Health Consultation

PUBLIC COMMENT RELEASE

SPRING VALLEY CHEMICAL MUNITIONS

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U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

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

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members.

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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Public Comment Release

Health Consultation

Public Health Evaluation

for the

Spring Valley Community

Washington, D.C.

February 7, 2005

Prepared by
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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 and other contaminants in soil, indoor dust and air, and drinking water. 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.*

- ***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. 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*

> 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.

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) *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.

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 chemical warfare agents, their breakdown products, as well as other 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. 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, the District of Columbia Department of Health could evaluate the incidence and mortality rates for leukemia by census tract, and compare with an area of similar demographics to determine any excess rates of disease.

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.

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 finding, 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 and 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 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 160 55-gallon barrels filled with soil, glass, and metal debris. 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 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.

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, and developed a health surveillance program in 2002.

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 AUES-related contaminants and what does that tell us about exposure potential?

Chemical warfare agents used and/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 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 hydrogen chloride (or bleach) can dechlorinate it (ATSDR 2003a; Morrill et al. 1985; Munro et al. 1999; NLM 2004; 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 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).

- Some residents who reported health concerns lived on properties where arsenic concentrations as high as 85 ppm were reported in surface soil. But surface samples collected from many other residents reporting health concerns were not elevated (e.g., arsenic concentrations in surface soil were within the typical background range).

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.

***** USACE has 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. It was detected in 9 out 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, the detected concentrations are well below the USACE standard of 39.1 ppm. Furthermore, thiodiglycol 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 not at harmful levels.
**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 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 area was 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.

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.

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 (μg/m^3). ATSDR's comparison value is 0.0002 μg/m^3. The minimal detectable concentration for this study was 0.05 μg/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 μg/m^3. The outdoor PM10 concentration was slightly higher at 0.0008 μg/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 settled indoor dust?

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. The average was 9.9 ppm of arsenic in dust from those households tested, which is lower than the soil clean-up level of 20 ppm (ATSDR 2001a; ATSDR 2002b). Exposure to these dust levels is, therefore, not considered a health concern. Further, as discussed below, hair and urine testing of residents living in these homes confirmed that harmful exposures were not occurring.

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 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 elevated 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 collected urine and hair samples from 32 individuals (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 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 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 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.

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.

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 soil exposures, but also addresses indoor air/dust exposures. ATSDR focuses on arsenic in soil because, as discussed earlier, inorganic arsenic is the most persistent degradation product of the organic arsenicals (e.g., lewisite) and is detected in some Spring Valley soils at elevated concentrations. 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 "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.

[1] Note that arsenic concentrations detected in 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.

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 below, 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. ATSDR's evaluation of possible health effects related to arsenic is discussed further in Appendix E.

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
85	Chronic ingestion	0.0005	0.00006	0.014	28

See Appendix E for dose equation and further discussion.

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.

Our Body's Ability to Detoxify Arsenic

As noted in the text, our body's 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).[2] 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)

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

[2] 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.

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.[3]

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

[3] 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.

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).

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 then 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 1,000) was a little 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.

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[4]

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.

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

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.) Even so, ATSDR has discussed evaluation of these health conditions with the DC DOH (personal communication with DC DOH representative, August 24, 2004 and February 4, 2005). The District of Columbia Department of Health could evaluate the incidence and mortality rates for leukemia by census tract, and compare with an area of similar demographics to determine any excess rates of disease. 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.

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 (greater than 20 ppm).

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 suggests 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 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.

- *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. Due to 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

- 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, the District of Columbia Department of Health could evaluate the incidence and mortality rates for leukemia by census tract, and compare with an area of similar demographics to determine any excess rates of disease. No widespread occurrence of contamination and exposure to contamination that would lead to leukemia or other adverse health effects has been found.

- 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 conducted health surveillance in Spring Valley. In addition, the agency 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.

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. 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.

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

6. 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.

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

8. 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.

