

This appendix also presents a brief overview of the toxicity data related to chemical warfare agents, lewisite and sulfur mustard, found in containers of surface disposal areas or burial pits. The potential for exposure in this scenario is extremely limited because people would need to be in a disposal area disturbing the soil and glassware containing the agent. There are four former burial pits with completion of remediation pending at one Glenbrook Road pit and one surface disposal area that contained or contain chemical warfare agents. Detected levels in soil are well below those associated with health-based comparison values and harmful effects. Soil gas migration from disposal areas into homes has not been thoroughly investigated and would be another limited but not impossible exposure scenario.

Lastly, we evaluate TNT because of its strong association with toxic effects on the blood. ATSDR looked closely at TNT toxicity in the context of site-related exposures. We also looked at phosphorus due to its concentration in residential surface soils.

Methodology

Deriving Exposure Doses

ATSDR estimated exposure doses, which are estimates of how much contaminant a person may be exposed to on a daily basis. Variables considered when estimating exposure doses include the contaminant concentration in the environmental media, the exposure amount (how much of the substance the person was actually exposed to), the exposure frequency (how often), and the exposure duration (how long). Together, these factors influence an individual's physiological response to chemical contaminant exposure and potential outcomes. Where possible, ATSDR used site-specific information about the frequency and duration of exposures. In cases where site-specific information was not available, ATSDR applied several conservative exposure assumptions to estimate exposures for Spring Valley residents. ATSDR also considered the extent to which arsenic is actually absorbed into the human body.

The following equation was used to estimate exposure doses for contaminants detected in Spring Valley soils, for both children and adults:

$$\textit{Estimated exposure dose} = \frac{\text{C x IR x EF x ED x AF}}{\text{BW x AT}}$$

where:

C: Contaminant concentration in soil (mg/kg or ppm)

IR: Ingestion rate (EPA 1997):

IRa: 100 mg/day for an adult (0.0001 kg/day)
IRc: 200 mg/day for a child (0.0002 kg/day)
5,000 mg/day for a pica child (0.005 kg/day)

EF: Exposure frequency (exposure events per year of exposure): 365 days/year

ED: Exposure duration (the duration over which exposure occurs):

Adult = 30 years (high end duration at one residence)
Child = 6 years

AF: Absorption factor: 0.5 (ATSDR 2000a and b; Parsons 2002a)[7]

BW: Body weight (EPA 1997):

BWa: Adult = 70 kg (154 pounds)
BWc: Child = 16 kg (35 pounds; average weight of child 1–6 years)

AT: Averaging time or the period over which cumulative exposures are averaged (ED x 365 days/year)

ATSDR also estimates "age-adjusted" doses, which take into account an integrated exposure dose over time. The approach considers changes in daily soil ingestion rates, body weight, and exposure duration for children from 1 to 6 years (EDc = 6 years) and for individuals aged 7–30 years (EDa = 24 years). The age-adjusted dose may be considered a more realistic estimate of a chronic dose a person living at a single residence for 30 years might get. Integrating in the higher intake rate of soil by children typically leads to a more conservative estimate of dose compared to an adult-only exposure scenario.

The following equation was used to estimate the age-adjusted dose:

$$\textit{Age-adjusted exposure dose} = \left(\frac{C \times EF \times AF}{AT}\right)\left(\frac{EDc \times IRc}{BWc} + \frac{EDa \times IRa}{BWa}\right)$$

Using Exposure Doses to Evaluate Potential Health Hazards

ATSDR performs an in-depth evaluation to determine whether exposures might be associated with adverse health effects (non-cancer and cancer). As part of this process, ATSDR examines relevant toxicologic, medical, and epidemiologic data to determine whether estimated doses are likely to result in adverse health effects. As a first step in evaluating non-cancer effects, ATSDR

[7] See main text discussion regarding selection of the most appropriate absorption factor.

compares estimated exposure doses to standard health guideline values, including ATSDR's minimal risk levels (MRLs) and the U.S. Environmental Protection Agency's (EPA's) reference doses (RfDs). The MRLs and RfDs are estimates of daily human exposure to substances that are unlikely to result in non-cancer effects over a specified duration. Estimated exposure doses that are less than these values are not considered to be of health concern. To be very protective of human health, MRLs and RfDs have built in "uncertainty" or "safety" factors that make them much lower than levels at which health effects have been observed. Therefore, if an exposure dose is much higher than the MRL or RfD, it does not necessarily follow that adverse health effects will occur.

To evaluate carcinogens, ATSDR compares the exposure levels to cancer effect levels that have been shown to cause cancer in animals or humans. In addition, ATSDR may calculate quantitative estimates of risk using EPA's cancer slope factors. These cancer estimates are based on conservative models and assumptions, so the actual risk may be substantially less than the calculated value.

If health guideline values are exceeded, ATSDR examines the effect levels seen in the literature and more fully reviews exposure potential to help predict the likelihood of adverse health outcomes. Specifically, ATSDR examines "no-observed-adverse-effect levels" (NOAELs) or the "lowest-observed-adverse-effect levels" (LOAELs) for the most sensitive outcome for a given route of exposure (e.g., ingestion or skin contact). ATSDR looks at human studies, when available, as well as experimental animal studies. In the case of arsenic, a great deal of human data is available, though most is related to water and air exposures versus soil exposures. This information is used to describe the disease-causing potential of a particular contaminant and compare site-specific dose estimates with doses shown to result in illness in applicable studies (known as the margin of exposure). For cancer effects, ATSDR also reviews genotoxicity studies to further understand the extent to which a contaminant might be associated with cancer outcomes. This process enables ATSDR to weigh the available evidence, in light of uncertainties, and offer perspective on the plausibility of adverse health outcomes under site-specific conditions. Reviewing the scientific literature in this way enabled ATSDR to evaluate the range of dose levels that may be associated with the substance being evaluated and the characteristics of that substance that may make adverse health effects less or more likely.

Health Effects Evaluation Findings

Arsenic

How estimated arsenic doses compare to MRLs and observed effect levels

Based on ATSDR's analysis, arsenic doses associated with possible Spring Valley soil exposures are below doses shown in the scientific literature to cause harmful health effects.

Using the dose equation presented above, ATSDR estimated doses for chronic (long-term) and acute (short-term) exposures. ATSDR considered the highest composite arsenic concentration (202 ppm) detected in the most contaminated residential yard and assumed that children and adults could have had regular contact with these soils over a long period of time. For acute exposures, ATSDR assumed exposure to the highest detected concentration (529 ppm) in a

single spot (discrete sample) in that same yard. Both standard child soil intakes and those associated with possible pica behavior were evaluated.[8] Lastly, ATSDR evaluated doses associated with the site cleanup level of 20 ppm.

As shown in Table E-1, the estimated chronic doses are more than 14 times lower than the most sensitive endpoint related to chronic arsenic exposure (skin lesions and skin cancer). In fact, for adults, chronic dose estimates are lower than the chronic MRL and doses at which no adverse effects have been reported. Acute doses generally fall below the acute MRL, clearly indicating that no observable adverse effects are expected (e.g., gastrointestinal disturbance). For the hypothetical pica child, however, estimated doses associated with exposures to the highest arsenic levels detected at the site would be in the range at which symptoms characteristic of acute arsenic "poisoning" (e.g., facial swelling, nausea, vomiting, and diarrhea) have been reported. This would only happen if relatively *large* amounts of the *most* contaminated soil were ingested in a short amount of time. The highest levels of soil arsenic in yards were removed during the time critical removal actions; remaining concentrations are not expected to result in harmful doses, even to a pica child. Estimated doses associated with a 20 ppm exposure concentration (site cleanup concentration) are below the MRL by 3-30 times.

Table E-1. Estimated Arsenic Exposure Doses Compared to Screening Values and Observed Effect Levels

Exposure Situation	Exposure Concentration	Estimated Exposure Dose (mg/kg/day)			MRL (mg/kg/day)	NOAEL** (mg/kg/day)	LOAEL** (mg/kg/day)
		Adult	Child	Age-Adjusted			
Acute	529 ppm	0.0004	0.003 0.08*	--	0.005	--	0.05
Chronic	202 ppm	0.0001	0.001	0.0004	0.0003	0.0008	0.014
Chronic	20 ppm	0.00001	0.0001	0.00004	0.0003	0.0008	0.014

* Represents the dose for a hypothetical pica child.

** Screening levels and observed effect levels are based on the following principle studies: Mizuta et al. 1956 and Tseng et al. 1968.

The discussion below provides additional perspective, including discussion of some of the uncertainties associated with the data used in our evaluation.

Arsenic-related health effects

As already discussed, whether harmful effects will occur depends—as with all toxins—on both the intensity (how much) and duration (how long) of the exposure. Much of what is known about

[8] Some children have a much higher tendency to ingest soil and other non-food items. This is known as pica behavior. Pica children could conceivably consume a teaspoon or more of contaminated soil each day. No documentation of this type of exposure has been identified at Spring Valley, so its consideration is purely hypothetical.

arsenic toxicity relates to high or "poisonous" levels of exposure (e.g., occupational exposures following an accidental release). Health effects associated with arsenic have been relatively well studied. But much uncertainty still exists regarding the effects caused by arsenic at relatively low environmental exposures, such as those associated with the Spring Valley site.

While researchers have studied situations in which people have been exposed to arsenic in drinking water, little data exist specifically describing the effects resulting from exposure to arsenic in soils. Further, deficiencies in the drinking water studies make interpretation difficult. Examples of such deficiencies include:

- exposure levels are not well documented,
- the study fails to account for a number of complicating factors, including exposure to other non-water sources of arsenic or genetic susceptibility to arsenic, and
- nutritional status of the exposed populations is missing.

Exposure situations described in the literature might not be fully analogous and exposure data might be sparse. Still, the available health effects data provide a relative sense of the magnitude of arsenic exposures shown to result in harmful effects.

Further, study data suggest that our bodies have the capacity to safely handle arsenic doses such as those estimated for the Spring Valley site. Various studies indicate that at low-level exposures, arsenic compounds are detoxified (or metabolized)—that is, changed into less harmful forms—and then excreted in the urine. When the body's capacity to detoxify is exceeded, blood levels of arsenic increase and adverse health effects can occur. Limited data suggest that the dose at which this happens is somewhere between 0.003–0.015 mg/kg/day (ATSDR 2000a). All of the estimated site-specific exposure doses fall below this range, indicating that the effective breakdown and excretion of arsenic could very well be expected at the exposure levels documented in Spring Valley.

The text below reviews what is known—and what is not known—about the toxicity of arsenic in general. We studied information on the toxicity of inorganic arsenic (arsenite and arsenate), and, where possible, examined the toxicity of its metabolites.

What bodily systems does arsenic affect?

Inorganic arsenic has been shown to affect multiple systems in the human body, including the gastrointestinal (stomach and intestines), hepatic (liver), renal (kidney), cardiovascular (heart and circulatory), blood and bone marrow, central nervous, skin, respiratory, and reproductive systems.

Does arsenic cause cancer?

EPA, IARC, and NTP have classified arsenic as a known human carcinogen. Chronic ingestion of soluble forms of inorganic arsenic is strongly associated with an increased risk of skin cancer. Arsenic is possibly associated with cancers of the lung, liver, bladder, kidney, and colon, but less is known about the association between inorganic arsenic and these internal organ cancers.

