PUBLIC HEALTH IMPLICATIONS OF WORKER EXPOSURE TO SURFACE AND SUBSURFACE SOIL AT THE DENVER FEDERAL CENTER PARCEL B PROPERTY

Lakewood, Jefferson County, Colorado

Health Consultation
7/23/2012

Prepared By: Colorado Department of Public Health and Environment Under a cooperative agreement with the U.S. Department of Health and Human Services Agency for Toxic Substances and Disease Registry. This document has not been reviewed and cleared by ATSDR

Foreword

The Colorado Department of Public Health and Environment's (CDPHE) Colorado Cooperative Program for Environmental Health Assessments has prepared this health consultation under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). ATSDR is part of the United States Department of Health and Human Services and is the principal federal public health agency responsible for the health issues related to hazardous waste. This health consultation was prepared in accordance with the methodologies and guidelines developed by ATSDR.

The purpose of this health consultation is to identify and prevent harmful health effects resulting from exposure to hazardous substances in the environment. Health consultations focus on health issues associated with specific exposures so that the state or local department of public health can respond quickly to requests from concerned citizens or agencies regarding health information on hazardous substances. The Colorado Cooperative Program for Environmental Health Assessments (CCPEHA) evaluates sampling data collected from a hazardous waste site, determines whether exposures have occurred or could occur in the future, reports any potential harmful effects, and then recommends actions to protect public health.

The findings in this report are relevant to conditions at the site during the time this health consultation was conducted and should not necessarily be relied upon if site conditions or land use changes in the future.

For additional information or questions regarding the contents of this health consultation, please contact the author of this document or the Principal Investigator/Program Manager of the CCPEHA:

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Statement and Summary of Issues

Introduction

The Colorado Cooperative Program for Environmental Health Assessment's (CCPEHA) top priority is to ensure that all stakeholders have the best health information possible to protect communities from health hazards associated with environmental contamination. Specifically, this document examines worker exposures to residual soil contamination that remains from previous site activities conducted at the Denver Federal Center Parcel B property prior to the acquisition of the land by Saint Anthony's Hospital. Parcel B/Saint Anthony's Hospital is located in Jefferson County, Colorado.

The Denver Federal Center (DFC) is located on West 6th Avenue and Kipling Street in Lakewood, Colorado, a western suburb of Denver (Figure A1). The DFC is a federal government facility that is currently used by over 25 federal bureaus and agencies for a variety of purposes including materials testing and storage, laboratories, maintenance facilities, and office space. Prior to becoming the DFC, the site was known as the Denver Ordnance Plant, a facility that manufactured small arms ammunition during World War II.

The DFC has had and continues to have a profound impact on the city of Lakewood and the surrounding community. In a continuing effort to improve the partnership with the surrounding community, the managing administration of the DFC began releasing portions of the property to private entities. Two of the major projects that are currently coming to fruition include the Federal Center Regional Transportation District (RTD) Station (Parcel A) and St. Anthony's Hospital (Parcel B). Both areas were initially purchased by the City of Lakewood and were sold to RTD and St. Anthony's for redevelopment. Since the site was included in a Corrective Action Order with the State of Colorado and has undergone remediation, there was some concern of the potential public health implications of current and future worker exposures to residual soil contamination during construction and maintenance of the Parcel A and Parcel B property. A previous health consultation was completed on the Federal Center RTD Transit Station in 2011 (CDPHE 2011). Construction of St. Anthony's Hospital began on the Parcel B property in 2008 and the hospital accepted its first patients in July of 2011. Finishing touches on the construction of the hospital were ongoing at that time this health consultation was performed. The focus of this evaluation is to evaluate the potential

public health implications of exposure to residual soil contamination in Parcel B/St. Anthony's Hospital.

Overview

CCPEHA has reached one conclusion regarding the public health implications of current and future exposure to residual soil contamination in Parcel B/St. Anthony's Hospital by maintenance and construction workers.

Conclusion 1

Contacting residual soil contamination is not expected to harm the health of current and future construction workers and maintenance workers.

Basis for Decision

This conclusion was reached because the estimated doses for maintenance and construction workers from exposure to soil in the Parcel B/St. Anthony Hospital are well below a level of concern for non-cancer and cancer health effects. Specifically, the estimated cancer risks from PAHs which are considered the primary site-related contaminants of potential concern are just above (i.e., 3 or 4 in a million) the low-end of the acceptable cancer risk range of 1 in a million to 100 in a million. It is important to note that the cumulative cancer risk estimates of 5.14E-06 and 5.32E-06 for construction and maintenance workers, respectively are associated with a large uncertainty (i.e., overestimation of risk) since the soil data used in this evaluation was collected before and after remediation. Thus, it is likely that the actual exposure point concentrations are lower than what was used in this evaluation.

Next Steps

Based on the conclusions reached in this health consultation, no recommendations are necessary at this time to protect worker's health from exposure to residual contamination in soil at Parcel B/St. Anthony's Hospital. CCPEHA will make the findings of this document available to the public and other stakeholders and will conduct the appropriate level of health education to address any concerns with the health consultation. Upon request, CCPEHA will also review any additional soil data that is collected from the Parcel B/St. Anthony's Hospital and update the health consultation accordingly.

For More Information

If you have immediate concerns about your health, you should contact your health care provider. For more information on this report, please call the health assessor, Thomas Simmons, at 303-692-2961 or principal investigator/program manager of the CCPEHA, Raj Goyal, at 303-692-2634.

Purpose

The Hazardous Materials and Waste Management Division (HWWMD) of the Colorado Department of Public Health and Environment (CDPHE) requested that the Colorado Cooperative Program for Environmental Health Assessments (CCPEHA) evaluate the public health implications associated with exposure to residual soil contamination at the Denver Federal Center (DFC) Parcel B Property, which is the current location of Saint Anthony's West Hospital. Construction workers and maintenance workers are the only two groups of individuals that are likely to come into contact with surface and subsurface soil contamination that exists at this site. The purpose of this document is to evaluate construction and maintenance worker exposures to surface and subsurface soil contamination at Saint Anthony's Hospital.

Background

The Parcel B Property is the site of the St. Anthony's West Hospital, which is located in Lakewood, Jefferson County, CO. Parcel B was a component of the Denver Federal Center until the land was transferred to St. Anthony's Hospital in 2007. The one square mile DFC is situated between Union Boulevard to the west, Kipling Street to the east, Alameda Parkway to the south, and 6th Avenue to the north (Figure A1). The history of the DFC dates back to December 1940, when the federal government purchased the property from a rancher to build a munitions manufacturing plant during World War II (USGS 2001). Construction of the Denver Ordnance Plant began in March 1941 and by 1943, over 200 buildings had been erected. At the height of production, the plant employed approximately 22,000 people who worked around the clock producing an estimated 6 million cartridges per day. When World War II ended in 1945, ordnance manufacturing ceased and the plant was converted into office, warehouse, and laboratory space for various federal agencies. At that time, the Denver Ordnance Plant was renamed the Denver Federal Center, which is owned and managed by the United States General Services Administration, or GSA. Today, the DFC has over 6,000 tenants from more than 25 federal agencies and bureaus housed in approximately 50 active buildings (GSA 2010).

The DFC has had and continues to have a profound impact on the city of Lakewood and the community, which surrounds it. In a continuing effort to improve the partnership with the surrounding community, the GSA began releasing portions of the DFC on the western border of the facility to private entities for redevelopment. Two of the major projects that are currently coming to fruition include the Federal Center Regional Transportation District (RTD) Station (Parcel A) and the St. Anthony's Hospital (Parcel B). The focus of this health consultation is the Parcel B property or St. Anthony's Hospital, located in the west-central portion of the DFC (Figure A2). A previous health consultation was completed on the Federal Center RTD Transit Station, or Parcel A property, in 2011 (CDPHE 2011).

Due to hazardous waste releases at the DFC, the GSA entered into Compliance Order on Consent #97-07-18-01 with the State of Colorado in July 1997. In 1998, the GSA began the process of identifying potential sources of contamination throughout the DFC. Extensive research was conducted into the available historical records, aerial

photography, DFC operations, tenant land-use, site inspections, and conversations with personnel that had knowledge of site history and practices (ECC 2005). The knowledge gained from this research led to the initial work plans for the site-wide Resource Conservation and Recovery Act Facility Investigation (FEC 2002).