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

Planned Actions by DC DOH and USACE

1. USACE plans to continue soil removals in the Spring Valley community over the next few years and to continue with some environmental sampling and geophysical surveys to identify any remaining buried hazardous materials. Further sampling at 4835 Glenbrook Road is planned. They are also conducting groundwater monitoring for contaminants in the Spring Valley area.

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XII. References

Apex Environmental Inc. 1996. Final Report (Apex Project No. 153.009) conducted on President's Residence, 4835 Glenbrook Road, Washington, D.C. 20016, Prepared for American University, Rockville, MD.

[ATSDR] Agency for Toxic Substances and Disease Registry. 1997. Toxicological profile for white phosphorus. Atlanta: U.S. Department of Health and Human Services.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2000a. Case studies in environmental medicine—arsenic toxicity. Course SS3060. Revision date: October 2000. Expiration date: October 20, 2003. Atlanta: U.S. Department of Health and Human Services.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2000b. Toxicological profile for arsenic. Atlanta: U.S. Department of Health and Human Services.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2001a. Health consultation—exposure investigation regarding Spring Valley. Atlanta: U.S. Department of Health and Human Services.

[ATSDR]. Agency for Toxic Substances and Disease Registry. 2001b. July 25 response letter to Theodore Gordon regarding DC DOH request for additional biomonitoring testing.

[ATSDR]. Agency for Toxic Substances and Disease Registry. 2001c. September 23 response letter to Gerald Williams regarding the petition for public health assessment, American University Experiment Station, Spring Valley Site, Washington, D.C.

[ATSDR]. Agency for Toxic Substances and Disease Registry. 2002a. July 1 response letter to Richard Lewis on the supplemental request for petition for public health assessment, American University Experiment Station, Spring Valley Site, Washington, D.C.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2002b. June 28 Health Consultation (Exposure Investigation) Spring Valley Neighborhood, Washington, D.C.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2003a. Toxicological profile for sulfur mustard (update). Atlanta: U.S. Department of Health and Human Services. September 2003.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2003b. November 7 letter to Ms. Bridgham, Esq. on clean-up standards at the Child Development Center.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2003c. Health Consultation: Evaluation of Indoor Air Sampling , 4625 Rockwood Parkway, American University Experiment Station/Spring Valley, Washington, D.C.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2003d. June 11 Health Consultation (Exposure Investigation-Phase II) Spring Valley Neighborhood, Washington, D.C.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2003e. Safe gardening, safe play, and a safe home, an interim guide to reducing arsenic exposure in Spring Valley. Released July 2003.

Battelle and Exponent. 2002. Guide for incorporating bioavailability adjustments into human health and ecological risk assessments at U.S. Navy and Marine Corps facilities. Part 1: Overview metals bioavailability.

Brenniman, GR, Levy, PS. 1984. Epidemiological study of barium in Illinois drinking water supplies. In: Advances in modern toxicology, Calabrese, EJ, Ed. Princeton, NJ:Princton Scientific Publications, pp. 231-249.

Chang LW, Magos L, Suzuki T eds. 1996. Toxicology of metals. Boca Raton: CRC Press.

Chung J, Kalman, D, Moore L et al. 2002. Family correlations of arsenic methylation patterns in children and parents exposed to high concentrations of arsenic in drinking water. Environ Health Perspect 110(7):729–33.

Cohen, Milsten, Hausfeld & Toll, P.L.L.C. 2002. April 25 letter from Richard Lewis to ATSDR Petition Coordinator regarding supplemental request for petition for public health assessment, American University Experiment Station, Spring Valley Site, Washington, DC.

[DC DOH] District of Columbia, Department of Health. 1999. Cancer Atlas of the District of Columbia. District of Columbia Cancer Registry. Bureau of Epidemiology and Health Risk Assessment.

[DC DOH] District of Columbia Department of Health. 2001a. June 15 letter from Theodore Gordon to Dr. Henry Falk regarding request for additional biomonitoring testing.

[DC DOH] District of Columbia Department of Health. 2001b. Descriptive epidemiological study of cancers associated with arsenic in the Spring Valley Area of Washington, DC.