ATSDR estimated the theoretical cancer risk from chronic (lifetime) exposure to the highest detected concentration of arsenic in a composite soil sample (202 ppm). Using this soil arsenic concentration and conservative assumptions for soil ingestion, the estimated cancer risk was 6 x 10^{-4}. However, soil with the highest levels of arsenic contamination has been removed, so exposures at this risk level are no longer occurring. Furthermore, the estimated exposure dose of arsenic (0.0004 mg/kg/day) is 35-times less than the lowest dose of arsenic (0.014 mg/kg/day) that has been shown to cause cancer in humans (Tseng et al. 1968).

What characteristic health conditions are related to arsenic exposure?

The hallmarks of chronic (long-term) inorganic soluble arsenic ingestion include skin changes, peripheral neuropathy (a condition characterized by weakness in the extremities caused by damage to the nerves leading to these areas), and anemia (ATSDR 2000b). Hyperpigmentation (darkening of the skin in small blotches) and hyperkeratosis (the formation of excess keratin, in the form of warts or corns) are the most common or characteristic effects of arsenic ingestion. Spring Valley residents reported neither of these skin conditions[9], though some residents did report rashes. The lowest dose at which hyperpigmentation and hyperkeratosis has been reported in the literature is 0.014 mg/kg/day. This value is based on observations in a Taiwanese population exposed to arsenic in drinking water for about 45 years (Tseng et al. 1968). Estimated site doses are at least 14 times lower than the effect level reported in this particular study. Note also that exposure has to occur for 10 to 40 years before damage to the skin occurs.

Peripheral neuropathy has been associated with arsenic doses ranging from 0.03–0.1 mg/kg/day. Researchers generally have not found neurological effects of any kind in populations chronically exposed to arsenic doses of 0.006 mg/kg/day or less. Some fatigue, headache, and numbness of the extremities were reported in a single study looking at inhabitants of Chinese villages exposed to arsenic via drinking water at 0.005 mg/kg/day. However, in another study no such symptoms were reported at slightly lower doses of 0.004 mg/kg/day (ATSDR 2000a). Spring Valley chronic dose estimates are generally lower than these reported effect levels. Although two reports of "neuropathy" were recorded on the DC DOH hotline, the maximum arsenic concentration detected in surface soils from these two residences was 4 ppm, which would result in doses of 0.000006 mg/kg/day (adult) and 0.00005 mg/kg/day (child). These estimated doses are more than 100 times lower than the lowest dose found to result in neurological effects.

Case reports have shown decreased white blood cell counts, fatigue, malaise, and gastrointestinal symptoms associated with arsenic exposures. However, these conditions are experienced by many people and from multiple causes. These non-specific conditions are generally not considered arsenic-induced until more obvious findings of pigmentation, keratosis, and peripheral neuropathy occur (Kyle and Pease 1965).

How estimated arsenic doses compare to observed effect levels associated with blood-related disorders reported by community members

Given the findings of our research, no blood-related disorders were shown to occur in the range of arsenic doses estimated for Spring Valley. In fact, arsenic-related blood conditions have

[9] One child at the American University Child Development Center was reported as having a "rash" and "warts."

generally not been reported in the absence of skin lesions, the most sensitive arsenic-related endpoint. For several of the reported conditions (e.g., leukemia and lymphoma), no documentation was found linking them to arsenic exposures.

The findings of the health effects assessment described in Section V reveal that exposures to the levels of arsenic detected in the Spring Valley neighborhood soils are not expected to result in adverse health effects. This conclusion was based on comparison of site-specific doses to the arsenic doses associated with the most sensitive effects or endpoints in the human body. Nonetheless, to thoroughly address community concerns, ATSDR further reviewed the scientific literature to document if and how site exposure doses relate to doses associated with the documented illness reported by some Spring Valley residents (see Appendix C). In the process, we attempted to identify information that could confirm or dispel possible links between arsenic and those health conditions reported by Spring Valley residents. The research was conducted in two phases: (1) literature search and (2) evaluation and comparison of available dose-response data to site-specific doses. We focused on blood, blood-forming, and lymphatic system disorders. Our research strategy and findings are detailed below.

Literature search methodology

An extensive search of the current scientific literature was conducted to identify information pertaining to: (1) the characteristics, known/suspected causes, and prevalence of the reported diseases (see Appendices C and D); (2) the behavior of arsenic and other site-related contaminants in the environment and within the human body; and (3) possible relationships between detected levels of contaminants in soil and dust/air and the diseases of concern.

The literature search was conducted in a step-wise manner. We first reviewed the secondary literature to identify pertinent studies already assembled and peer-reviewed, including ATSDR's Toxicological Profile for Arsenic (ATSDR 2000a), EPA's Integrated Risk Information System (IRIS), and the World Health Organization (WHO) Environmental Health Criteria (WHO 2001). Water quality criteria documentation was also reviewed (NAS 1999, 2001). Original references cited in these documents were obtained and reviewed, as appropriate. A literature search was then conducted to identify additional toxicity data published that might not have been captured in the secondary sources, including study data published since the release of the secondary sources. Search dates generally covered the years 1990–2002. The primary on-line libraries searched include PubMed and TOXLINE. Primary terms searched included: inorganic arsenic (CAS# 7440-38-2), inorganic arsenic compounds, arsine, and specific organoarsenical chemical warfare agents (e.g., adamsite and lewisite).[10] A secondary search was conducted to identify studies specific to arsenic associated with chemical warfare weapons and arsenic in soils. A search was also performed for dimethylarsinate (DMA)/cacodylic acid, a primary metabolite of arsenic.

Key words used in the search included[11]: anemia* (e.g., anemia, aplastic anemia, megaloblastic anemia, and pernicious anemia), autoimmun*, blood disorders, bone marrow, eosinophilia, erythro* (e.g., erythropoiesis), granulocytopenia, hemato*, immunotox*, leuk* (e.g., leukemia

[10] For example: arsenic trioxide, *arsenite, and *arsenate.

[11] * Indicates that any word that includes that fragment was captured.

and leukopenia), lymph* (e.g., lymphatic and lymphoma), multiple myeloma, myelofibrosis, and plasma* (e.g., plasmacytoma).

More than 400 abstracts were considered relevant to this effort. A subset of articles was retrieved and critically reviewed.

Findings

Table E-2 summarizes how Spring Valley exposure doses compare with doses observed to result in anemia and other blood-related disorders (referred to as the "margin of exposure"). As can be seen, site doses are 20 to thousands of times lower than these documented adverse effect levels. The table presents the type of exposures (e.g., acute, intermediate and chronic) and the medium by which the dose was received (e.g., water or food). None of the exposure situations are directly analogous to the Spring Valley soil exposures under study. They do, however, provide some basis for comparison. Note also that dose-response data available for hematological effects are drawn primarily from case reports. As such, dose-response data come from a relatively small data pool. Many of the larger-scale epidemiologic studies that have studied environmental exposures to arsenic (e.g., drinking water studies) either lack the exposure data necessary to define dose-response relationships or do not specifically evaluate blood-related conditions. Nonetheless, these comparisons offer a fair amount of perspective, as does the narrative that follows.

Anemia often accompanies the skin lesions and neuropathy seen in patients chronically poisoned by arsenic. But these conditions tend to be associated with high or intense exposures. Exposures of several milligrams of arsenic a day, for example, can result in anemia within a few weeks to months (ATSDR 2000b). Estimated Spring Valley exposures, however, are believed to be in the range of 0.02–0.04 milligrams per day, assuming ingestion of the highest detected concentration of arsenic in soil (202 ppm).

Anemia is a common feature of arsenic poisoning following oral (ingestion) exposures. Anemia and leukopenia (a reduced number of white blood cells) have been observed in humans following acute, intermediate, and chronic oral exposures at doses of 0.05 mg/kg/day or more. Still, anemia has not been observed in all cases of arsenic exposure or poisonings. Observed effects could be due to direct action on the blood cells or suppression of the formation of blood cells in the bone marrow (ATSDR 2000a; Chang et al. 1996).

Arsenic has not been directly linked to aplastic anemia. While some references list arsenic among substances possibly associated with aplastic anemia, no data were identified that showed any specific dose-response relationships between arsenic exposures and aplastic anemia (Young 1994).

No identified studies found statistically significant associations between arsenic and cancers of the blood, bone marrow, or lymphatic systems (e.g., leukemia, multiple myeloma, and lymphoma). As mentioned above, arsenic is strongly associated with skin cancer; some studies suggest that associations could also exist for tumors of the bladder, kidney, liver, lung, and prostate (ATSDR 2000a; EPA 2002).

Table E-2. In the Scientific Literature, How Do Site-Specific Estimated Exposure Doses Compare to Levels Associated with Blood-related Effects?

Observed Effect*	Observed Effect Level (mg/kg/day)	Matrix	Form	Reference	Margin of Exposure†
Pancytopenia, leukopenia	0.2 (A)	water	NS	Armstrong et al. 1984‡	67
Hemolysis	8 (A)	NS	As^{3+}	Fincher and Koerker 1987‡	2,667
Increase in blood enzyme levels	13 (A)	acute poisoning	As^{3+}	Kamijo et al. 1998‡	4,333
Increase in blood enzyme levels	22 (A)	acute poisoning	As^{3+}	Levin-Scherz et al. 1987‡	7,333
High leukocyte count, low hematocrit	6 (A)	acute poisoning	As^{3+}	Lugo et al. 1969‡	2,000
Mild anemia, leukopenia	0.05 (A)	dietary	As^{5+}	Mizuta et al. 1956‡	17
Decrease polychromatic erythrocytes in bone marrow (mouse)	6 (A)	gavage in water	As^{3+}	Tice et al. 1997‡	2,000
Anemia, leukopenia	0.1 (I)	water	As^{3+} As^{5+}	Franzblau and Lilis 1989‡	100
Anemia, leukopenia, erythroid hyperplasia of bone marrow	0.06 (I)	water	NS	Wagner et al. 1979‡	60
Anemia	0.06 (C)	water	NS	Guha Mazumder et al. 1988‡	60
Anemia	0.05 (C)	water	NS	Zaldivar and Guillier 1977‡	50
Slight transient decrease in hemoglobin values (rat)	20 (C)	dietary	As^{3+}	Byron et al. 1967‡	20,000
Slight to moderate anemia (dog)	2.4 (C)	dietary	As^{5+}	Byron et al. 1967‡	2,400

Key:
A = acute exposures
I = intermediate exposures
C = chronic exposures
mg/kg/day = milligram per kilogram per day
NS = not specified

* The observed effects are reported from human studies, unless otherwise noted.

† The margin of exposure (MOE) represents the ratio between estimated doses at Spring Valley and the observed effect level reported in the table. For intermediate and chronic effects, we compared the most conservative chronic dose estimate of 0.001 mg/kg/day (child dose) to the observed effect levels reported in the table. Similarly for acute effects, we compared the estimated acute dose estimate of 0.003 mg/kg/day (child dose). For example, for the first entry in the table, the MOE = 0.2 mg/kg/day (observed effect level) ÷ 0.003 mg/kg/day (estimated acute dose at Spring Valley) = 67.

‡ Cited in ATSDR 2000a.