In the area that will become Saint Anthony's Hospital, CH2MHILL began phase 1 of the Resource Conservation and Recovery Act Facility Investigation (RFI) in January 2003 (CH2MHILL 2006a). Soil, groundwater, and sediment samples were collected from various depths at site features associated with potential contamination. The samples were analyzed for a wide array of chemical constituents including the contaminants that were expected from previous site activities. Based on the results of this study, a Corrective Measures Work Plan was developed to address soil contamination in this area, which posed unacceptable risk assuming an unrestricted land-use scenario (CH2MHILL, 2006b). The primary contaminants of concern to be remediated included polycyclic aromatic hydrocarbons (PAHs) and asbestos found in building materials used in the construction of DOP and DFC era buildings.

Three main Investigation Areas from former activities at the DOP and DFC comprise Parcel B: 1) Investigation Area 12S (Former Outdoor Storage Area), 2) South Investigation Area 10W (Open Storage Area), and 3) the southwestern portion of South Investigation Area 6 (DOP Primer Production Area). A brief description of historical activities in these investigation areas is given below for each area. Additional historical information can be found in the reference material noted below.

Investigation Area 12 South (IA12S)

IA12S, located in the southern portion of Parcel B, is relatively flat and undeveloped. A large portion of IA12S is a fenced storage area with pavement covering approximately one-half of the area. Towards the western edge of IA12S was a large C-shaped berm that was once used as a firing range. According to aerial photography, the firing range was present in 1955 and was removed between 1991-1995 (CH2MHILL 2006a). In addition, a large mound was also present that was once the location of a landfill. The landfill appears to have been active from the mid-1970's to between 1984-1991 (CH2MHILL 2006a). At the time of the RFI, only one building was present in the eastern portion of IA12S that was used as a Marine Corps military armored tank maintenance facility from the mid-1970's to the mid-1990's. Prior to the redevelopment of Parcel B, IA12S was used for storage of vehicles, equipment, and building materials by various federal agencies. Potential contaminants in IA12S include lead and unexploded ordnance (firing range), automotive fluids (vehicle maintenance and storage), and potentially contaminated building materials and soil (landfill).

South Investigation Area 10 West (South IA10W)

South IA10W is located in the western section of Parcel B and is bounded by Center Avenue to the north, South IA6 to the east, South IA12S to the south, and the former DFC western boundary to the west. From aerial photography and personnel interviews, it appears that South IA10W was relatively undisturbed during the Denver Ordnance Plant era. During the DFC era, South IA10W was primarily used as a disposal area for soil and

construction debris. It was reported that coal, which at one time had caught fire in the Powerhouse building was spread in South IA10W and extinguished with water and possibly oil including transformer oil. A later attempt was made to recover as much coal as possible. Building 110D was the only structure that is thought to have existed in South IA10W. During site reconnaissance in 1998, Building 110D was present and had signs on the door that read "Do Not Enter or Open Door", which suggests that the building could have been used to house animals. However, it is unclear what exactly Building 110D was actually used for. Aerial photography suggests that the building was constructed sometime between 1963 and 1971. With the exception of one groundwater well installed as part of the site-wide groundwater investigation, no other environmental data prior to 2003 is available from South IA10W.

South Investigation Area 6 (South IA6)

South IA6 is located in the eastern portion of the Parcel B property and is bounded by Center Avenue to the north, Routt Street to the east, IA12S to the south and IA10W to the west. A variety of activities have occurred in South IA6 with a potential to release hazardous substances into the environment. During the DOP era, South IA6 was a munitions primer production area. This area was considered one of the most hazardous areas of the DOP, due to the potential for explosions. Buildings within South IA6 included a primer manufacturing building, primer pre-mix houses, primer mixing buildings, primer composition storehouses, primer chemical distribution houses, a trinitrotoluene (TNT) storage magazine, vacuum pump houses, an office and locker building, and primer storage houses. A variety of potentially hazardous materials were used in the primer production that include phosphate, alkaline cleaners, sulfuric acid, soap, oil emulsions, explosives, and sodium hydroxide (FEC 2002b). Solvents could also have been used in this area during the DOP era.

During the DFC era, a wide variety of activities occurred in South IA6, including animal research, algae testing, solar collector operations involving ethylene glycol, storage of hazardous materials, including explosives and pesticides; and storage of radioactive materials. In addition, this area contained above and underground storage tanks containing diesel fuel and ethylene glycol. At the start of the RFI in 2003, many of the buildings of the former primer production area had been removed.

For chemical remediation of the Parcel B property, the area was divided into lots that measured 100 ft. * 100 ft., which is typical of a residential parcel (CH2MHILL 2006). Based on the sampling conducted in 2003, the lots that had contaminant levels that would result in an estimated cancer risk value greater than 1 excess cancer case per million exposed individuals were targeted for excavation. Additional soil samples were collected in 2005 and 2006 in a step-out fashion to confirm the extent of soil contamination identified in earlier sampling. Specifically, soil samples were collected from lots adjacent to lots containing soil contaminants above the screening value to determine the horizontal extent of contamination. Hot samples were pursued in a step-out fashion in that if a sample from the adjacent lot exceeded the health-based cleanup values, an additional sample was collected further out in the same direction. A similar process was used to define the depth of contamination.

All of the lots with soil contamination above the cleanup value were excavated and surveyed. After the excavation, contaminated soil was sent to a solid waste landfill for disposal (CH2MHILL 2006b). The area was re-graded and offsite soil was brought in to fill any remaining voids. As per GSA and CDPHE site managers, this soil is presumed to be "clean" and free of any site-related contamination. In the summer of 2008, construction began on St. Anthony's West Hospital and the hospital accepted its first patients in July of 2011.

Community Health Concerns

The GSA conducted extensive public involvement work as they were updating the Master Site Plan for the DFC in 2004 – 2005. The Master Plan public meetings were heavily attended and the use of Parcel A for the RTD station and Parcel B and C for the new hospital had already been proposed. The primary public concern was the increase in traffic on the already busy Union Blvd. and Alameda that would result from the hospital and RTD Station. The generic remediation plan of excavate soil in Parcels A and B and dispose of the soil offsite was discussed during those meetings and there was no public opposition regarding the remedy.

During construction of the St. Anthony's Hospital, there were some very active public concerns after a local news agency and a community activist raised questions about buried radioactive waste and groundwater contaminated with trichloroethene and the potential exposure to construction workers. However, radioactive waste was never buried in Parcel B, nor is there any groundwater contamination in this area.

Most recently, a public meeting and comment period was held for the Parcel C (St. Anthony's extension) landfill remedy. The landfill was a former dump for cartridge (i.e. bullets) waste. Quite a few people attended the meeting and it appeared that CDPHE staff successfully answered various questions from the public on the remedy. The most common public comment was concerns that prairie dogs would be harmed during the remedial process. No other community concerns have been noted.

Discussion

The overall goal of this health consultation is to determine if residual soil contamination poses a public health hazard to current and future construction and maintenance workers of St. Anthony's Hospital and to make recommendations to protect public health if need be. The first steps of the health consultation process include an examination of the currently available environmental data and how individuals could be exposed to contaminants of potential concern (COPCs). If exposure pathways to COPCs exist, exposure doses are estimated and compared to health-based guidelines established by the ATSDR and EPA. This is followed by an in-depth evaluation if the estimated exposure doses exceed health-based guidelines.

Environmental Data

The RFI field investigation activities in South IA6, South IA10W, and IA12S began in January and February 2003 by CH2MHILL for the GSA (CH2MHILL 2006a). The goal of the field activities was to assess whether former activities at the DOP and DFC released contaminants that could have impacted soil, surface water, or groundwater and whether contaminant migration could have occurred. All field activities were conducted in accordance with the Quality Assurance and Protection Plan (QAPP), the standard operating procedures (URS 2005a, RFI), and the RFI Work Plan, with the exception of minor field modifications.

The location of historic spills or surface contaminants was not known at the time, the RFI was conducted. Therefore, soil sampling was conducted in areas considered the most likely locations of surface spills such as the vicinity of buildings, storage tanks, and loading dock areas. In the 1998 Pre-Historical Data Report Addendum, the estimated locations of subsurface features were based on historical aerial photography from discrete points in time that may not be representative of the actual extent of the subsurface feature. Therefore, a combination of geophysical surveys, aerial photography, drilling of boreholes, and excavation of test pits was used to determine subsurface soil contamination. When new or extensions of subsurface features were encountered during field activities, the sampling plan was altered to determine the extent of the feature. The primary field tasks considered important for this evaluation are noted below:

- Drilling, sampling, and analysis of surface and subsurface soil and waste from approximately 42 boreholes,
- Excavation, sampling, and analysis of surface and subsurface soil and waste from approximately 10 test pits,
- Collection and analysis of surface and shallow subsurface soil samples at approximately 84 composite boreholes locations,
- Collection and analysis of sump sediment samples from 3 locations, and
- Collection and analysis of groundwater samples from 26 monitoring wells.