[DC DOH] District of Columbia, Department of Health. 2002. Descriptive epidemiological analyses of cancers in the Spring Valley Area of Washington, DC.

[EPA] Environmental Protection Agency. 1997a. American University, Bunker Operation Analytical Summary, Spring Valley Chemical Munitions, Washington, D.C. TDD#9501-012A, PCS# 1316. Philadelphia, Pennsylvania.

[EPA] United States Environmental Protection Agency. 1997b. Exposure factors handbook. Washington, DC: National Center for Environmental Assessment; EPA/600/P-95/–2Fa. Available at: http://www.epa.gov/ncea/pdfs/efh/front.pdf. Last accessed August 19, 2003.

[EPA] U.S. Environmental Protection Agency. 1999. Draft risk assessment report. Washington D.C., Army Munitions Site, Spring Valley. October 1999.

[EPA] U.S. Environmental Protection Agency. 2002. Draft guidance for evaluating the vapor intrusion to indoor air pathway form groundwater and soils (subsurface vapor intrusion guidance). November 29, 2002. Available at: http://www.epa.gov/correctiveaction/eis/vapor.htm. Last accessed: August 14, 2004.

[ERDEC] Edgewood Research, Development & Engineering Center, Aberdeen Proving Ground, Maryland--Operation Safe Removal: Spring Valley, Washington, D.C., Analytical Results: January-February 1993. ERDEC-SP-008. July 1993.

Freeland-Graves, JH, Bales, CW and Behmardi, F. 1987. Manganese requirements of humans. In: Nutitional Bioavailability of Manganese, C. Kies, ed. American Chemical Society, Washington, DC. P. 90-104.

Henriksson J, Johannisson A, Bergqvist PA, Norrgren L. 1996. The toxicity of organoarsenic-based warfare agents: in vitro and in vivo studies. Arch Environ Contam Toxicol 30(2):213–19.

Institute of Medicine. 1999. Dietary Reference Intakes for Calcium, Phosphorus, Magnesium, Vitamin D, and Fluoride (Chapter 5 Phosphorus). Standing Committee on the Scientific Evaluation of Dietary Reference Intakes, Food and Nutrition Board. National Academy Press.

Jaffe H. 2000. Ground zero. Washingtonian, December.

Morrill LG, Reed LW, Chinn KSK. 1985. Toxic chemicals in the soil environment: volume 2. Interactions of some toxic chemicals/chemical warfare agents and soils. U.S. Army Dugway Proving Ground. TECOM Project 2-CO-210-049. June 1985.

Munro NB, Talmage SS, Griffin GD, Waters LC, Watson AP, King JF, et al. 1999. The sources, fate, and toxicity of chemical warfare agent degradation products. Environ Health Perspect 107(12):933–74.

[NLM] National Library of Medicine. 2004a. Hazardous Substances Data Bank. Bis(2-chloroethyl)sulfide [sulfur mustard] CASRN: 505-60-2. Last review date: September 14, 2000. Available at: http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB. Last accessed August 6, 2004.

[NLM] National Library of Medicine. 2004b. Hazardous Substances Data Bank. Vinyl sulfoxide CASRN: 1115-15-7. Last review date: January 20, 2001. Available at: http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB. Last accessed August 6, 2004.

[NLM] National Library of Medicine. 2004c. Hazardous Substances Data Bank. Vinyl sulfone CASRN: 77-77-0. Last review date: January 20, 2001. Available at: http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB. Last accessed August 6, 2004.

[NRC] National Research Council. 1989. Recommended Dietary Allowances, 10th ed. Food and Nutrition Board, National Research Council, National Academy Press. Washington, DC. P. 230-235.

The Northwest Current 2004. Letter on health survey, Spring Valley disease list and map, Diseases in Spring Valley with possible links to arsenic, and health survey. Forwarded to ATSDR by U.S. EPA. P.O. Box 40400, Washington, D.C. 20016-0400.