Chemical Warfare Agents Found in Containers of Disposal Areas

Some chemical warfare agents and associated breakdown products were detected at trace levels (below health-based comparison values) in only a few soil samples. Based on soil concentrations, exposure to these substances via the soil pathway has no adverse health consequences. Information regarding the toxicity of the chemical warfare agents found in disposal areas is presented below to give readers an overview of the toxicity of these agents. Containerized chemical warfare agents, if contacted, are clearly toxic and at high enough doses can have some debilitating effects. *However, as previously stated, direct exposure to these agents at such levels in Spring Valley is only a remote possibility.*

Organoarsenicals: Lewisite and Adamsite

During World War I, chemical warfare agents, lewisite and adamsite, were reportedly handled at the American University Experiment Station (AUES). Although the U.S. Army Corps of Engineers (USACE) identified lewisite and its breakdown products in some of the buried bottles removed from the Spring Valley site, these agents were not prevalent in area soils. Therefore, while no question remains regarding whether these agents are highly toxic, in all likelihood most area residents would not come in contact with them at all, let alone at harmful levels. Workers involved in soil excavations might have had some short-term exposures to higher levels, consistent with some reports of burning eyes and respiratory system reaction.

Exposure potential

The extent to which people might have been directly exposed to lewisite and adamsite chemical warfare agents (e.g., during past excavations or contact with containers) and some of the breakdown products is not fully known. Nevertheless, as discussed in Section IV and Appendix B, these chemical warfare agents are broken down (degrade) fairly rapidly in soil. Samples of materials from buried bottles removed from the Glenbrook Road area in the summer of 2001 were analyzed for lewisite derivatives. [12] Nine of 33 samples detected concentrations up to 148,220 ppm (U.S. Army Soldier Biological Chemical Command 2001). This maximum concentration was identified as L3 [tris-(2-chlorovinyl)arsine]. A small amount of lewisite was also detected in a bottle from a surface disposal area on American University Lot 18. One surface soil sample for which lewisite was tested did not contain detectable concentrations (Parsons 2002b). No lewisite breakdown products (CVAA/CVAO [2-chlorovinyl arsonous acid/chlorovinyl arsenous oxide]) were detected in sampled soils.

These data show that human contact with organoarsenicals from surface disposal areas and burial pits is feasible, but not likely, especially at harmful levels. Because detectable levels were found in excavated containers, some future potential remains for digging up the soil in yet undiscovered surface disposal areas/burial pits to depths of several feet and becoming exposed to

[12] The results of bottle contents were reported as L1+CVAA [2-chlorovinyl arsine dichloride +2-chlorovinyl arsonous acid], L2+L2-acid [bis-(2-chlorovinyl)chloroarsine +bis-(2-chlorovinyl) arsinous acid], and L3 [tris-(2-chlorovinyl)arsine]. The sums were used because gas chromatograph methods could not distinguish between the compounds.

agents in broken or degraded containers. However, as discussed in Appendix B, lewisite and its breakdown products are not likely to persist in the environment.

Physiologic effects

Both blister agent, lewisite, and vomiting agent, adamsite, are harmful upon direct contact. More lewisite than adamsite toxicity information was identified in the literature.

Lewisite can cause painful blistering on contact with the skin or mucous membranes. It can be absorbed by the skin and act as a "systemic" poison, producing effects such as pulmonary edema, diarrhea, restlessness, and low blood pressure (NRC 1995). Tissues and organs that could be affected by lewisite include the liver, gall bladder, bladder, lungs, and kidneys. Regarding the specific doses of lewisite required to produce toxic effects, however, a large knowledge gap remains (ORNL 1997). Still, some acute toxicity studies in rats and rabbits are available. The Army developed an interim RfD for lewisite of 0.0001 mg/kg/day (ORNL 1997).[13] But in an independent assessment of the RfD, the National Research Council (NRC) reported that because of the poor data, the strength of evidence for deriving the RfD for lewisite is weak. To account for the uncertainty, the National Research Council recommended using a rabbit study and applying more uncertainty factors. The resulting RfD is 0.00001 mg/day/day—10 times lower than the Army value (NRC 1999). No mammalian toxicity data are available for the CVAA or CVAO, but are presumed to have comparable toxicity to lewisite (Munro et al. 1999).

The cancer-causing potential of lewisite is uncertain. No studies were identified in which the carcinogenicity of lewisite was specifically evaluated or quantified. Genotoxicity studies (e.g., mutation assays), which can provide some supporting evidence for a chemical's carcinogenic potential, have been conducted for lewisite. Most test results were negative, but the overall data set is considered inconclusive (NRC 1995; ORNL 1997). We do know, however, that lewisite breakdown products are carcinogenic (e.g., the arsenicals).

Adamsite is a nose and throat irritant. The Army described it as a vomiting agent. First produced during World War I, it was not considered "toxic enough" for battlefield use (USACHPPM 1998). Comparative *in vitro* studies looking at the inhibition of cell proliferation reveals adamsite to be less toxic than lewisite (Henriksson et al. 1996). The human body "will detoxify" the effects of mild exposures within 30 minutes of evacuation (USACHPPM 1998). Little other toxicity data for adamsite were identified.

Sulfur Mustard

Available sampling data indicate that neither sulfur mustard (also referred to as "HD" or "mustard HD") nor its breakdown products are present in Spring Valley soils at harmful levels. The Army has established an RfD of 0.000007 mg/kg/day for sulfur mustard (USACHHPM

[13] An RfD represents a dose at or below which no harmful health effects would be expected. It is calculated by critically reviewing studies to identify the highest dose at which a critical or sensitive effect is not observed and applying a series of "safety" factors to account for uncertainties. For lewisite, the RfD is based on a NOAEL of 0.44 mg/kg/day, reported in a reproductive study in rats. An uncertainty factor of 3,000 was applied to account for differences between humans and animals and variability among individuals. (The same RfD has been recommended for lewisite oxide [USACHPPM 1999]).

1999). Detected levels of the mustard breakdown product thiodiglycol in Spring Valley soils are lower than the RfD established for the more toxic parent compound.

Exposure potential

Sulfur mustard was detected in some of the materials sampled from buried bottles. Its primary breakdown product (thiodiglycol) was detected in a few soil samples, but at very low levels. Resulting exposures to these levels are well below health-based screening values. Assuming some individuals could be exposed to the maximum detected concentration of thiodiglycol (2.1 ppm detected in subsurface soils) on a regular basis, estimated doses would be 0.000003 mg/kg/day for adults and 0.00003 mg/kg/day for children. As described below, no known evidence suggests that dose levels this low could result in harmful effects.

Biological fate

Sulfur mustard is fat-soluble and therefore, readily absorbed through exposed tissues. It can affect multiple tissues, depending on the route, extent, and duration of exposure. Sulfur mustard is considered an "alkylating" agent and can harm cells through chemical reactions with proteins, enzymes, and nucleic acids in the cells (Reutter 1999; Watson and Griffin 1992).

Physiological effects

Like lewisite, sulfur mustard is a blister agent. It can produce direct or delayed toxicity. Sulfur mustard is directly toxic to the various components of human cells (e.g., DNA, RNA, and proteins) and produces cellular damage in a manner similar to radiation. For example, mustard can be directly toxic to hematopoietic tissues, leading to decreased white blood cell counts (ATSDR 2003; USACHPPM 1998; Watson and Griffin 1992). The effects of battlefield exposure have been well described, but the doses that produced them are not specifically known. Upon acute exposure, sulfur mustard has been shown to produce chemical burns on tissues that come in contact with the vapors or with the aerosols containing the agent. Affected tissues include the eyes, nose, throat, skin, bronchial, and upper gastrointestinal tract (Reutter 1999; Watson and Griffin 1992). Wartime exposures include eye and skin lesions, with respiratory and gastrointestinal problems observed in more severe cases. Soldiers exposed to sulfur mustard in World War I also seemed to have a higher rate of respiratory cancers (Reutter 1999). Exposures to mustard high enough to cause acute symptoms (such as might occur on the battlefield or in test chambers) are associated with an increased risk of respiratory and skin cancers, and perhaps leukemia (Perrotta 1996). Nothing in the published literature, however, points to associations between sulfur mustard or its breakdown products with aplastic anemia, or any cancers of the blood or hematopoietic systems.

Unlike the parent sulfur mustard, the mustard degradation products—including thiodiglycol—appear to have relatively low toxicity. The acute toxicity of sulfur mustard degradation products has been fairly well studied in animals, but no dose-response data were identified for humans. In a recent subchronic study, only mild effects (decreased body weights and mild kidney effects) were observed in rats exposed to doses of thiodiglycol as high as 5,000 mg/kg/day; no effects at all were reported at 500 mg/kg/day (Munro et al. 1999). While no human studies were identified and uncertainty remains regarding the effects that could be seen at lower, longer-term doses,

what is known is that the estimated thiodiglycol doses (0.000003-0.00003 mg/kg/day) are more than a million times lower than doses shown to cause no effects at all in the recent subchronic study mentioned above.

Both 1,4-dithiane and 1,4-oxathiane are of low acute toxicity to mammalian species (Munro et al. 1999), and although few longer-term (chronic) studies were identified in a recent review, available data suggest only very high doses triggered adverse health effects. Similarly, only mild effects were observed in a study of mustard breakdown product 1,4-dithiane at doses ranging from 105 mg/kg/day (nasal lesions) to 420 mg/kg/day (liver and kidney effects) (Munro et al. 1999; EPA 2002). Neither of these chemicals were detected in tested soil samples.

The Army has compiled some data on the toxic properties of mustard-lewisite mixture. The mixture, like its single components, is considered a blister and alkylating agent that can affect multiple tissues (USACHPPM 1998). The mixture degrades into hydrochloric acid, thiodiglycol, and nonvesicant arsenic compounds.

Explosives

2,4,6-Trinitrotoluene (TNT)

Soils samples showed that TNT is not present at harmful levels. As noted earlier, TNT was not detected in burial areas (reported less than 0.1 ppm). The reported detection limit of 0.1 ppm is 200 times lower than ATSDR's health-based comparison value, which represents a level of TNT considered to be safe. Because of TNT's strong association with toxic effects on the blood, ATSDR looked a little more closely at TNT toxicity in the context of what is known about site-related exposures.

Exposure potential

Based on available sampling data, exposure to harmful levels of TNT is not occurring. General information on TNT toxicity is presented below for some general perspective.

Physiological effects

At levels associated with its use as an explosive, TNT can be a potent toxicant. At high doses, the blood, lymphatic, and immune systems have all become severely impaired. Anemia is one of the signs of TNT toxicity. During World War I numerous reports of anemia and some cases of aplastic anemia were reported among munition workers exposed to airborne TNT. In animal studies moderate anemia was seen at doses ranging from 8–200 mg/kg/day. In these same studies no anemia was reported at doses below approximately 1–5 mg/kg/day (ATSDR 1995).

Although available cancer data for TNT are sparse, both human and animal studies report possible links between TNT and leukemias and lymphomas. EPA has therefore classified TNT as a possible human carcinogen. This is based largely on a preliminary study of a German population living near World War II munitions plants. The study supposedly established an association between humans living near wastes from the plants and some types of leukemia. While a causal relationship is suggested, further investigation is needed to identify possible confounding factors (e.g., other exposures), environmental conditions (no environmental data are

available), and overall living conditions (Kolb 1993). In addition, leukemias and lymphoma of the spleen have been reported in mice exposed to 1.5 mg/kg/day TNT in their food (Army 1984). The data from the mice study at least suggest that cancer effects, like the anemias described above, have been linked with TNT. But those links appear at doses far greater than those known to be present in Spring Valley.