As noted above, composite and grab soil sampling was utilized to define the nature and extent of contamination. In general, samples collected from > 3 feet below ground surface (bgs.) were grab samples and samples collected from 0-3 feet bgs. were composite samples. Composite sampling was conducted in an “X” pattern with samples collected from the extremities and center of the pattern. The samples were then homogenized and a single soil sample was submitted to the laboratory for analysis. All soil samples were collected using a hollow-stem auger, hand-auger, or direct push borehole based on the depth of the sample. Soil, sediment, and groundwater samples were analyzed for a wide array of chemical constituents including ammonia (groundwater only), anions (groundwater only), carbamate pesticides, total cyanide, explosives, chlorinated herbicides, dioxins/furans, mercury, metals, nitrate/nitrite (groundwater only), organochlorine pesticides, organophosphorous herbicides and pesticides, polycyclic aromatic hydrocarbons (PAHs), Polychlorinated Biphenyls (PCBs), semi-volatile organic compounds (SVOCs), strychnine, tributyl tin, and volatile organic compounds

(VOCs). Over thirty different EPA sampling methods were used to analyze the environmental samples for potential contaminants.

It should be noted that groundwater sampling was conducted at 21 monitoring wells during the 2003 RFI and did not show any groundwater contamination above the state or federal standards (CH2MHILL 2006a). In addition, the water supply for St. Anthony's Hospital will be supplied by the city of Lakewood. This suggests an incomplete pathway of exposure to groundwater. Therefore, exposure to groundwater was not considered any further in this evaluation.

As shown in Tables A1 and A2, a variety of chemical constituents have been detected subsurface soil (0.5 - 12 ft.) and surface soil (0-6 in.) in the Parcel B property/St. Anthony's Hospital. As the results of the soil sampling analysis were received, the evaluation became progressively focused on contaminants that were detected above the screening level and were likely present in soil at the site. Thus, there are an uneven number of samples available for all of the analytes. The environmental data considered in this evaluation includes data collected from 2002 to 2006. This period includes both pre-remediation and post-remediation data. In 2005 and 2006, areas of known contamination were excavated to the vertical and horizontal extent of the contamination. The land was regraded and segmented with clean fill, as per GSA and CDPHE site managers. However, no soil sampling is available on the fill material.

Table A1 and Table A2 are summaries of the soil sampling results from the depth intervals under consideration in this evaluation. Metals, pesticides, and Polycyclic Aromatic Hydrocarbons (PAHs) were, by and large, the most prevalent groups of contaminants found in Parcel B soil. Most metals were detected in 100% of the soil samples collected at the site. This is not a striking revelation since metals are a natural component of soil in Colorado and most types of soil throughout the nation. At the maximum detected concentration, the concentration of some metals could be slightly elevated in relation to typical background concentrations. However, for the most part, this elevation does not appear significant and may not be related to former site activities. For example, the maximum detected concentration of arsenic is 3.5 parts per million (ppm) with a mean concentration of 1.8 ppm. This is well within range of typical background levels of arsenic. In addition, metal contamination is dispersed throughout the site and does not appear to be concentrated in any particular area that would suggest a source of contamination. One notable exception for metal contaminants is lead. The maximum detected concentration of lead (1,600 ppm) is well above the mean concentration of 51.4 ppm. This could indicate a point source of contamination not associated with background levels. In fact, the maximum concentration was found in the 12S01 area, which is likely a result of the former firing range or landfill material. In addition, 3 other detections of lead above 400 ppm occurred in the 10W06 area (coal burn area). It is unclear what exactly this source of lead is attributable to; however, these 4 sampling points above 400 ppm of residential screening level are not important from public health perspective because the mean value of 51.4 ppm is well below 400 ppm.

PAHs were also widely detected constituents in soil at the site, but the pattern of the PAH detections suggest a site related source. PAHs are a group of structurally and functionally similar compounds with a number of different chemical configurations. The most common source of PAH compounds is from the incomplete combustion of organic material such as wood, coal, charcoal, oil, etc. At least 7 of the 15 PAH compounds that were detected in Parcel B soil were detected in over 60% of all soil samples collected. This includes two of the more toxic forms of PAHs, benzo(a)pyrene and dibenz(a,h)anthracene. The concentration of benzo(a)pyrene ranged from 0.00011 – 43 ppm with a mean concentration of 0.29 ppm. Dibenz(a,h)anthracene ranged from 0.000095 – 9.2 ppm with a mean concentration of 0.08 ppm. There is a wide range in concentration of these contaminants that appears consistent with the other detected PAHs. The maximum detected concentrations of benzo(a)pyrene and dibenz(a,h)anthracene (along with many of the other PAH compounds) were found in the area 12S01 suggesting that a source of PAH contamination is present in the former landfill. Coal was also stored in piles around buildings for heat. It should be noted that there are also background sources of PAHs in most urban environments, which could also be contributing to the overall PAH concentration found in soil. Based on the soil data collected to date, it appears that the former coal piles are a likely source of PAHs.

In addition, a number of pesticides, including but not limited to aldrin, pentachlorophenol, dieldrin, endrin, Endosulfan, and toxaphene were detected in soil at Parcel B/St. Anthony's Hospital. However, the detections appear infrequent and at relatively low concentrations, suggesting widespread application. These detections could be related to the agricultural chemical testing, the grounds maintenance crew, and/or pesticide storage.

Selection of Contaminants of Potential Concern

To identify contaminants of potential concern (COPCs), the soil data that was utilized in this evaluation was screened with soil comparison values established by the ATSDR, EPA, and state agencies. The comparison values (CVs) from these sources were reviewed and the most conservative, or health-protective, screening value was used to identify COPCs. Table C1 contains a complete list of the CVs used in this evaluation. All of the CVs used in this evaluation are derived for residential soil exposures, which are based on 350 days of exposure per year over a 30 year period. Based on what is known about current and future land-use of the site, the use of residential CVs is considered protective of the individuals that are likely to come into contact with soil contaminants at the Parcel B/St. Anthony's Hospital property. Therefore, if the maximum concentration of any soil contaminant is below the respective CV, that contaminant is dropped from further evaluation since it is unlikely to present a health-risk to receptors. If the maximum value of a soil contaminant is above the respective CV, that contaminant is generally retained for further evaluation as a COPC.

The identification of COPCs does not indicate that a health hazard exists from exposure to these contaminants, only that further evaluation is necessary. The selection of soil COPCs is summarized below in Table 1 and the full screening of all detected compounds is shown in Appendix Table A1. Soil data was collected on the essential nutrients calcium, potassium, magnesium, and sodium. No CVs area available for these

compounds so the Recommended Daily Intake established by the U.S. Department of Agriculture and the Food and Drug Administration were used to calculate screening values for comparison (IOM 2011). The concentration of all of the essential nutrients in soil resulted in exposures well below the RDI and were dropped from further evaluation.

Table 1. Soil Screening and Selection of Contaminants of Potential Concern

COPC	Maximum Detected Concentration (in mg/kg)	Residential Screening Value (in mg/kg)	Basis of Screening Value
Aldrin	0.03	0.029	cancer
Aluminum	51,000	50,000	non-cancer
Arsenic	3.5	0.39	cancer
Benzo(a)anthracene	48	0.15	cancer
Benzo(a)pyrene	43	0.015	cancer
Benzo(b)fluoranthene	50	0.15	cancer
Benzo(k)fluoranthene	23	1.5	cancer
Chromium	24	0.29	cancer
Chrysene	52	15	cancer
Dibenz(a,h)anthracene	9.2	0.015	cancer
Dieldrin	0.13	0.03	cancer
Indeno(1,2,3-cd)pyrene	26	0.15	cancer
Lead	1,600	400	non-cancer
Naphthalene	13	3.6	cancer
Vanadium	160	5.5	non-cancer

NOTES: COPC = Contaminant of Potential Concern, mg/kg = milligram contaminant per kilogram of soil

It should be noted that there are contaminants that were detected in Parcel B soil, which do not have screening values available. This includes carbazole, strychnine, acenaphthylene, phenanthrene, and benzo(g,h,i)perylene. These contaminants are evaluated qualitatively. As briefly noted below, exposures to these compounds are not likely to be significant but are noted as a source of uncertainty (i.e., potential underestimation) in the uncertainty analysis.