Oomen AG, Hack A, Minekus M, Zeijdner E, Cornelis C et al. 2002.Comparison of five in vitro digestion models to study the bioaccessibility of soil contaminants. Environ Sci Technol Aug 1;36(15):3326-34.

[Parsons] Parsons Engineering Science, Inc. 1995. Final Remedial Investigation Report for the Operation Safe Removal Formerly Used Defense Site, Washington, D.C., Fairfax, Virginia.

[Parsons] Parsons Engineering Science, Inc. 1996. Remedial Investigation Report for the Spaulding and Captain Rankin Areas. Operation Safe Removal. Formerly Used Defense Site, Washington, D.C., Fairfax, Virginia.

[Parsons] Parsons Engineering Science, Inc. 1996. Remedial Investigation Evaluation Report for the Operation Safe Removal Formerly Used Defense Site, Washington, D.C. Prepared for US ACE, Baltimore District.

[Parsons] Parsons Engineering Science, Inc. 2001. Draft of final work management plan—remedial investigation/feasibility study (RI/FS), Spring Valley Operable Unit 5, Washington, D.C. Fairfax, Virginia.

[Parsons] Parsons Engineering Science, Inc. 2002a. Report of analytical results—American University Experiment Station (AUES) list of chemicals for four Spring Valley Operable Unit 4 properties, Washington, D.C. Fairfax, Virginia.

[Parsons] Parsons Engineering Science, Inc. 2002b. Report of analytical results—American University Experiment Station (AUES) list of chemicals for Sedgwick trench area, Spring Valley Operable Unit 5, Washington, D.C. Fairfax, Virginia.

[Parsons] Parsons Engineering Science, Inc. 2002c. Report of analytical results—American University Experiment Station (AUES) list of chemicals for Child Development Center and American University Lot 12, Spring Valley Operable Unit 4, Washington, D.C. Fairfax, Virginia.

[Parsons] Parsons Engineering Science, Inc. 2002d. January 23 report: Indoor Air Monitoring Results—5065 Sedgwick Street, Spring Valley Formerly Used Defense Site, Washington, DC.

[Parsons] Parsons Engineering Science, Inc. 2002e. Technical memorandum—arsenic bioavailability study. Spring Valley Operable Unit 4, Washington, D.C.

[Parsons] Parsons Engineering Science, Inc. 2003a. Post Removal Action Report, Time Critical Removal Action, Child Development Center, Spring Valley Operable Unit 4, Washington, DC. Fairfax, Virginia.

[Parsons] Parsons Engineering Science, Inc. 2003b. Indoor Air Sampling Report. Spring Valley FUDS, Washington, D.C., Remedial Investigation/Feasibility Study Operable Unit 5. Fairfax, Virginia.

[Parsons] Parsons Engineering Science, Inc. 2003c. Draft final Site-specific Removal Report, 4801 Glenbrook Road, Spring Valley, Operable Unit 3, DERP/FUDS site, Washington, D.C., Fairfax, Virginia.

[Parsons] Parsons Engineering Science, Inc. 2003d. Engineering Evaluation/Cost Analysis (EE/CA) for Arsenic and Other Selected Contaminants in Soil, Spring Valley Operable Units 4 and 5, Washington, D.C. Volumes 1, 2, and 3. July 2003.

[Parsons] Parsons Engineering Science, Inc. 2004a. Organic and Inorganic Data Validation Report for Spring Valley SCRA Burn Sample Collected on October 29, 2003. Fairfax, Virginia.

[Parsons] Parsons Engineering Science, Inc. 2004b. Table X. Validated analytical data –Spring Valley sub slab soil gas sampling. Final data. Excel spreadsheet: All DATA version for meeting.xls. July 28, 2004.

[Parsons] Parsons Engineering Science, Inc. 2004c. Final Site-Specific Removal Report- Small Disposal Area, Spring Valley, Operable Unit 3, SERP/FUDS Site, Washington, D.C. Prepared for U.S. Army Engineering and Support Center, Huntsville and the U.S. Army Corps of Engineers, Baltimore District. September 30, 2004.