Phosphorus

Phosphorus was reported at concentrations up to 1,530 parts per million (ppm) in residential soil. Estimated exposure doses associated with this concentration of phosphorus are 0.019 mg/kg/day for a child and 0.002 mg/kg/day for an adult. These estimated doses are close to or below the dose (0.015 mg/kg/day) at which *no* effects were reported in animal studies following exposure to white (or elemental) phosphorus, the most toxic form of phosphorus. However, they are above ATSDR's child and adult EMEG (10 and 100 ppm, respectively) for white phosphorus and are within an order of magnitude of LOAELs for adverse health effects that have been observed in animals and humans. White phosphorus is used mainly for producing phosphoric acid and other chemicals used to make fertilizers, food additives, cleaning compounds, etc. In the military, it has been used in ammunitions (ATSDR 1997). The form of phosphorus detected at the site is not specified; different chemical forms of phosphorus differ greatly in their toxicity. Assuming that all of the phosphorus is white phosphorus overestimates toxicity; total phosphorus actually includes other less toxic forms such as phosphates. It is unlikely that phosphorus in surface soil remains predominantly elemental in the form of white phosphorus.

Note that phosphorus also can occur naturally (less toxic forms from phosphate-bearing minerals and rocks) and is part of the normal diet. Reported background levels range up to 6,800 ppm in eastern U.S. soils (Boerngen and Shacklette 1984). Tolerable upper intake levels of phosphorus have been developed: 4 grams per day (g/day) for adolescents and adults (ages 9–70 years), 3 g/day for toddlers and children (1–8 years) and older adults (>70 years), and 3.5 g/day for pregnant women (Institute of Medicine 1999). For perspective, estimated phosphorus intakes associated with the incidental ingestion of 1,530 ppm phosphorus in soil would be much lower—approximately 0.0003 g/day for a child (assuming an intake of 200 milligrams of soil per day) and 0.00015 g/day for an adult (assuming an intake of 100 milligrams of soil per day).

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Appendix F. Brochure: Safe Gardening, Safe Play, and a Safe Home

Safe Gardening, Safe Play, and a Safe Home

An interim guide to reducing arsenic exposure in Spring Valley

This pamphlet was designed for residents of Spring Valley. The purpose is to provide residents with good health practice tips for the home, lawn and garden work, and play. By following the tips in this pamphlet, residents can greatly reduce their exposure to arsenic as well as to other potentially harmful materials such as pesticides and germs that might be in the soil.

Introduction

Approximately 146 properties in the Spring Valley area have some soil arsenic levels greater than 20 parts per million (ppm), a level designated by local and federal officials as a clean-up level for this community. Although the levels of arsenic detected in this community are in some cases elevated in soil, limited exposure studies to date suggest that the arsenic is not getting into residents' bodies in any greater amounts than what you would find in the general public. Although this is reassuring, it is recognized that some residents may still be concerned until the cleanup of their yards has occurred. For those and other concerned residents, the good practice tips in this pamphlet will be effective in reducing exposures to arsenic, pesticides, and germs that might be present in the soil.

Enjoying Your Lawn and Garden

Eating fruits and vegetables and getting plenty of exercise are essential parts of a healthy lifestyle. People enjoy many activities on their lawn and in their garden, which provide places both for exercise and for growing fresh fruits and vegetables. The levels of arsenic found in the soil of most properties in Spring Valley are at or below background (natural) levels and present no health hazard for people doing lawn or garden activities. Still, some families have arsenic in their soil at levels higher than the clean-up level and wish to reduce their exposure to the lowest possible level. Activities such as playing, gardening, and working on your lawn can increase your opportunity for exposure even though they are healthful. The information in this pamphlet will help you understand how to reduce your chances of exposure so you do not feel you have to give up the outdoor activities that you and your family enjoy. Understand that each property is different. Some of the tips outlined may apply to your situation and some may not.

Arsenic

A major source of elevated arsenic in Spring Valley surface soils is from degradation of chemical warfare agents tested there during World War I (WWI).

The U.S. Environmental Protection Agency (EPA), Army Corps of Engineers (ACOE), and the D.C. Department of Health set an arsenic cleanup level of 20 ppm for yards in Spring Valley. ACOE has removed soil from some contaminated properties and is planning to continue soil removals over the next several years. Until the contaminated soil is replaced, residents may

reduce their chances of exposure by following the guidelines in this pamphlet. Additional information about arsenic can be found at the ATSDR Spring Valley Information Repository at Palisades Library (4901 V Street N.W. at 49th Street N.W.) or through the ATSDR Spring Valley Web site at www.atsdr.cdc.gov/sites/springvalley.

Arsenic and Gardening

Arsenic is a naturally occurring element. Two types of arsenic are found in the environment. The first is **inorganic arsenic**, which is usually found in the environment combined with other elements such as oxygen, iron, and sulfur. The second type of arsenic is **organic arsenic**. Organic arsenic is formed by arsenic combined with carbon and hydrogen. It is found in plants, fish, and shellfish and is considered less harmful than inorganic arsenic.

For most properties in Spring Valley the soil arsenic levels are not high enough to cause any health problems associated with eating homegrown vegetables. Indeed, even for those areas showing elevated levels of arsenic, the uptake into home grown vegetables or fruits, is not likely to be sufficient to cause any health effects to persons gardening in the soil or eating vegetables grown in the garden. This will be explained below.

Gardening in soil with elevated levels of arsenic has two main issues: cleaning soil from the edible portion of the plant and absorption of arsenic by the plant. It is always a good health practice to wash all fruits and vegetables thoroughly whether they are bought or homegrown. Washing the soil from your homegrown fruits and vegetables is one of the most effective ways of reducing your exposure to not only arsenic but to pesticides and germs as well.

Most edible plants absorb some small amounts of arsenic, but usually do not contain enough arsenic to be of health concern. The amount of arsenic absorbed by plants can depend on many factors. Some of the most important factors are soil acidity, nutrient content, iron, organic matter, and plant type. Plants can absorb more arsenic if you have acidic soil. Keeping your soil at a near-neutral range (pH 6–7) can help reduce the amount of arsenic absorbed in plants. Maintaining adequate levels of plant nutrients in your soil can help reduce arsenic absorption. Adding a balanced commercial fertilizer to soil can help maintain correct levels of key plant nutrients. Iron can prevent arsenic from being absorbed. The iron combines with arsenic to form iron arsenate, a form of arsenic that is not well absorbed by plants. Increased amounts of organic matter are also helpful; the organic matter binds to arsenic and reduces how much plants take up. Some lawn and garden products contain arsenic, so it is a good idea to check with your lawn and garden store for products that do not contain arsenic.

Another important thing to keep in mind is that arsenic deposited by the chemical weapons tests in Spring Valley has been in the soil for 80 years. The longer the arsenic stays in the soil, the more it becomes bound to the soil, making it less available to plants and humans.

Arsenic levels in garden areas tend to be lower than in other areas of the property because most gardeners add soil conditioners such as compost and topsoil. By adding these conditioners, the concentration of arsenic in the soil is diluted. Some gardeners might want to add additional compost or topsoil from an area of their yard that does not have elevated levels of arsenic. In some cases it may be best to remove the soil from the place you want to garden and replace it with topsoil from a commercial garden center.

Plants vary in the amount of arsenic they absorb from the soil and where they store arsenic. Some plants move arsenic from the roots to the leaves, while others absorb and store it in the roots only. Fruit-type vegetables such as tomatoes concentrate arsenic in the roots and very little arsenic is taken up in the edible portion of the plant. Leafy vegetables also store arsenic in their roots, but some is also stored in the stems and leaves. Lettuce and some members of the Brassica plant family such as collards, kale, mustard, and turnip greens store more arsenic in the leaves than do other crops, but not at concentrations high enough to cause concern. Root crops such as beets, turnips, carrots, and potatoes absorb most of the arsenic in the surface skin of the vegetable. By peeling the skins of root crops, you can eliminate the portion of the plant that contains arsenic. Again, garden vegetables grown in Spring Valley should not contain enough arsenic to be of health concern. Recommendations for conditioning your soil, washing vegetables, and peeling root crops are intended to provide you the property owner with additional options for reducing exposure to arsenic.

For some properties with limited space for gardens, a raised garden bed might be an option. Instructions for building a raised garden bed can be found in most gardening books. The raised beds can be filled with soil from commercial gardening centers or from an area of your yard that does not contain elevated levels of arsenic. Your local agricultural extension office is an excellent source of for all types of gardening information.

Can I Eat Fruits and Vegetables Grown in My Garden?

Yes. Homegrown fruits and vegetables are highly unlikely to contain arsenic levels that would affect your health. Vegetables grown in soils with arsenic will take up some small amounts of arsenic. However, we believe the benefits from the eating your homegrown fruits and vegetables outweigh the risk presented by their arsenic content. By following the recommendations in the Tips for Safe Gardening, Safe Play, and a Safe Home section, you can greatly reduce your exposure to arsenic from the soil.

Unknown Buried Material

As the result of activities performed at the American University Experimental Station during WWI, dangerous materials used in the war effort were often buried as a means of disposal. ACOE, using historical records, has identified several areas of concern and continues to investigate. Buried items already discovered include buried munitions (both conventional and those containing chemical warfare agents), chemical weapon agents in ceramic jugs, laboratory waste, and other related items. These items have been buried since WWI and many have rusted and deteriorated to a point that they pose little health risk but it is possible for some to contain chemical agents. There have been very few reports of these items being uncovered through normal yard work, but the possibility does exist. Existing gardens and flowerbeds that have already been tilled or dug in are considered very low risk, but you should follow precautions. If you dig up any suspicious glass or metal object, do not attempt to remove the item yourself. Call ACOE at 1-800-434-0988, 410-962-7522, or 202-686-3359 for assistance.

Tips for Safe Gardening, Safe Play, and a Safe Home

Preparing Your Garden Soil

We are all exposed to a little arsenic every day. The recommendations below are for people who want to keep their exposure to the minimum possible. These recommendations are intended to be on the safe side. Under normal circumstances, a lapse in following these recommendations will not, by itself, lead to health problems.

- Increase the organic matter in your soil by adding compost or manure from outside sources such as commercial garden centers.
- Keep soil pH in the near-neutral range (pH 6–7). For a soils test, check with your local agricultural extension office or purchase a soils test kits at a garden center.
- Maintain adequate levels of plant nutrients by using a balanced commercial fertilizer.
- Maintain adequate levels of iron in your soil.
- Consider building a raised-bed garden. Fill it with topsoil and compost from outside sources or areas of your yard that do not have elevated levels of arsenic.

Note: Do not use chromated copper arsenate (CCA)-treated wood to build your raised garden beds. CCA contains arsenic that can leach into your soil. Use a safer nonarsenic pressure-treated wood such as ammoniacal copper quaternary (ACQ). Bricks, stone, or other wood products such as cedar or redwood can be used to build a raised garden bed.

Working in the Garden and Yard

- Avoid eating or drinking while working in the yard or garden because contaminated soil and dust might get on your food and you could accidentally swallow it.
- Dampen soils with water before you garden to limit the amount of dust you inhale.

- Avoid working in the yard on windy days, when dust can be stirred up and possibly increase your exposure.
- Consider wearing a mask if you spend time in dusty areas.
- Wash your hands after gardening.
- Wash work clothes to remove dust and dirt.
- Take your shoes off at the door to avoid tracking soil into your home.