Carbazole is a compound that is found in coal tar and has also been synthesized through organic chemistry. The commercial uses of carbazole have been primarily for European developments including dyes, pesticides, and vinylcarbazole polymers. However, in the U.S., its use in pesticides and vinylcarbazole polymers has not progressed past the pilot stages (Dressler and Baum). In this case, it is likely that carbazole was used during pesticide testing based on what is known about the former site activities. It could also be related to the coal that was stored on Parcel B during the DOP and DFC eras. Carbazole was only detected three times out of 126 soil samples analyzed for this compound. The detections ranged from 0.041 to 0.049 ppm. Due to the low detection frequency and the low concentration of carbazole found in Parcel B soil, exposure to this compound is not likely to be significant.

Strychnine is commonly used as a rat poison. It was also detected at a low frequency (2 detects out of 55 soil samples) and at low concentrations (0.007 ppm and 0.0097 ppm). Based on what is known about former site activities it was probably used by workers to control rats or possibly used in animal testing since the detections occurred in South IA6. However, this cannot be corroborated.

Acenaphthylene, benzo(g,h,i)perylene, and phenanthrene are PAH compounds that have not been well studied. These PAHs were detected at low concentrations and also follow the same dispersion pattern as the other 8 PAHs that were selected as COPCs. Thus, they were likely remediated along with the other PAHs.

Exposure Evaluation

The objective of the exposure evaluation is to determine if and how individuals may come into contact with residual soil contaminants at St. Anthony's Hospital. The land-use of the area is examined to develop a conceptual site model that describes the potential receptors as well as the route, frequency, and duration of exposure for these individuals. Just because soil COPCs exist in this area does not mean that a public health hazard exists. If people do not come into contact with site-related contamination, adverse health effects cannot occur.

At the time this health consultation was conducted, all of the former DFC era buildings have been demolished and removed. Construction workers are currently onsite finalizing this phase of construction at the hospital. Due to the nature of their work, they will, or have already, come into contact with soil and the low levels of contamination it contains. It is also possible that construction work will continue for some time as all phases of the hospital are completed. Therefore, it was assumed in this evaluation that construction workers could be exposed to soil contaminants for 250 days per year over a period of 5 years.

Groundskeepers and maintenance workers will also likely be exposed to soil contaminants at St. Anthony's Hospital while gardening, landscaping, planting trees and flowers, etc. Maintenance workers are likely to remain onsite longer than construction workers to take care of the property. Therefore, it was assumed that maintenance workers would be exposed to soil 100 days per year over a period of 25 years. The assumed exposure frequency and exposure duration for construction workers is based on professional judgment and site-specific circumstances. The assumed exposure frequency and duration for maintenance workers is a combination of the standard default assumptions provided in the EPA and/or ATSDR risk assessment guidance and professional judgment based on site-specific factors. For instance, the exposure frequency of 100 days per year was used in this case because it is unlikely that maintenance workers would be in contact with soil for more than 100 days per year over 25 years because of seasonal factors (i.e. snow) and the varying types of work that maintenance workers perform, which will limit their contact with surface soil.

It is not likely that patients (or their families), doctors, nurses, or any other St. Anthony employees will come into contact with residual soil contamination to any significant

degree since the grounds have been sodded and landscaped. Therefore, these individuals were not considered in this evaluation.

In general, all receptors come into contact with soil contaminants in a similar manner although the intensity of exposure varies based on the type of activities they perform. The primary routes of exposure to soil COPCs under the future potential exposure scenarios identified in this health consultation are incidental ingestion of soil and dermal contact with soil. Incidental ingestion of soil occurs in a variety of ways including hand-to-mouth activity, construction, landscaping, gardening, and excavation. Skin coming into contact with soil contaminants, or dermal exposure, is another potential route of exposure for these receptors. Dermal exposure to soil occurs during the same type of activities noted above. Inhalation of dust particles containing COPCs is another potential route of exposure. However, inhalation of dust particles is a relatively minor route of exposure for the receptors identified in this health consultation and was not considered further. The exposure scenarios evaluated in this evaluation are summarized below in the Conceptual Site Model (Table 2).

Table 2. Conceptual Site Model

Source	Point of Exposure	Affected Environmental Medium	Potentially Exposed Populations	Timeframe of Exposure	Route of Exposure
Industrial Waste from the former operations at the Denver Ordnance Plant and the Denver Federal Center	St. Anthony's Hospital (Parcel B)	Surface and subsurface soil	Maintenance Workers (groundskeepers) and Construction Workers	Current and Future	1) Incidental Ingestion and Dermal Exposure to Soil

NOTE: Inhalation of dust is considered a relatively minor route of exposure to soil COPCs in this evaluation and was not considered further.

Exposure Point Concentrations

As discussed in the Environmental Data section of this document, soil samples collected from the Parcel B property have been collected from various depths up to 30 ft. bgs. However, it is very unlikely that the receptors under consideration in this evaluation would come into contact with soil deeper than 12 ft. below ground surface. In this evaluation, it was assumed that the 0-2 ft. depth interval would apply to maintenance workers. Construction workers could come into contact with soil in the 0-12 ft. depth interval during construction activities.

The soil data collected from Parcel B was divided into the appropriate depth intervals for both receptors and an exposure point concentration (EPC) was calculated that was used to estimate doses for each receptor. The EPC describes the concentration of soil contaminants that people are likely to come into contact within the exposure unit. The EPC is a high-end arithmetic mean concentration (e.g., 95% upper confidence limit on the mean) of the soil data that is designed to account for random exposures throughout the entire exposure unit. In this case, the exposure unit for maintenance workers would be soil within Parcel B at a depth of 0-2 ft. bgs. The exposure unit for construction workers is soil within Parcel B at a depth of 0-12 ft. bgs. EPA's statistical software package called ProUCL, which was designed for this purpose, was used to calculate the exposure point concentrations (EPA 2011). The resulting EPCs calculated for both receptors in this evaluation can be found in Table B3 and B4 in Appendix B. It should be noted that the non-detected values were handled in accordance with the EPA ProUCL guidance (i.e. half the detection limit was not used).

Public Health Implications

To evaluate the public health implications of construction workers and future maintenance workers coming into contact with residual soil contamination at St. Anthony's Hospital, non-cancer and cancer exposure doses were calculated for both receptors and compared to health-based reference values. Dose calculations are based on the frequency, duration, and intensity of the particular exposure scenario (i.e., maintenance or construction worker). Non-cancer and cancer doses are evaluated separately due to differences in the averaging time and toxicological mode of action. More information regarding the exposure factors used in this health consultation and the resulting exposure doses are available in Appendix B of this document. To simplify the evaluation process to estimate the potential for non-cancer adverse health effects, the non-cancer doses were divided by chemical-specific health-based guidelines established by the ATSDR and EPA. The health-based guidelines used in this evaluation are the ATSDR chronic oral Minimal Risk Level (MRL) and the EPA Oral Reference Dose (RfD). The health-based guidelines, shown in Table C1, are doses of a chemical that are not likely to result in any appreciable non-cancer health hazard. Dividing the estimated exposure dose for construction and maintenance workers by the non-cancer health-based guidelines results in a Hazard Quotient (HQ), which is simply a ratio of the estimated dose to the health-based guideline. As per ATSDR Guidance, HQs greater than one require further evaluation since the estimated dose for that particular contaminant is greater than the health-based guideline. HQs lower than the health-based guidelines are typically dropped from further evaluation.

It should be noted that the soil samples included in this evaluation are most likely representative of soil exposures that would have occurred prior to remediation. The nature of the sampling and analysis plan inhibited the ability to delineate samples that would be representative of current exposures. An exhaustive data review to determine the final step out sampling points was pursued, but even then, the accuracy of the data representativeness would remain a question. Thus, a very conservative approach that includes all samples collected from the start of the initial characterization were included to remain protective of public health. It should be noted that the actual contaminant levels

in soil during the construction of St. Anthony's Hospital were much lower considering the remediation and fill with clean soil. However, the actual contaminant concentration cannot be accurately determined.