Ruby MV, Schoof R, Brattin, W et al. 1999. Advance in evaluating the oral bioavailability of inorganics in soil for use in human health risk assessment. Environ Sci Technol 33(21):3697–705.

Smart JK. 1993. Memorandum for Record. Subject: Chemical agents, toxins, smoke, incendiary, and detonator materials investigated at American University Experiment Station during World War I. Jeffery K. Smart, Historical Division, Corporate Information Office, Chemical Biological Defense Agency. January 27, 1993.

Tucker JB. 2001. Chemical weapons: buried in the backyard. B Atom Sci 57(5):51–6.

[USABC] U.S. Army Soldier Biological Command. 2001. Container contents of Spring Valley burial pit, unpublished.

[USACE] United States Army Corps of Engineers. 1999. Community relations plan for OU3, Spring Valley, Washington, D.C. GISHome. Available at: http://gis.parsons.com/springvalley/PDFs/sss_vol3_Section4.pdf.

[USACE] United States Army Corps of Engineers. 2001a. Spring Valley Washington, DC: project overview. Baltimore District. Available at: http://www.nab.usace.army.mil/projects/WashingtonDC/springvalley/overview.htm. Last accessed June 23, 2003.

[USACE] United States Army Corps of Engineers. 2001b. October Spring Valley Washington, DC: fact sheet. Arsenic sampling and the removal decision process.

[USACE] United States Army Corps of Engineers. 2001c. Washington Aqueduct Division. Arsenic monitoring results, January 1975 through July 2001.

[USACE] United States Army Corps of Engineers. 2001d. Environmental Health and Safety Issues in Spring Valley/American University Park Arising from World War I Munitions Experiments. February 14 presentation to the DC City Council, Committee on the Judiciary, Committee on Public Works, and the Environment Committee on Human Services, Joint Public Oversight Roundtable.

[USACE] United States Army Corps of Engineers. 2002. Electronic database containing environmental data through September.

[USACE] United States Army Corps of Engineers. 2003. News Release, Release No.03-09 on USACE website for Spring Valley.

[USACE] United States Army Corps of Engineers. 2004a. March 2004 Project Update on USACE website for Spring Valley.

[USACE] United States Army Corps of Engineers. 2004b. Item inventory list for the ordnance pit located at 4825 Glenbrook Road. Electronic submission from E. Hughes to L. Frazier on May 14, 2004.

[USACHPPM] U.S. Army Center for Health Promotion and Preventive Medicine. 1999. Derivation of health-based environmental screening levels for chemical warfare agents. A technical evaluation. March 1999.

Watson AP, Griffin GD. 1992. Toxicity of vesicant agents scheduled for destruction by the chemical stockpile disposal program. Environ Health Perspect 98:259–80.

[WOHA] Washington Occupational Health Associates, Inc. March 26, 2001. Health Consultation: Arsenic Exposure Investigation at American University. Washington, D.C.

Wengrover S. 2001. Toxic contamination at Spring Valley, Washington, D.C. College Park: University of Maryland, School of Public Affairs.

[WHO] World Health Organization. 1973. Trace Elements in Human Nutrition: Manganese. Report of a WHO expert Committee. Technical Report Service 532, WHO Geneva, Switzerland.

[WHO] World Health Organization. 2001. Arsenic and arsenic compounds. Environmental health criteria series, no. 224. 2nd ed. Geneva, Switzerland.

WHO [World Health Organization]. 2002. Concise International Chemical Assessment Document 47. Arsine: human health aspects. Available at: http://www.inchem.org/documents/cicads/cicads/cicad47.htm. Last accessed: October 26, 2004.

Williams, Cuker & Berezofsky. 2001. March 16 letter from Gerald Williams to Dr. Henry Falk re: petition for public health assessment, American University Experiment Station, Spring Valley Site, Washington, DC.

Wones, RG, BL Stadlet, LA Frohman. 1990. Lack of effect of drinking water barium on cardiovascular risk factor. Environ Health Perspectives 85:355-359.