Preparing Fruits and Vegetables

- Clean your hands, cutting boards, and kitchen tools with hot, soapy water and rinse well before and after handling your fruits and vegetables.
- Soak garden produce in cool water and rinse thoroughly until the water runs clear. Commercial vegetable-cleaning products are available in supermarkets to help free soil residues from your produce. These products work well with leafy vegetables. Vinegar can also be used for cleaning produce.
- Scrub firm fruits and root crops with a vegetable-cleaning brush to remove dust and dirt before peeling or eating.
- Peel root crops like carrots, rutabagas, radishes, and turnips.
- Wash berry fruits like strawberries and blackberries, and remove the "caps" (the tops of the berries where the stem and leaves attach).

Buy Some, Grow Some

- Eat some fruits and vegetables from your garden and some from the farmer's market or grocery store. Eating a mix of homegrown and commercial products can help reduce your potential exposure.

Creating Play Areas for Children

- Fill sandboxes with sand or soil from an outside source such as a commercial gardening center.
- Cover bare soil with grass or other material such as mulch.
- Keep children from playing in contaminated soil. The most likely way for children to become exposed to arsenic is from ingesting (eating) dirt.
- Have children wash hands and faces after they play in the yard.

Cleaning Your Home

- Remove work and play shoes before entering your house.
- Damp-mop floors and wipe down counters, tables, and window ledges regularly.
- To reduce dust levels in the home, consider upgrading your vacuum cleaner bags to those that filter better or simply change your bags more often. Some persons may want to buy a vacuum cleaner with a HEPA (high-efficiency particulate air) filter to better reduce dust levels.
- Wash the soil from homegrown fruits and vegetables before bringing them into your home.
- Keep pets out of areas of contaminated soil. Dogs and cats carry contaminated soil on their feet and fur into the home. Bathe your pets frequently.

For more information about ATSDR's work at Spring Valley, visit our web site at www.atsdr.cdc.gov/sites/springvalley or contact any of ATSDR's Spring Valley Team members:

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Note: (Personal communication from Dr. David Stilwell, Department of Analytical Chemistry, The Connecticut Agricultural Experiment Station, New Haven, CT).

Appendix G. ATSDR Glossary of Terms

ATSDR Glossary of Terms

The Agency for Toxic Substances and Disease Registry (ATSDR) is a federal public health agency with headquarters in Atlanta, Georgia, and 10 regional offices in the United States. ATSDR's mission is to serve the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent harmful exposures and diseases related to toxic substances. ATSDR is not a regulatory agency, unlike the U.S. Environmental Protection Agency (EPA), which is the federal agency that develops and enforces environmental laws to protect the environment and human health. This glossary defines words used by ATSDR in communications with the public. It is not a complete dictionary of environmental health terms. If you have questions or comments, call ATSDR's toll-free telephone number, 1-888-42-ATSDR (1-888-422-8737).

Absorption
The process of taking in. For a person or an animal, absorption is the process of a substance getting into the body through the eyes, skin, stomach, intestines, or lungs.

Acute
Occurring over a short time [compare with chronic].

Acute exposure
Contact with a substance that occurs once or for only a short time (up to 14 days) [compare with intermediate duration exposure and chronic exposure].

Additive effect
A biologic response to exposure to multiple substances that equals the sum of responses of all the individual substances added together [compare with antagonistic effect and synergistic effect].

Adverse health effect
A change in body function or cell structure that might lead to disease or health problems

Aerobic
Requiring oxygen [compare with anaerobic].

Ambient
Surrounding (for example, ambient air).

Anaerobic
Requiring the absence of oxygen [compare with aerobic].

Analyte
A substance measured in the laboratory. A chemical for which a sample (such as water, air, or blood) is tested in a laboratory. For example, if the analyte is mercury, the laboratory test will determine the amount of mercury in the sample.

Analytic epidemiologic study
A study that evaluates the association between exposure to hazardous substances and disease by testing scientific hypotheses.

Antagonistic effect
A biologic response to exposure to multiple substances that is less than would be expected if the known effects of the individual substances were added together [compare with additive effect and synergistic effect].

Background level
An average or expected amount of a substance or radioactive material in a specific environment, or typical amounts of substances that occur naturally in an environment.

Biodegradation
Decomposition or breakdown of a substance through the action of microorganisms (such as bacteria or fungi) or other natural physical processes (such as sunlight).

Biologic indicators of exposure study
A study that uses (a) biomedical testing or (b) the measurement of a substance [an analyte], its metabolite, or another marker of exposure in human body fluids or tissues to confirm human exposure to a hazardous substance [also see exposure investigation].

Biologic monitoring
Measuring hazardous substances in biologic materials (such as blood, hair, urine, or breath) to determine whether exposure has occurred. A blood test for lead is an example of biologic monitoring.

Biologic uptake
The transfer of substances from the environment to plants, animals, and humans.

Biomedical testing
Testing of persons to find out whether a change in a body function might have occurred because of exposure to a hazardous substance.

Biota
Plants and animals in an environment. Some of these plants and animals might be sources of food, clothing, or medicines for people.

Body burden
The total amount of a substance in the body. Some substances build up in the body because they are stored in fat or bone or because they leave the body very slowly.

CAP [see Community Assistance Panel.]

Cancer
Any one of a group of diseases that occur when cells in the body become abnormal and grow or multiply out of control.

Cancer risk
A theoretical risk for getting cancer if exposed to a substance every day for 70 years (a lifetime exposure). The true risk might be lower.

Carcinogen
A substance that causes cancer.

Case study
A medical or epidemiologic evaluation of one person or a small group of people to gather information about specific health conditions and past exposures.

Case-control study
A study that compares exposures of people who have a disease or condition (cases) with people who do not have the disease or condition (controls). Exposures that are more common among the cases may be considered as possible risk factors for the disease.

CAS registry number
A unique number assigned to a substance or mixture by the American Chemical Society Abstracts Service.

Central nervous system
The part of the nervous system that consists of the brain and the spinal cord.

CERCLA [see Comprehensive Environmental Response, Compensation, and Liability Act of 1980]

Chronic
Occurring over a long time [compare with acute].

Chronic exposure
Contact with a substance that occurs over a long time (more than 1 year) [compare with acute exposure and intermediate duration exposure]

Cluster investigation
A review of an unusual number, real or perceived, of health events (for example, reports of cancer) grouped together in time and location. Cluster investigations are designed to confirm case reports; determine whether they represent an unusual disease occurrence; and, if possible, explore possible causes and contributing environmental factors.

Community Assistance Panel (CAP)
A group of people from a community and from health and environmental agencies who work with ATSDR to resolve issues and problems related to hazardous substances in the community. CAP members work with ATSDR to gather and review community health concerns, provide information on how people might have been or might now be exposed to hazardous substances, and inform ATSDR on ways to involve the community in its activities.

Comparison value (CV)
Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause

harmful (adverse) health effects in exposed people. The CV is used as a screening level during the public health assessment process. Substances found in amounts greater than their CVs might be selected for further evaluation in the public health assessment process.

Completed exposure pathway [see exposure pathway].

Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)
CERCLA, also known as Superfund, is the federal law that concerns the removal or cleanup of hazardous substances in the environment and at hazardous waste sites. ATSDR, which was created by CERCLA, is responsible for assessing health issues and supporting public health activities related to hazardous waste sites or other environmental releases of hazardous substances. This law was later amended by the Superfund Amendments and Reauthorization Act (SARA).

Concentration
The amount of a substance present in a certain amount of soil, water, air, food, blood, hair, urine, breath, or any other media.

Contaminant
A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.

Delayed health effect
A disease or an injury that happens as a result of exposures that might have occurred in the past.

Dermal
Referring to the skin. For example, dermal absorption means passing through the skin.

Dermal contact
Contact with (touching) the skin [see route of exposure].

Descriptive epidemiology
The study of the amount and distribution of a disease in a specified population by person, place, and time.

Detection limit
The lowest concentration of a chemical that can reliably be distinguished from a zero concentration.

Disease prevention
Measures used to prevent a disease or reduce its severity.

Disease registry
A system of ongoing registration of all cases of a particular disease or health condition in a defined population.

DOD
United States Department of Defense.

DOE
United States Department of Energy.

Dose (for chemicals that are not radioactive)
The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An "exposure dose" is how much of a substance is encountered in the environment. An "absorbed dose" is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.

Dose (for radioactive chemicals)
The radiation dose is the amount of energy from radiation that is actually absorbed by the body. This is not the same as measurements of the amount of radiation in the environment.

Dose-response relationship
The relationship between the amount of exposure [dose] to a substance and the resulting changes in body function or health (response).

Environmental media
Soil, water, air, biota (plants and animals), or any other parts of the environment that can contain contaminants.

Environmental media and transport mechanism
Environmental media include water, air, soil, and biota (plants and animals). Transport mechanisms move contaminants from the source to points where human exposure can occur. The environmental media and transport mechanism is the second part of an exposure pathway.

EPA
United States Environmental Protection Agency.

Epidemiologic surveillance [see Public health surveillance].

Epidemiology
The study of the distribution and determinants of disease or health status in a population; the study of the occurrence and causes of health effects in humans.

Exposure
Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [acute exposure], of intermediate duration, or long-term [chronic exposure].

Exposure assessment
The process of finding out how people come into contact with a hazardous substance, how often

and for how long they are in contact with the substance, and how much of the substance they are in contact with.

Exposure-dose reconstruction
A method of estimating the amount of people's past exposure to hazardous substances. Computer and approximation methods are used when past information is limited, not available, or missing.

Exposure investigation
The collection and analysis of site-specific information and biologic tests (when appropriate) to determine whether people have been exposed to hazardous substances.

Exposure pathway
The route a substance takes from its source (where it began) to its end point (where it ends), and how people can come into contact with (or get exposed to) it. An exposure pathway has five parts: a source of contamination (such as an abandoned business); an environmental media and transport mechanism (such as movement through groundwater); a point of exposure (such as a private well); a route of exposure (eating, drinking, breathing, or touching), and a receptor population (people potentially or actually exposed). When all five parts are present, the exposure pathway is termed a completed exposure pathway.

Exposure registry
A system of ongoing followup of people who have had documented environmental exposures.

Feasibility study
A study by EPA to determine the best way to clean up environmental contamination. A number of factors are considered, including health risk, costs, and what methods will work well.

Geographic information system (GIS)
A mapping system that uses computers to collect, store, manipulate, analyze, and display data. For example, GIS can show the concentration of a contaminant within a community in relation to points of reference such as streets and homes.

Grand rounds
Training sessions for physicians and other health care providers about health topics.

Groundwater
Water beneath the earth's surface in the spaces between soil particles and between rock surfaces [compare with surface water].

Half-life (t½)
The time it takes for half the original amount of a substance to disappear. In the environment, the half-life is the time it takes for half the original amount of a substance to disappear when it is changed to another chemical by bacteria, fungi, sunlight, or other chemical processes. In the human body, the half-life is the time it takes for half the original amount of the substance to disappear, either by being changed to another substance or by leaving the body. In the case of radioactive material, the half life is the amount of time necessary for one half the initial number of radioactive atoms to change or transform into another atom (that is normally not radioactive). After two half lives, 25% of the original number of radioactive atoms remain.

Hazard
A source of potential harm from past, current, or future exposures.

Hazardous Substance Release and Health Effects Database (HazDat)
The scientific and administrative database system developed by ATSDR to manage data collection, retrieval, and analysis of site-specific information on hazardous substances, community health concerns, and public health activities.