Metals, pesticides, and polycyclic aromatic hydrocarbons (PAHs) are the primary contaminants of potential concern found in soil at the Parcel B property and all contaminants of potential concern were found at low levels. As mentioned previously, incidental ingestion of soil and dermal exposure to soil are the two primary routes of exposure under consideration in this evaluation. Non-cancer and cancer exposure doses are estimated for both pathways and the results are combined, when applicable, to arrive at an overall dose received during a particular activity (i.e. construction work, maintenance work) for a given contaminant of concern. In this health consultation, PAHs were selected as contaminants of potential concern, many of which are classified as "probable human carcinogens" by the USEPA (EPA 1994a). PAHs are generally treated similarly in risk assessments due to their similar structures and toxicities. Per EPA guidance, the cancer risks of individual carcinogenic PAHs were estimated in terms of benzo(a)pyrene toxicity equivalents and adding the cancer risk for all PAHs. Non-cancer toxicity values (or health guidelines) have not been developed by the federal or state agencies for carcinogenic PAHs (EPA 1994a). This is addressed as a source of uncertainty. Details of toxicity values and health effects of PAHs are provided in Appendix C and Appendix D, respectively.

Construction Worker

The HQs for construction workers are shown in Table A3 and the estimated combined non-cancer exposure doses for dermal exposure and incidental ingestion of soil during construction work are shown in Table B6. As shown, all of the combined HQs are lower than one for each COPC. The greatest HQ in this evaluation results from the estimated exposure to aluminum, which is approximately ten times lower than the health-based guideline for aluminum. In addition, the cumulative non-cancer Hazard Index (HI), or sum of all HQs, is also below one (0.2). This information indicates that exposure to soil during construction work at the St. Anthony's/Parcel B site is not likely to result in non-cancer adverse health effects.

The evaluation of any potential cancer risks is similar to the non-cancer evaluation with a couple of important exceptions. The first exception is the estimated cancer doses are averaged over the lifetime of the individual (70 years). Secondly, the estimated cancer doses are multiplied by the oral cancer slope factor established by the EPA to quantify the theoretical cancer risk and provided in Table C2. The estimated theoretical cancer risks are then compared to the EPA acceptable cancer risk range of $1*10^{-6} – 1*10^{-4}$, or 1 excess cancer case per million exposed individuals to 100 excess cancer cases per million.

The estimated cancer doses for construction workers are shown in Table B7 and the resulting theoretical cancer risks are shown in Table A4. All of the estimated theoretical cancer risks are at the low end of the acceptable cancer risk range. The highest estimated cancer risk for construction workers from exposure to any one contaminant is from soil

exposure to benzo(a)pyrene, which equals $2.0 * 10^{-6}$, or 2 excess cancer cases per million exposed individuals. Benzo(a)pyrene is a PAH, which are evaluated by combining the exposure to all PAHs as mentioned previously. The theoretical cancer risk from all PAHs combined is $3.0 * 10^{-6}$, or 3 excess cancer cases per million exposed individuals. The total theoretical cancer risk estimated from all COPCs combined is equal to $5.0 * 10^{-6}$, or 5 excess cancer cases per million exposed individuals. Therefore, the estimated cancer risks for construction workers at the St. Anthony's/Parcel B site are associated with a very low increased risk of developing cancer. It should again be noted that these risks are representative of site conditions prior to remediation, and the actual cancer risks associated with construction work after remedial actions were completed are likely much lower.

Maintenance Workers

The combined non-cancer HQs from dermal exposure and incidental ingestion of soil contaminants during maintenance work are shown in Table A5 and the estimated exposure dose results for are shown in Table B8. As shown in Table A5, all of the combined HQs are lower than one for each COPC that was identified in this evaluation. The greatest HQ results from the estimated exposure to vanadium, which is equal to 0.006, or approximately two hundred times lower than the health-based guideline. The cumulative non-cancer HI is also well below one (0.01). This information indicates that exposure to soil during maintenance work at the St. Anthony's/Parcel B site is not likely to result in non-cancer adverse health effects.

The estimated theoretical cancer risks of contacting soil contaminants during maintenance work are shown in Table A6 and the estimated cancer doses are shown in Table B9. All of the estimated theoretical cancer risks for maintenance workers are also at the low end of the acceptable cancer risk range. In fact, the estimated cancer risks for maintenance workers are similar to those estimated for construction workers. The highest estimated cancer risk from exposure to any one contaminant is also from exposure to benzo(a)pyrene in soil, which equals $3.0 * 10^{-6}$, or 3 excess cancer cases per million exposed individuals. The theoretical cancer risk from all PAHs combined is $4.0 * 10^{-6}$, or 4 excess cancer cases per million exposed individuals. The total theoretical cancer risk estimated from all COPCs combined is equal to $5.0 * 10^{-6}$, or 5 excess cancer cases per million exposed individuals. Thus, the estimated cancer risks for maintenance workers at the St. Anthony's/Parcel B site are associated with a very low increased risk of developing cancer, especially when taking into account that these risks are representative of site conditions prior to remedial actions took place.

Uncertainties and Limitations

In general, the uncertainties associated with any risk-based health consultation are likely to over- or underestimate environmental exposures and the associated health hazards because all aspects of the exposure are typically unknown. This section of the discussion is not intended to be an in-depth description of all the uncertainties associated with this evaluation. Rather, the focus is to highlight the major assumptions and limitations that are specific to this evaluation and result in uncertainty.

- Overall, the current and future cancer and non-cancer risks are likely overestimated in this evaluation based on the following: (a) the assumption of all hexavalent chromium in soil instead of total chromium; (b) the assumption of 100% bioavailability of arsenic and chromium in soil; and (c) consideration of both pre- and post-remediation data from 2002 to 2006 for estimating the exposure point concentration for workers.

- It should be noted that the estimated risks for arsenic are similar to the risks associated with background levels of arsenic in soil.

- As mentioned previously one major uncertainty associated with this evaluation is the present concentration of contaminants in soil at St. Anthony's Hospital. In 2005 and 2006, areas of known contamination were excavated to the vertical and horizontal extent of the contamination. The land was regraded and augmented with "clean" fill as per GSA and CDPHE site managers. However, no data was available to review regarding the potential for soil contaminants or their chemical concentration in this fill. This evaluation included soil data collected before and after remedial actions were complete. Therefore, it is likely that this evaluation overestimates the current potential health hazards to maintenance and construction workers.

- Screening values for COPC selection were not available for carbazole, strychnine, acenaphthylene, phenanthrene, or benzo(g,h,i)perylene. This could result in a slight underestimation of risk in this evaluation.

- As discussed previously, there are no available non-cancer toxicity values for PAHs. However, this appears to be a minor source of uncertainty because the estimated cumulative non-cancer hazards from all contaminants of potential concern are significantly (>10-fold) lower than the acceptable level of one. Nonetheless, it would likely elevate the non-cancer health hazards estimated in this evaluation without significantly changing the conclusions drawn here.

- The overall cancer and non-cancer risks may be over- or under-estimated based on the assumption of additivity due to the potential for antagonistic or synergistic effects of multiple chemical interactions. However, it is not considered a significant source of uncertainty because the cumulative non-cancer hazards (Hazard Indexes) are significantly (> 10-fold) lower than the acceptable level of one and the estimated cancer risks are driven by the cancer risks for arsenic, which are similar to cancer risks associated with background levels of arsenic in soil. In addition, the conservative assumption of all chromium in soil as hexavalent chromium was used in this evaluation. It should be noted that the current state of the science is unable to assess exposures to complex mixtures, especially, at the very low environmental levels as found at this site.

Child Health Considerations

In communities faced with air, water, or food contamination, the many physical and behavioral differences between children and adults demand special emphasis. Children could be at greater risk than are adults from certain kinds of exposure to hazardous substances. Children play outdoors and sometimes engage in hand-to-mouth behaviors that increase their exposure potential. Children are shorter than are adults; this means they breathe dust, soil, and vapors close to the ground. A child's lower body weight and higher intake rate results in a greater dose of hazardous substance per unit of body weight. If toxic exposure levels are high enough during critical growth stages, the developing body systems of children can sustain permanent damage. Finally, children are dependent on adults for access to housing, for access to medical care, and for risk identification. Thus adults need as much information as possible to make informed decisions regarding their children's health.

This note was included in this document to highlight the importance of childhood exposures to environmental contaminants and the commitment of ATSDR to consider children in all health consultations. However, children were not specifically addressed in this evaluation because children are not expected to come into contact with site-related soil contamination to any significant degree.

Conclusions

Based on the soil data and exposure pathways evaluated in this health consultation, CCPEHA has reached one conclusion regarding current and future worker exposures to residual soil contamination at the Parcel B/St. Anthony Hospital:

Contacting residual soil contamination is not expected to harm the health of current and future construction workers and maintenance workers. This conclusion was reached because the estimated doses for both workers from exposure to soil in the Parcel B/St. Anthony Hospital are well below a level of concern for non-cancer and cancer health effects. Specifically, the estimated cancer risks from PAHs which are considered the primary site-related contaminants of potential concern are just above (i.e., 3 or 4 in a million) the low-end of the acceptable cancer risk range of 1 in a million to 100 in a million. It is important to note that the cumulative cancer risk estimates of 5.14E-06 and 5.32E-06 for construction and maintenance workers, respectively are associated with a large uncertainty (i.e., overestimation of risk) since the soil data used in this evaluation was collected before and after remediation. Thus, it is likely that the actual exposure point concentrations are lower than what was used in this evaluation.

Recommendations

Based on the conclusions reached in this health consultation, no recommendations are necessary at this time to protect worker's health from exposure to residual contamination in soil at Parcel B/St. Anthony's Hospital.

Public Health Action Plan

The public health action plan for the site contains a description of actions that have been or will be taken by CCPEHA and other governmental agencies at the site. The purpose of the public health action plan is to ensure that this public health consultation both identifies public health hazards and provides a plan of action designed to mitigate and prevent harmful human health effects resulting from breathing, drinking, eating, or touching hazardous substances in the environment. Included is a commitment on the part of CCPEHA to follow up on this plan to be sure that it is implemented.

Public health actions that will be implemented include:

- CCPEHA will make the findings of this document available to the public and other stakeholders.

- If questions arise regarding the health consultation, CCPEHA will conduct the appropriate level of health education to address the concerns.

- Upon request, CCPEHA will review any additional soil data that is collected from the Parcel B/St. Anthony's Hospital and update the health consultation accordingly.

Report Preparation

This Health Consultation for the Denver Federal Center (DFC) Parcel B Property, which is the current location of Saint Anthony's West Hospital, was prepared by the Colorado Department of Public Health and Environment (CDPHE) under a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with approved agency methodology and the procedures existing at the time the health consultation was initiated.

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References

Agency for Toxic Substances and Disease Registry (ATSDR 2005). *Public Health Assessment Guidance Manual*, Revised January 2005. Available on the Internet at: http://www.atsdr.cdc.gov/HAC/PHAManual/toc.html, accessed February 2011.

CH2MHILL (CH2MHILL 2005). *Final Corrective Measures Work Plan for the Denver Federal Center for the Southern RTD Expansion Area, Denver Federal Center, Lakewood, Colorado.* Prepared for the U.S. General Services Administration by CH2MHILL, October 2005.

CH2MHILL (CH2MHILL 2006a). *Final Phase I RCRA Facility Investigation of the Denver Federal Center for the Southern RTD Expansion Area, Denver Federal Center, Lakewood, Colorado.* Prepared for the U.S. General Services Administration by CH2MHILL, March 2006.

CH2MHILL (CH2MHILL 2006b). *Final Corrective Measures Closure Report for the Denver Federal Center for the Southern RTD Expansion Area, Denver Federal Center, Lakewood, Colorado.* Prepared for the U.S. General Services Administration by CH2MHILL, September 2006.

Colorado Department of Public Health and Environment, Colorado Cooperative Program for Environmental Health Assessments (CDPHE 2011). *Public Health Implications of Exposure to Surface and Subsurface Soil at the Federal Center RTD Intermodal Station,* July 2011.

Dressler, Hans and Baum, Melvin E; Koppers Company, Inc. (Dressler and Baum). Chemicals From Carbazole by Reductive Processes, date unknown. Available on the Internet from Argonne National Laboratories at: http://web.anl.gov/PCS/acsfuel/preprint%20archive/Files/04_1_CLEVELAND_04-60_0034.pdf, Accessed March 2011.

Environmental Chemistry Corporation (ECC 2005). *Closure Report: Northern RTD Expansion Areas IA6 and IA17S, Denver Federal Center (Draft Final);* July 2006.

Environmental Chemistry Corporation (ECC 2006a). *Phase 2 RCRA Facility Investigation: Northern and Southern RTD Expansion Areas (Final), Denver Federal Center;* July 2006.

Foothills Engineering Company, LLC (FEC 2002). *Phase 1, RCRA Facility Investigation of the Denver Federal Center, Northern RTD Expansion Area (Draft Final),* August 2002.

National Academy of Sciences, Institute of Medicine, Food and Nutrition Board (IOM 2011). Dietary Reference Intakes: Recommended Intakes for Individuals, 2011. Available

on the Internet at:
http://fnic.nal.usda.gov/nal_display/index.php?info_center=4&tax_level=3&tax_subject=256&topic_id=1342&level3_id=5140, Accessed March 2011.

U.S. Environmental Protection Agency, Office of Emergency and Remedial Response (EPA 1989). *Risk Assessment Guidance for Superfund, Part A;* December 1989.

U.S. Environmental Protection Agency, (EPA 1993). *Superfund's Standard Default Exposure Factors for the Central Tendency and Reasonable Maximum Exposure (Draft),* November 1993.

U.S. Environmental Protection Agency, (EPA 1994a). *Integrated Risk Information System for Benzo(a)pyrene, Profile 0136*, First made available on 3/31/1987, last update 11/1994. Available on the Internet at: http://www.epa.gov/iris/subst/0136.htm, accessed April 2012.

U.S. Environmental Protection Agency, Region 8 Superfund Technical Guidance, (EPA 1994b). *Evaluating and Identifying Contaminants of Concern for Human Health*, September 1994.

U.S. Environmental Protection Agency, National Center for Environmental Assessment (EPA 1997c). *Exposure Factors Handbook*, August 1997. Available on the Internet at: http://www.epa.gov/ncea/efh/report.html, Accessed February 2011.

U.S. Environmental Protection Agency (EPA 2002). *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites*, December 2002. Available on the Internet at: http://www.epa.gov/superfund/health/conmedia/soil/pdfs/ssg_main.pdf, Accessed February 2011.

U.S. Environmental Protection Agency (EPA 2010). *Regional Screening Level Tables*, last update November 2010. Available on the Internet at:
http://www.epa.gov/region9/superfund/prg/, Accessed February 2011.

U.S. Environmental Protection Agency, Technical Support Center for Monitoring and Site Characterization, (EPA 2011). *Statistical Software ProUCL 4.1 for Environmental Applications For Data Sets with and without Nondetect Observations, Version 4.1.00*. Last update July 2011. Available on the Internet at:
http://www.epa.gov/osp/hstl/tsc/software.htm, accessed February 2012.

U.S. General Services Administration (GSA 2010). *The Denver Federal Center, Yesterday, Today, and Tomorrow*, 2010. Available on the Internet at:
http://www.gsa.gov/portal/content/102970, Accessed May 2011.