Hazardous waste
Potentially harmful substances that have been released or discarded into the environment.

Health consultation
A review of available information or collection of new data to respond to a specific health question or request for information about a potential environmental hazard. Health consultations are focused on a specific exposure issue. Health consultations are therefore more limited than a public health assessment, which reviews the exposure potential of each pathway and chemical [compare with public health assessment].

Health education
Programs designed with a community to help it know about health risks and how to reduce these risks.

Health investigation
The collection and evaluation of information about the health of community residents. This information is used to describe or count the occurrence of a disease, symptom, or clinical measure and to evaluate the possible association between the occurrence and exposure to hazardous substances.

Health promotion
The process of enabling people to increase control over, and to improve, their health.

Health statistics review
The analysis of existing health information (i.e., from death certificates, birth defects registries, and cancer registries) to determine if there is excess disease in a specific population, geographic area, and time period. A health statistics review is a descriptive epidemiologic study.

Indeterminate public health hazard
The category used in ATSDR's public health assessment documents when a professional judgment about the level of health hazard cannot be made because information critical to such a decision is lacking.

Incidence
The number of new cases of disease in a defined population over a specific time period [contrast with prevalence].

Ingestion
The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see route of exposure].

Inhalation
The act of breathing. A hazardous substance can enter the body this way [see route of exposure].

Intermediate duration exposure
Contact with a substance that occurs for more than 14 days and less than a year [compare with acute exposure and chronic exposure].

In vitro
In an artificial environment outside a living organism or body. For example, some toxicity testing is done on cell cultures or slices of tissue grown in the laboratory, rather than on a living animal [compare with in vivo].

In vivo
Within a living organism or body. For example, some toxicity testing is done on whole animals, such as rats or mice [compare with in vitro].

Lowest-observed-adverse-effect level (LOAEL)
The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.

Medical monitoring
A set of medical tests and physical exams specifically designed to evaluate whether an individual's exposure could negatively affect that person's health.

Metabolism
The conversion or breakdown of a substance from one form to another by a living organism.

Metabolite
Any product of metabolism.

mg/kg
Milligram per kilogram.

mg/cm^2
Milligram per square centimeter (of a surface).

mg/m^3
Milligram per cubic meter; a measure of the concentration of a chemical in a known volume (a cubic meter) of air, soil, or water.

Migration
Moving from one location to another.

Minimal risk level (MRL)
An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified time period

(acute, intermediate, or chronic). MRLs should not be used as predictors of harmful (adverse) health effects [see reference dose].

Morbidity
State of being ill or diseased. Morbidity is the occurrence of a disease or condition that alters health and quality of life.

Mortality
Death. Usually the cause (a specific disease, a condition, or an injury) is stated.

Mutagen
A substance that causes mutations (genetic damage).

Mutation
A change (damage) to the DNA, genes, or chromosomes of living organisms.

National Priorities List for Uncontrolled Hazardous Waste Sites (National Priorities List or NPL)
EPA's list of the most serious uncontrolled or abandoned hazardous waste sites in the United States. The NPL is updated on a regular basis.

National Toxicology Program (NTP)
Part of the Department of Health and Human Services. NTP develops and carries out tests to predict whether a chemical will cause harm to humans.

No apparent public health hazard
A category used in ATSDR's public health assessments for sites where human exposure to contaminated media might be occurring, might have occurred in the past, or might occur in the future, but where the exposure is not expected to cause any harmful health effects.

No-observed-adverse-effect level (NOAEL)
The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.

No public health hazard
A category used in ATSDR's public health assessment documents for sites where people have never and will never come into contact with harmful amounts of site-related substances.

NPL [see National Priorities List for Uncontrolled Hazardous Waste Sites]

Physiologically based pharmacokinetic model (PBPK model)
A computer model that describes what happens to a chemical in the body. This model describes how the chemical gets into the body, where it goes in the body, how it is changed by the body, and how it leaves the body.

Pica
A craving to eat nonfood items, such as dirt, paint chips, and clay. Some children exhibit pica-related behavior.

Plume
A volume of a substance that moves from its source to places farther away from the source. Plumes can be described by the volume of air or water they occupy and the direction they move. For example, a plume can be a column of smoke from a chimney or a substance moving with groundwater.

Point of exposure
The place where someone can come into contact with a substance present in the environment [see exposure pathway].

Population
A group or number of people living within a specified area or sharing similar characteristics (such as occupation or age).

Potentially responsible party (PRP)
A company, government, or person legally responsible for cleaning up the pollution at a hazardous waste site under Superfund. There may be more than one PRP for a particular site.

ppb
Parts per billion.

ppm
Parts per million.

Prevalence
The number of existing disease cases in a defined population during a specific time period [contrast with incidence].

Prevalence survey
The measure of the current level of disease(s) or symptoms and exposures through a questionnaire that collects self-reported information from a defined population.

Prevention
Actions that reduce exposure or other risks, keep people from getting sick, or keep disease from getting worse.

Public availability session
An informal, drop-by meeting at which community members can meet one-on-one with ATSDR staff members to discuss health and site-related concerns.

Public comment period
An opportunity for the public to comment on agency findings or proposed activities contained in draft reports or documents. The public comment period is a limited time period during which comments will be accepted.

Public health action
A list of steps to protect public health.

Public health advisory
A statement made by ATSDR to EPA or a state regulatory agency that a release of hazardous substances poses an immediate threat to human health. The advisory includes recommended measures to reduce exposure and reduce the threat to human health.

Public health assessment (PHA)
An ATSDR document that examines hazardous substances, health outcomes, and community concerns at a hazardous waste site to determine whether people could be harmed from coming into contact with those substances. The PHA also lists actions that need to be taken to protect public health [compare with health consultation].

Public health hazard
A category used in ATSDR's public health assessments for sites that pose a public health hazard because of long-term exposures (greater than 1 year) to sufficiently high levels of hazardous substances or radionuclides that could result in harmful health effects.

Public health hazard categories
Public health hazard categories are statements about whether people could be harmed by conditions present at the site in the past, present, or future. One or more hazard categories might be appropriate for each site. The five public health hazard categories are no public health hazard, no apparent public health hazard, indeterminate public health hazard, public health hazard, and urgent public health hazard.

Public health statement
The first chapter of an ATSDR toxicological profile. The public health statement is a summary written in words that are easy to understand. The public health statement explains how people might be exposed to a specific substance and describes the known health effects of that substance.

Public health surveillance
The ongoing, systematic collection, analysis, and interpretation of health data. This activity also involves timely dissemination of the data and use for public health programs.

Public meeting
A public forum with community members for communication about a site.

Radioisotope
An unstable or radioactive isotope (form) of an element that can change into another element by giving off radiation.

Radionuclide
Any radioactive isotope (form) of any element.

RCRA [see Resource Conservation and Recovery Act (1976, 1984)]

Receptor population
People who could come into contact with hazardous substances [see exposure pathway].

Reference dose (RfD)
An EPA estimate, with uncertainty or safety factors built in, of the daily lifetime dose of a substance that is unlikely to cause harm in humans.

Registry
A systematic collection of information on persons exposed to a specific substance or having specific diseases [see exposure registry and disease registry].

Remedial investigation
The CERCLA process of determining the type and extent of hazardous material contamination at a site.

Resource Conservation and Recovery Act (1976, 1984) (RCRA)
This Act regulates management and disposal of hazardous wastes currently generated, treated, stored, disposed of, or distributed.

RFA
RCRA Facility Assessment. An assessment required by RCRA to identify potential and actual releases of hazardous chemicals.

RfD [see reference dose]

Risk
The probability that something will cause injury or harm.

Risk reduction
Actions that can decrease the likelihood that individuals, groups, or communities will experience disease or other health conditions.

Risk communication
The exchange of information to increase understanding of health risks.

Route of exposure
The way people come into contact with a hazardous substance. Three routes of exposure are breathing [inhalation], eating or drinking [ingestion], or contact with the skin [dermal contact].

Safety factor [see uncertainty factor]

SARA [see Superfund Amendments and Reauthorization Act]

Sample
A portion or piece of a whole. A selected subset of a population or subset of whatever is being studied. For example, in a study of people the sample is a number of people chosen from a larger population [see population]. An environmental sample (for example, a small amount of soil or water) might be collected to measure contamination in the environment at a specific location.

Sample size
The number of units chosen from a population or an environment.

Solvent
A liquid capable of dissolving or dispersing another substance (for example, acetone or mineral spirits).

Source of contamination
The place where a hazardous substance comes from, such as a landfill, waste pond, incinerator, storage tank, or drum. A source of contamination is the first part of an exposure pathway.

Special populations
People who might be more sensitive or susceptible to exposure to hazardous substances because of factors such as age, occupation, sex, or behaviors (for example, cigarette smoking). Children, pregnant women, and older people are often considered special populations.

Stakeholder
A person, group, or community who has an interest in activities at a hazardous waste site.

Statistics
A branch of mathematics that deals with collecting, reviewing, summarizing, and interpreting data or information. Statistics are used to determine whether differences between study groups are meaningful.

Substance
A chemical.

Substance-specific applied research
A program of research designed to fill important data needs for specific hazardous substances identified in ATSDR's toxicological profiles. Filling these data needs would allow more accurate assessment of human risks from specific substances contaminating the environment. This research might include human studies or laboratory experiments to determine health effects resulting from exposure to a given hazardous substance.

Superfund [see Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and Superfund Amendments and Reauthorization Act (SARA)

Superfund Amendments and Reauthorization Act (SARA)
In 1986, SARA amended the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and expanded the health-related responsibilities of ATSDR. CERCLA and SARA direct ATSDR to look into the health effects from substance exposures at hazardous waste sites and to perform activities including health education, health studies, surveillance, health consultations, and toxicological profiles.

Surface water
Water on the surface of the earth, such as in lakes, rivers, streams, ponds, and springs [compare with groundwater].

Surveillance [see public health surveillance]

Survey
A systematic collection of information or data. A survey can be conducted to collect information from a group of people or from the environment. Surveys of a group of people can be conducted by telephone, by mail, or in person. Some surveys are done by interviewing a group of people [see prevalence survey].

Synergistic effect
A biologic response to multiple substances where one substance worsens the effect of another substance. The combined effect of the substances acting together is greater than the sum of the effects of the substances acting by themselves [see additive effect and antagonistic effect].

Teratogen
A substance that causes defects in development between conception and birth. A teratogen is a substance that causes a structural or functional birth defect.

Toxic agent
Chemical or physical (for example, radiation, heat, cold, microwaves) agents that, under certain circumstances of exposure, can cause harmful effects to living organisms.

Toxicological profile
An ATSDR document that examines, summarizes, and interprets information about a hazardous substance to determine harmful levels of exposure and associated health effects. A toxicological profile also identifies significant gaps in knowledge on the substance and describes areas where further research is needed.

Toxicology
The study of the harmful effects of substances on humans or animals.

Tumor
An abnormal mass of tissue that results from excessive cell division that is uncontrolled and progressive. Tumors perform no useful body function. Tumors can be either benign (not cancer) or malignant (cancer).

Uncertainty factor
Mathematical adjustments for reasons of safety when knowledge is incomplete. For example, factors used in the calculation of doses that are not harmful (adverse) to people. These factors are applied to the lowest-observed-adverse-effect-level (LOAEL) or the no-observed-adverse-effect-level (NOAEL) to derive a minimal risk level (MRL). Uncertainty factors are used to account for variations in people's sensitivity, for differences between animals and humans, and for differences between a LOAEL and a NOAEL. Scientists use uncertainty factors when they have some, but not all, the information from animal or human studies to decide whether an exposure will cause harm to people [also sometimes called a safety factor].