U.S. Geological Survey (USGS 2001). Historical Perspectives of the Denver Federal Center Area 1930-1996, last update 5/16/2001. Available on the Internet at:
http://rockyweb.cr.usgs.gov/frontrange/virtour/fedcen.htm**,** Accessed May 201

APPENDICES

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Appendix A. Additional Tables and Figures

Table A1. Summary Statistics of Detected Compounds and Selection of Contaminants of Potential Concern in Parcel B Soil Samples Collected From 0-12 feet below ground surface

Detected Compounds (0-12 ft. bgs.)	Mean (in mg/kg)	Minimum (in mg/kg)[1]	Maximum (in mg/kg)	Screening Value[2] (in mg/kg)	Detection Frequency (in percent detected)	*n*	Contaminant of Potential Concern
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	0.0000072	0.00000048	0.000015	0.00045*	42.9%	7	
1,2,3,4,6,7,8-Heptachlorodibenzofuran	0.0000013	0.0000013	0.0000013	0.00045*	14.3%	7	
1,2,3,7,8-Pentachlorodibenzofuran	0.0000012	0.0000012	0.0000012	0.00015*	14.3%	7	
1-Methylnaphthalene	0.14	0.14	0.14	22	0.8%	126	
2,3,4,6,7,8-Hexachlorodibenzofuran	0.00000054	0.00000054	0.00000054	0.000045*	14.3%	7	
2,3,4,7,8-Pentachlorodibenzofuran	0.00000097	0.00000097	0.00000097	0.000015*	14.3%	7	
2,3,7,8-Tetrachlorodibenzo-p-dioxin	0.0000051	0.0000051	0.0000051	0.0000045	14.3%	7	
2,3,7,8-Tetrachlorodibenzofuran	0.00000048	0.00000048	0.00000048	0.000045*	14.3%	7	
2,4-Dichlorophenoxyacetic acid	0.0091	0.0091	0.0091	690	1.0%	98	
2-Butanone	0.0074	0.0074	0.0074	28,000	0.9%	105	
2-Methylnaphthalene	0.1	0.1	0.1	200	0.8%	126	
4,6-Dinitro-2-methylphenol	0.35	0.35	0.35	4.9	0.8%	126	
Acenaphthene	0.161	0.00011	32	3,000	48.7%	481	
Acenaphthylene**	0.00729	0.00012	0.21	NA	43.9%	481	
Acetone	0.0124	0.002	0.093	50,000	15.2%	105	
a-Chlordane	0.002	0.00031	0.0037	1.6	4.4%	115	

Table A1 (continued). Summary Statistics of Detected Compounds and Selection of Contaminants of Potential Concern in Parcel B Soil Samples Collected From 0-12 feet below ground surface

Detected Compounds (0-12 ft. bgs.)	Mean (in mg/kg)	Minimum (in mg/kg)[1]	Maximum (in mg/kg)	Screening Value[2] (in mg/kg)	Detection Frequency (in percent detected)	*n*	Contaminant of Potential Concern
Aldrin	0.00715	0.00036	0.03	0.029	12.9%	124	X
alpha-Hexachlorocyclohexane	0.00097	0.00084	0.0011	0.077	1.6%	124	
Aluminum	25,367	2,800	51,000	50,000	100.0%	112	X
Anthracene	0.164	0.00012	34	17,000	56.6%	481	
Antimony	1.739	0.15	19	20	64.3%	112	
Aroclor 1254	0.0118	0.0065	0.019	0.22	6.8%	44	
Arsenic	1.815	0.54	3.5	0.39	100.0%	112	X
Barium	211.9	45.7	480	10,000	100.0%	112	
Benzene	0.0003	0.00013	0.00047	1.1	1.9%	105	
Benzo(a)anthracene	0.292	0.00019	48	0.15	71.5%	481	X
Benzo(a)pyrene	0.291	0.00011	43	0.015	72.1%	481	X
Benzo(b)fluoranthene	0.372	0.00018	50	0.15	71.1%	481	X
Benzo(g,h,i)perylene**	0.2	0.00018	28	NA	71.3%	481	
Benzo(k)fluoranthene	0.222	0.00017	23	1.5	46.2%	481	X
Beryllium	0.848	0.039	1.7	100	87.5%	112	
Boron	3.023	0.53	7.6	10,000	33.9%	112	
Bromodichloromethane	0.00045	0.00045	0.00045	0.27	0.9%	105	
Butyl benzyl phthalate	0.82	0.54	1.1	260	1.6%	126	
Cadmium	0.591	0.046	1.9	5.0	54.5%	112	
Calcium	15724	830	39000	1,100,000***	100.0%	112	
Carbazole**	0.045	0.041	0.049	NA	2.4%	126	
Carbon Disulfide	0.0013	0.0013	0.0013	820	0.9%	105	
Chloroform	0.00048	0.00048	0.00048	0.29	0.9%	105	

Table A1 (continued). Summary Statistics of Detected Compounds and Selection of Contaminants of Potential Concern in Parcel B Soil Samples Collected From 0-12 feet below ground surface

Detected Compounds (0-12 ft. bgs.)	Mean (in mg/kg)	Minimum (in mg/kg)[1]	Maximum (in mg/kg)	Screening Value[2] (in mg/kg)	Detection Frequency (in percent detected)	*n*	Contaminant of Potential Concern
Chromium	13.4	6.5	24	0.29	100.0%	112	X
Chrysene	0.327	0.00011	52	15	75.1%	481	X
Cobalt	12.56	6.2	20	23	100.0%	112	
Copper	30.96	13	73	500	100.0%	112	
Dibenz(a,h)anthracene	0.0767	0.000095	9.2	0.015	58.6%	481	X
Dichlorodiphenyldichloroethane	0.00459	0.0005	0.018	2.0	14.5%	124	
Dichlorodiphenyldichloroethylene	0.00716	0.00044	0.11	1.4	21.8%	124	
Dichlorodiphenyltrichloroethane	0.00871	0.00053	0.1	1.7	28.2%	124	
Dichlorvos	0.013	0.013	0.013	1.7	1.3%	75	
Dieldrin	0.0137	0.0003	0.13	0.03	30.7%	124	X
Endosulfan I	0.001	0.001	0.001	370	0.8%	124	
Endosulfan II	0.0046	0.0046	0.0046	370	0.8%	124	
Endosulfan sulfate	0.000535	0.00051	0.00056	370	1.6%	124	
Endrin	0.00077	0.00065	0.00089	18.0	1.6%	124	
Endrin ketone	0.004	0.004	0.004	18.0	0.8%	124	
Fluoranthene	0.672	0.0003	120	2,000	73.6%	481	
Fluorene	0.175	0.0001	35	2,000	49.1%	481	
Formaldehyde	215	150	380	12,000	66.7%	12	
g-Chlordane	0.00166	0.00048	0.0031	1.6	4.4%	115	
Heptachlor epoxide	0.00041	0.00041	0.00041	0.053	0.8%	124	
Indeno(1,2,3-cd)pyrene	0.199	0.00015	26	0.15	68.0%	481	X
Iron	29,773	3,100	47,000	55,000	100.0%	112	
Lead	51.42	8.4	1,600	400	100.0%	132	X

Table A1 (continued). Summary Statistics of Detected Compounds and Selection of Contaminants of Potential Concern in Parcel B Soil Samples Collected From 0-12 feet below ground

Detected Compounds (0-12 ft. bgs.)	Mean (in mg/kg)	Minimum (in mg/kg)[1]	Maximum (in mg/kg)	Screening Value[2] (in mg/kg)	Detection Frequency (in percent detected)	*n*	Contaminant of Potential Concern
Lithium	10.43	1	19	160	100.0%	112	
m,p-Xylene	0.00069	0.00069	0.00069	600	0.9%	105	
Magnesium	5,186	490	10,000	446,000***	100.0%	112	
Manganese	637.9	250	1,100	1,800	100.0%	112	
Mercury	0.0209	0.0039	0.4	5.6	82.9%	111	
Methoxychlor	0.011	0.011	0.011	310	0.8%	123	
Methylene chloride	0.00164	0.00089	0.0047	11.0	21.0%	105	
Molybdenum	0.562	0.17	1	300	22.3%	112	
Naphthalene	0.168	0.00016	13	3.6	25.2%	481	X
Nickel	8.942	5	15	1,000	100.0%	112	
Octachloro-p-dibenzodioxin	0.00005	0.000003	0.00014	0.0015*	71.4%	7	
OCDF	0.0000019	0.00000046	0.0000033	0.0015*	42.9%	7	
o-Xylene	0.00029	0.00029	0.00029	690	0.9%	105	
Phenanthrene**	0.763	0.00011	160	NA	61.1%	481	
Potassium	2544	42	6000	5,250,000***	100.0%	112	
Pyrene	0.611	0.00013	120	1,700	74.6%	481	
Selenium	1.317	0.56	2	300	38.4%	112	
Silver	0.433	0.18	0.63	300	45.5%	112	
Sodium	537.4	73	1500	1,670,000***	88.4%	112	
Strontium	263.1	63	730	30,000	100.0%	112	
Strychnine**	0.00835	0.007	0.0097	NA	3.5%	57	
Tetrachloroethene	0.00177	0.00079	0.0024	0.55	5.7%	105	
Thallium	0.27	0.09	0.75	5.0	100.0%	112	

Table A1 (continued). Summary Statistics of Detected Compounds and Selection of Contaminants of Potential Concern in Parcel B Soil Samples Collected From 0-12 feet below ground surface