Urgent public health hazard
A category used in ATSDR's public health assessments for sites where short-term exposures (less than 1 year) to hazardous substances or conditions could result in harmful health effects that require rapid intervention.

Volatile organic compounds (VOCs)
Organic compounds that evaporate readily into the air. VOCs include substances such as benzene, toluene, methylene chloride, and methyl chloroform.

Other glossaries and dictionaries:
Environmental Protection Agency (http://www.epa.gov/OCEPAterms/)
National Center for Environmental Health (CDC)
(http://www.cdc.gov/nceh/dls/report/glossary.htm)
National Library of Medicine (NIH)
(http://www.nlm.nih.gov/medlineplus/mplusdictionary.html)

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Appendix H. Responses to Public Comments on the Spring Valley Community Health Consultation

The Agency for Toxic Substances and Disease Registry (ATSDR) received the following comments from the public and local organizations during the public comment period (February 14 to April 29, 2005). For comments that questioned the validity of statements made in the Health Consultation, ATSDR verified or corrected the statements. The list of comments does not include comments that were strictly editorial in nature, but ATSDR addressed such comments as appropriate.

General

Comment: Overall, the report seemed accurate in its statements, particularly in reference to the need for additional soil, soil gas, and groundwater sampling. At present, many data gaps exist in our understanding of contamination at Spring Valley. The commenter agrees with ATSDR's recommendations that additional study is required to accurately determine risks to public health.

> **ATSDR Response:** ATSDR acknowledges this comment. Though data gaps exist, ATSDR believes that available data do allow conclusions to be drawn about potential community exposures and health hazards.

Comment: The health consultation does not seem to capture all of the events that have taken place in recent decades, specifically investigations undertaken by the Army prior to 1993. The events prior to 1993 could shed light on possible health risks associated with unremediated properties. Expanding the time period evaluated could also provide a clearer picture of health effects associated with contaminants at the Spring Valley FUDS. Epidemiological evaluations are incomplete without these data.

> **ATSDR Response:** The health consultation is not an epidemiological evaluation. Its purpose is to review available exposure and health effects data to determine if potentially harmful exposures have occurred, are occurring, or could occur in the future and to identify the need for further study or action.
>
> ATSDR states in Section II (Introduction and Purpose) the scope and purpose of this health consultation. ATSDR documented that the health consultation focuses primarily on environmental and health data collected after 1999 because prior data had been the focus of earlier ATSDR evaluations. These earlier evaluations are provided on ATSDR's Spring Valley Web site, www.atsdr.cdc.gov/sites/springvalley, and are summarized in Appendix A. Nonetheless, to complete as comprehensive an exposure assessment as possible—especially in responding to community health concerns—ATSDR examined multiple data sets.
>
> As discussed in Section IV, ATSDR reviewed the types of contaminants disposed on site and provided an overview of environmental sampling results, with emphasis on identifying potential exposure points (e.g., surface soil, indoor air)—both past and

present. The purpose of this exercise was to identify whether elevated levels of any contaminants were or could be present in locations accessible to area residents. In the absence of historical data, ATSDR based its conclusions on exposure on more recent sampling data, disposal patterns, and our understanding of the breakdown of buried and near surface waste materials. Conclusions were drawn in light of acknowledged uncertainties (see next comment).

Comment: The health consultation focused primarily on arsenic, without as much emphasis on chemical warfare material (CWM) or the products associated with the breakdown of chemical warfare agents beyond arsenic. Several metals not routinely sampled at the site such as lead and mercury could potentially pose significant risks to public health. The nature and toxicity of many sulfur mustard breakdown products is still uncertain. While it is acknowledged that there are limited data on which ATSDR can make its recommendations regarding these compounds, the report fails to clearly identify and evaluate these uncertainties in its conclusions.

ATSDR Response: The health consultation is purposely focused on arsenic because of its known presence and persistence in soils, and because of its toxicity. For this reason, arsenic became the focal point for ongoing site investigations, and the data from the arsenic investigations served as the primary source of data for this evaluation. ATSDR did, however, also review the subset of soil samples that were tested for a broader suite of chemicals (e.g., AUES list chemicals, VOCs, SVOCs, metals).

ATSDR believes the health consultation does clearly identify what is and is not known about the nature and extent of non-arsenic contaminants. ATSDR clearly acknowledges in the summary (page 3), discussion of contaminants of potential concern (Section IV), health effects assessment (Section V), and conclusions (Section VIII) that uncertainties remain about the presence and levels of non-arsenic contaminants in surface soil, and that some of the data provide only a snapshot in time and place.

As stated in the text, although only a limited amount of sampling data is available to answer questions about potential exposures to non-arsenic contaminants, our understanding of the behavior and toxicity of AUES-related contaminants provides some insights. Much of the discussion in Section IV is aimed at providing perspective on what is and is not known about the persistence and migration potential of CWM and CWM breakdown products. The section titled “What are the general characteristics of AUES-related contaminants and what does that mean about exposure potential?” and Appendix B describe the environmental fate of contaminants of potential concern. In addition, ATSDR discussed the toxicity of detected CWM in Appendix E (pages E-13 through E-19).

Because much of the information identified in the scientific literature suggests a relatively low likelihood that CWM would persist in surface soil and the relative low toxicity of breakdown products, we are provided some assurances that exposure potential to harmful levels of CWM is low. In cases where persistence or migration potential are less certain, ATSDR has recommended further investigation. Acknowledging the absence of comprehensive surface soil data for CWM, CWM breakdown products, and elements other than arsenic, ATSDR recommends additional sampling to validate the conclusions

of the health consultation. As such, ATSDR believes the health consultation does acknowledge and address the uncertainties highlighted in this comment.

Comment: Some of the conclusions and statements in the document are not well supported by the data; some of the statements have remarkably little data. ATSDR determined that elevations of arsenic and chemical warfare agents pose "No Apparent Public Health Hazard," despite several instances where soil sampling detected extremely high levels of arsenic (in several instances greater than 1,000 ppm). Arsenic levels within the range found at several properties are more than sufficient to pose a hazard to an individual's health. While these levels have not found to be widespread, additional testing is still required (particularly at depth) to assess the true extent of soil contamination at the site. Until the entire site is sampled, the possibility exists that some areas may still be contaminated at unacceptable levels. The continued presence of high levels of contaminants at some properties cannot be classified as "No Apparent Public Health Hazard."

ATSDR Response: ATSDR disagrees that our conclusions are not well supported by the data. ATSDR based its conclusions on the close examination of available environmental sampling and exposure data. ATSDR's exposure assessment process involves identifying the ways in which people may come in contact with site-related contaminants. At Spring Valley, contact with *surface* soil is the predominant exposure pathway. Widespread testing of surface soils for arsenic has occurred. Figure 3 shows that arsenic levels in surface soil are elevated in a relatively low subset of the many Spring Valley properties sampled. As discussed in detail in Section V (Health Effects Assessment) and Appendix E, detected arsenic levels even in the most contaminated yard (up to 529 ppm) fall below those at which adverse health effects are expected to occur. ATSDR's "no apparent public health hazard" is further supported by the findings of exposure investigations, which revealed that arsenic levels in the hair and urine of residents living on properties with the highest arsenic levels were not elevated. In addition, detected levels of contaminants other than arsenic in tested samples fell below health-based screening values for adverse effect levels.

We agree that higher arsenic detections were found in *subsurface* soil. However, contact with soils at depth is not occurring and therefore poses no hazard from a public health perspective.

Ongoing site investigations will provide additional information on soil contaminants. The USACE has indicated that ATSDR recommendations fit in with already identified data needs, with the focus on CWM and CWM breakdown products. At the March 2005 partnering meeting, the partners agreed to develop a plan to address ATSDR recommendations for additional soil, soil gas, and groundwater sampling. If requested, ATSDR will review newly released data.

Comment: The report gives the impression that ATSDR conducted an exhaustive survey of CWM at the Spring Valley site when this is not the case. Although no CWM have been found outside any of the identified burial pits thus far, there is still the possibility that other CWM may be located in the future; the geotechnical investigations and Lot 18 work are investigating CWM.

Investigations are still being conducted to determine the location and the potential for CWM at the Rick Woods site. Greater transparency is required on this issue.

> **ATSDR Response:** ATSDR believes the health consultation is transparent on the issue of potential hazards associated with any remaining buried CWM. ATSDR states that "any remaining chemical warfare materials, other chemicals, explosives, etc…could pose a chemical or physical hazard if disturbed." In Section VIII (Conclusions), conclusion #4 reiterates this point and recognizes the unknown nature of any possible remaining wastes. In Section IX (Recommendations), under Community Activities, ATSDR emphasizes the importance of ongoing USACE activities associated with identifying and rapidly removing any remaining buried materials and for community members to immediately alert USACE should they find any suspicious objects. We have added text earlier in the document (page 3) to more clearly state that ATSDR is referring to possible newly discovered areas, as well already identified areas of buried CWM.

Specific Comments

Comment: A map of the Spring Valley site should be included in Section III to aid in the reference of previous army activities.

> **ATSDR Response:** Figure 2 shows Spring Valley "points of interest," which relate directly to previous Army activities. No additional figure has been included.

Comment: Page 12, line 11: "USACE removed 160 55-gallon barrels filled with soil, glass, and metal debris" should be changed to "USACE removed soil, glass, and metal debris from the general vicinity of Lot 18, enough to fill 160 55-gallon barrels." At present, the language leaves the impression that the barrels were dug out of the ground.

> **ATSDR Response:** ATSDR modified the text as suggested.

Comment: Page 12, lines 25-26: "Testing of residential soils in the Spring Valley neighborhood has shown composite soil levels of arsenic ranging from background to approximately 202 ppm." This statement is at least misleading. Several soil samples cited later in this report were found to have arsenic concentrations greatly exceeding 1,000 ppm.

> **ATSDR Response:** As stated in our responses to the general comments above, ATSDR's exposure evaluation is centered on contamination found in *surface* soils, and the possible implications of short and longer terms exposure to the detected arsenic levels in Spring Valley surface soils. In discussing overall site conditions, ATSDR describes the presence of higher detections of arsenic in subsurface soil. Text on page 12 and at the beginning of Section V has been revised to make better distinctions between surface and subsurface soil findings and to present more clearly ATSDR's approach in evaluating soil exposures.

Comment: Page 15, lines 14-17: "If a contaminant has not been reported at levels greater than its comparison value… ATSDR examines those contaminants more closely." This approach has many flaws. New data are continually being gathered on compounds such as lead and mercury, quickly making comparison values based on old data obsolete. Several compounds, including some analyzed by ATSDR during the course of this consultation have no comparison value.

Comparison values are limited to EPA Region III risk based values, or EPA IRIS values, or other regulatory numbers that do not well consider long term exposure to children, the elderly and persons with chronic health conditions (heart problems and immune challenges). A more thorough approach is required that utilizes the most up to date information and includes site specific information such as the potential for harmful interactions between metals that increases toxicity.

ATSDR Response: ATSDR fully agrees that the best science needs to be used in such evaluations and adheres to this principle as part of our public health assessment process. ATSDR followed the standard ATSDR health assessment approach when evaluating Spring Valley environmental contamination data. This approach involves several layers of analysis. As a first screen, ATSDR compiles environmental data and compares maximum detected concentrations in a given medium (e.g., soil, water) to available "comparison values," which are screening guidelines set well below levels that are known or anticipated to result in adverse health effects. Screening values are generally derived based on the most sensitive endpoint across reliable study data; uncertainty or safety factors also are applied (generally factors of 10) to account for sensitive subpopulations, differences across species, and other uncertainties. This approach renders comparison values that are typically 10-1,000+ times lower than those shown in underlying study data to cause adverse effects.

ATSDR relies on screening values derived by ATSDR itself first and then looks for values from other authoritative agencies or scientific bodies if no ATSDR value is available (e.g., EPA, state agencies, and in the case of Spring Valley the U.S. Army). ATSDR and other agencies update screening values on a relatively regular basis based on review of newly released toxicological/epidemiological data. ATSDR recognizes that new data often emerge prior to screening value updates, but feels reasonably confident that existing values serve their purpose as a conservative first screen. For those contaminants detected at levels greater than available screening values or for which no screening values exist, ATSDR performs a more in-depth evaluation. In doing so, ATSDR reviews data from the scientific literature. For the Spring Valley evaluation, ATSDR relied heavily on toxicity data in the primary literature, and available through the National Academy of Sciences, National Research Council, and the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM). Further, because of the health concerns expressed by the Spring Valley community, ATSDR conducted a comprehensive literature search on arsenic and on CWM, especially looking for links between levels of exposure to Spring Valley contaminants and the diseases and conditions that the community was most concerned about. Our findings are discussed in Appendices D and E. Appendix D presents general information on the predominant diseases and conditions of community concern to provide additional perspective on the nature and prevalence of these diseases, including information on risk factors, sensitive populations, etc. Appendix E compares site-specific dose estimates to doses shown in the literature to cause adverse health outcomes.

Comment: Page 16, lines 23-25: "The more degradable arsenic-containing warfare agents… which can persist in the environment." This statement should note that inorganic forms of arsenic

persist indefinitely in the environment. Other metals that remain indefinitely in soil—such as lead, mercury, tin, and titanium—should also be noted.

> **ATSDR Response:** ATSDR agrees. The persistence of arsenic forms the primary basis for ATSDR's approach to the Spring Valley assessment and its recommendations. ATSDR added the word "indefinitely" to the referenced sentence. Because of their known persistence and detections in surface disposal areas, ATSDR recommended that lead and mercury be tested as part of ongoing soil investigations.

Comment: Page 18, lines 10-11: "For example… hydrogen chloride (or bleach) can dechlorinate it." This statement implies that hydrogen chloride is bleach, which is not true. HCl is hydrochloric acid, and bleach is sodium hypochlorite.

> **ATSDR Response:** ATSDR has corrected the text to read "…hypochlorite solutions (e.g., bleach)…"

Comment: Page 21, lines10-13: "Although ATSDR does not have a comparison value for thiodiglycol…thiodiglycol has low toxicity to people and most people have limited contact with these deeper soils." Where is the USACE standard of 39.1 ppm reported? This value has not been reported elsewhere in previous USACE documents pertaining to Spring Valley. Additionally, how is ATSDR evaluating thiodiglycol without a comparison value? Without documentation of the context for USACE standard, the consequences of long-term lower level exposure remain unclear.

> **ATSDR Response:** ATSDR identified USACE's action level of 39.1 ppm in the Engineering Evaluation/Cost Analysis for Arsenic in Soil (Parsons 2004) and included it as a point of reference in the absence of other available screening values for thiodiglycol (TDG). The standard was reportedly developed as part of the 1995 Remedial Investigation. As presented in Appendix E (page E-18), ATSDR reviewed the available scientific literature to evaluate TDG more fully. As noted, TDG does not retain the vesicant property of HD and is considered relatively nontoxic upon acute exposure (Munro et al. 1999). ATSDR acknowledges that little longer-term toxicity data are available for TDG. However, the USACHPPM estimated a reference dose (RfD) of 0.5 mg/kg/day for TDG based on a no-observed-adverse-effect-level (NOAEL) of 500 mg/kg/day in a subchronic oral toxicity study in rats (Munro et al. 1999). Estimated doses associated with incidental ingestion of 0.813 ppm TDG (the highest concentration detected in surface soil at Spring Valley) would equal 0.00001 mg/kg/day (child) and 0.000001 mg/kg/day (adult); this is thousands of times lower than the USACHPPM RfD and more than a million times lower than the NOAEL, the level at which no adverse effects are observed.
>
> Nonetheless, ATSDR added some clarifying text to Appendix E to emphasize that very little data exist on which to evaluate the longer-term toxicity of TDG; however, the concentrations of TDG detected at Spring Valley are well below those shown to cause acute or subchronic effects in available studies. ATSDR believes this offers perspective on how low the detected TDG concentrations are and the very low likelihood of harmful effects.

Comment: Page 22, lines 12-14: "The form of phosphorous detected in site soils is not specified… levels are lower than those expected to cause harmful effects." As stated in Appendix E, these levels exceed the recommended exposure dose for children for white phosphorous. While the form of phosphorous found in the samples is not known, the report later states munitions containing white phosphorous have been found at Spring Valley (page 29, lines 18-19). Therefore there is a potential risk for adverse effects to public health from phosphorous.

> **ATSDR Response:** ATSDR based its conclusions on the weight of the available evidence. The form of phosphorous was not specified in laboratory reports. However, ATSDR's discussion in Appendix E explains that even assuming the presence of 100% white phosphorous (the most toxic form) estimated site-related doses only begin to approach those at which harmful effects have been reported. ATSDR argues that it is highly unlikely that the total phosphorous reported in available data sets is solely white phosphorous.

Comment: Page 28, lines 9-10: "USACE plans further soil removal at 4835 Glenbrook Road." Soil removal is also planned in the pit at 4835 as well as at 4825 Glenbrook Road.

> **ATSDR Response:** ATSDR revised the text to include additional areas where soil removals are planned or underway.

Comment: Page 29, lines 14-15: "The other area was on American University Lot 18 with potential extension onto American University rental properties on Rockwood Parkway." This investigation is far from complete—it is underway at present and not scheduled for completion before early 2006.

> **ATSDR Response:** The text does not imply that the Lot 18 investigation is complete, but the text has been revised to clarify further the status of the investigation.

Comment: Page 31, lines 6-9: "Concentrations of arsenic dust ranged from not detected to 63 ppm… which is lower than the soil clean-up level of 20 ppm." The highest value of 63 ppm is above health screening levels. Additionally, it is difficult to compare the average dust concentration of 9.9 ppm with the soil clean-up level of 20 ppm. Household dust is more readily disturbed and is generally more available for exposure than outdoor soils. Particles are generally smaller and more easily inhaled, and people are generally more likely to be exposed to the dust through daily activity such as vacuuming. The commenter therefore disagrees with the statement that exposure to household dust is not a concern.

> **ATSDR Response:** ATSDR agrees that, as written, this statement does not fully describe the basis for the conclusion that detected dust levels are not of public health concern. ATSDR based this conclusion on the overall findings of the 2002 exposure investigation, which measured arsenic levels in household dust and in the urine and hair of residents of those households. Only three individuals showed detectable arsenic levels, even in the home with the highest arsenic dust concentrations (63 ppm). The conclusions of that investigation were as follows:

- Urine and hair arsenic testing show low levels of arsenic exposure in the tested population.
- These levels would not be expected to cause health problems.
- Small amounts of arsenic are present in the dust of some homes in the Spring Valley neighborhood.
- It is not clear whether the small elevations of inorganic arsenic in the three individuals are related to soil or dust arsenic contamination, or represent dietary intake of arsenic.

As a prudent public health measure, however, ATSDR did recommend that exposures be decreased in and outside the house where the highest concentrations were detected.

To put these findings in better context within the health consultation, ATSDR combined the discussions of dust, hair, and urine sampling results.

Comment: Page 34, lines 1-8: "ATSDR reviewed arsenic monitoring results… These arsenic in drinking water pose no health concern and present no notable additional source of arsenic exposure for Spring Valley residents." This text is incomplete to the point of being wrong. There are little data on the effect of exposures of low levels of arsenic over long periods of time.

ATSDR Response: ATSDR acknowledges that more scientific data are needed to better understand the possible effects of low-level long-term exposures to arsenic. This is clearly stated in Appendix E (e.g., "much uncertainty still exists regarding the effects caused by arsenic at relatively low environmental exposures, such as those associated with the Spring Valley site). ATSDR also explains in Section V (page 39) the uncertainties of how our bodies handle and detoxify low doses of arsenic. However, these uncertainties do not affect the conclusion drawn about the drinking water supply. In fact, the uncertainties about arsenic indirectly lend support to the statement. The arsenic levels in the Dalecarlia finished water have consistently been reported below EPA's maximum contaminant level (MCL) of 0.01 ppm. EPA's Arsenic Rule finalized in 2002 established the 0.01 ppm limit largely to account for uncertainties associated with low dose exposures and uncertainties about how our bodies handle low levels. ATSDR, therefore, still believes that exposures to detected arsenic in drinking water (generally less than 0.004 ppm) present no notable additional source of arsenic exposure for Spring Valley residents.

Comment: Page 36, lines 16-22: "To study possible health effects…doses reported in the scientific literature that are associated with harmful effects." This paragraph does not mention historical doses. Exposures may have changed over the years, leading to significant variations in concentrations of contaminants that individuals have been exposed to.

ATSDR Response: Historical doses cannot be easily recreated. Our understanding of the characteristics of site contaminants, coupled with available environmental sampling results, provides a reasonable data set on which to base our public health conclusions. As

noted in previous comments, arsenic is very persistent; levels of inorganic arsenic would not be expected to change over time. Though ATSDR understands that the parent CWM is highly toxic, most is rapidly degraded to less toxic forms especially in the presence of water and light at the ground's surface. Contained or buried waste remains a concern if disturbed, as stated in the health consultation.

Comment: Page 37, lines 8-14: "Soil intake… approximately one teaspoon/day)." What is the distribution and confidence interval for this data?

ATSDR Response: As indicated in the health consultation, the source of the soil intake values is the U.S. EPA's Exposure Factors Handbook (EPA 1997b). EPA (1997b) presents the results of various studies using tracer methods to estimate the amount of soil ingested by children at different ages, with different behavior patterns. Wide ranges of values are reported, with mean values for soil ingestion among children ranging from 39 mg/day to 271 mg/day, with an average of 146 mg/day for soil ingestion and 191 mg/day for soil and dust ingestion. Upper percentile values ranged from 106 mg/day to 1,432 mg/day, with an average of 383 mg/day for soil ingestion and 587 mg/day for soil and dust ingestion. EPA recommends 100 mg/day as a mean intake value and an upper percentile intake of 400 mg/day. ATSDR's standard soil intake rate for children is 200 mg/day.

Fewer studies are available to estimate soil ingestion rates among adults; these studies indicate exposures ranging from 0.56 to 110 mg/day. EPA recommends a mean value of 50 mg/day be used to assess adult soil exposures; ATSDR policy calls for using an intake rate of 100 mg/day.

Comment: Page 37, footnote 1: "Note that arsenic concentrations detected… Spring Valley neighborhood." It should be stated at what depth the soil samples were taken.

ATSDR Response: The sentence has been modified to indicate that we are referring to surface soils.