Detected Compounds (0-12 ft. bgs.)	Mean (in mg/kg)	Minimum (in mg/kg)[1]	Maximum (in mg/kg)	Screening Value[2] (in mg/kg)	Detection Frequency (in percent detected)	*n*	Contaminant of Potential Concern
Toluene	0.00226	0.00011	0.0045	1,000	17.1%	105	
Total Xylene	0.00098	0.00098	0.00098	630	0.9%	105	
Trichloroethene	0.00143	0.0011	0.0017	0.91	3.8%	105	
Uranium	1.16	0.43	2.3	200	100.0%	174	
Vanadium	77.49	45	160	5.5	100.0%	112	X

NOTES:
N/a = Not applicable, NA = Comparison Value Not Available, *n* = Number of samples collected
[*] Please note that the Comparison Value displayed has been adjusted based on EPA 2010 using a Toxicity Equivalent Factor (TEF). TEFs are based on the relative toxicity of the compound in comparison to 2,3,7,8-Tetrachlorodibenzo-p-dioxin, which has a TEF of 1.0 (http://www.epa.gov/raf/files/tefs-for-dioxin-epa-00-r-10-005-final.pdf). Therefore, the appropriate CV surrogate for these compounds was calculated with the following TEFs: 1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin (0.01); 1,2,3,4,6,7,8-Heptachlorodibenzofuran (0.01); 1,2,3,7,8-Pentachlorodibenzofuran (0.03); 2,3,4,7,8-Hexachlorodibenzofuran (0.1); 2,3,7,8-Tertachlorodibenzofuran (0.1); Octachlorodibenzo-p-dioxin (0.003); and Octachlorodibenzofuran (0.003).
[**] Compounds do not have comparison values established by the ATSDR or EPA.
[***] Calculated Screening Level based on Recommended daily allowance of essential minerals or FDA supplemental dietary mineral levels, for a 70kg adult (IOM 2011).
[1] Minimum of detected data.
[2] Please see Table A7 for additional information on the screening values used in this evaluation.

Table A2. Summary Statistics of Detected Compounds in Parcel B Soil Samples Collected From 0-2 feet below ground surface

Detected Compounds (0-2 ft. bgs.)	Mean (in mg/kg)	Minimum (in mg/kg)[1]	Maximum (in mg/kg)	Screening Value[2] (in mg/kg)	Detection Frequency (in percent detected)	*n*	Contaminant of Potential Concern
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	0.0000105	0.000006	0.000015	0.0000045[a]	66.7%	3	
1,2,3,4,6,7,8-Heptachlorodibenzofuran	0.0000013	0.0000013	0.0000013	0.0000045[a]	33.3%	3	
1-Methylnaphthalene	0.14	0.14	0.14	22	1.9%	53	
2,4-Dichlorophenoxyacetic acid	0.0091	0.0091	0.0091	690	2.3%	43	
2-Methylnaphthalene	0.1	0.1	0.1	200	1.9%	53	
4,6-Dinitro-2-methylphenol	0.35	0.35	0.35	4.9	1.9%	53	
Acenaphthene	0.213	0.00012	32	3,000	63.8%	271	
Acenaphthylene**	0.00698	0.00012	0.21	NA	59.8%	271	
Acetone	0.0299	0.0056	0.093	50,000	12.9%	31	
a-Chlordane	0.002	0.00031	0.0037	1.6	8.2%	61	
Aldrin	0.00792	0.00053	0.03	0.029	16.9%	65	X
alpha-Hexachlorocyclohexane	0.0011	0.0011	0.0011	0.077	1.5%	65	
Aluminum	23666	8500	41400	50,000	100.0%	53	
Anthracene	0.219	0.00012	34	17,000	71.2%	271	
Antimony	1.972	0.17	19	20	77.4%	53	
Aroclor 1254	0.00815	0.0065	0.0098	0.22	10.5%	19	
Arsenic	1.843	1.1	3.5	0.39	100.0%	53	X

Table A2 (continued). Summary Statistics of Detected Compounds in Parcel B Soil Samples Collected From 0-2 feet below ground surface

Detected Compounds (0-2 ft. bgs.)	Mean (in mg/kg)	Minimum (in mg/kg)[1]	Maximum (in mg/kg)	Screening Value[2] (in mg/kg)	Detection Frequency (in percent detected)	*n*	Contaminant of Potential Concern
Barium	199.3	100	310	10,000	100.0%	53	
Benzo(a)anthracene	0.384	0.00019	48	0.15	84.1%	271	X
Benzo(a)pyrene	0.386	0.0002	43	0.015	84.5%	271	X
Benzo(b)fluoranthene	0.501	0.0002	50	0.15	83.4%	271	X
Benzo(g,h,i)perylene**	0.266	0.00023	28	NA	84.1%	271	
Benzo(k)fluoranthene	0.293	0.00017	23	1.5	51.3%	271	X
Beryllium	0.799	0.039	1.4	100	84.9%	53	
Boron	3.472	0.77	5.5	10,000	35.9%	53	
Butyl benzyl phthalate	0.54	0.54	0.54	260	1.9%	53	
Cadmium	0.585	0.046	1.3	5.0	66.0%	53	
Calcium	14981	5800	38000	1,100,000***	100.0%	53	
Carbazole**	0.045	0.041	0.049	NA	5.7%	53	
Chromium	12.99	6.5	23	0.29	100.0%	53	X
Chrysene	0.436	0.00011	52	15	87.1%	271	X
Cobalt	11.44	6.2	20	23	100.0%	53	
Copper	30.03	13	73	500	100.0%	53	
Dibenz(a,h)anthracene	0.0939	0.000095	9.2	0.015	74.2%	271	X
Dichlorodiphenyldichloroethane	0.00454	0.0005	0.018	2.0	20.0%	65	
Dichlorodiphenyldichloroethylene	0.00745	0.00044	0.11	1.4	30.8%	65	
Dichlorodiphenyltrichloroethane	0.00654	0.00053	0.063	1.7	36.9%	65	
Dieldrin	0.0153	0.0003	0.13	0.03	41.5%	65	
Endrin	0.00077	0.00065	0.00089	18	3.1%	65	
Endrin ketone	0.004	0.004	0.004	18	1.5%	65	

Table A2 (continued). Summary Statistics of Detected Compounds in Parcel B Soil Samples Collected From 0-2 feet below ground surface

Detected Compounds (0-2 ft. bgs.)	Mean (in mg/kg)	Minimum (in mg/kg)[1]	Maximum (in mg/kg)	Screening Value[2] (in mg/kg)	Detection Frequency (in percent detected)	*n*	Contaminant of Potential Concern[3]
Fluoranthene	0.913	0.0004	120	2,000	86.0%	271	
Fluorene	0.235	0.0001	35	2,000	63.1%	271	
g-Chlordane	0.00166	0.00048	0.0031	1.6	8.2%	61	
Indeno(1,2,3-cd)pyrene	0.266	0.00022	26	0.15	80.1%	271	X
Iron	27857	14000	44000	55,000	100.0%	53	
Lead	77.95	8.7	1600	400	100.0%	72	X
Lithium	10.19	6	18.9	160	100.0%	53	
Magnesium	4933	2100	9400	446,000***	100.0%	53	
Manganese	604.2	250	1100	1,800	100.0%	53	
Mercury	0.0165	0.0048	0.11	5.6	83.0%	53	
Methylene chloride	0.00172	0.00096	0.0047	11.0	19.4%	31	
Molybdenum	0.664	0.17	1	300	32.1%	53	
Naphthalene	0.247	0.00032	13	3.6	29.5%	271	X
Nickel	8.823	5.6	15	1,000	100.0%	53	
Octachlorodibenzo-p-dioxin	0.000078	0.000043	0.00014	0.0000045[b]	100.0%	3	
Octachlorodibenzofuran	0.0000026	0.0000019	0.0000033	0.0000045[b]	66.7%	3	
Phenanthrene**	1.04	0.0006	160	NA	74.9%	271	
Potassium	2694	1100	5300	5,250,000***	100.0%	53	
Pyrene	0.855	0.00024	120	1,700	85.2%	271	
Selenium	1.236	0.57	2	300	34.0%	53	
Silver	0.407	0.26	0.56	300	37.7%	53	
Sodium	434	85	1300	1,670,000***	83.0%	53	
Strontium	239.5	69	390	30,000	100.0%	53	

Table A2 (continued). Summary Statistics of Detected Compounds in Parcel B Soil Samples Collected From 0-2 feet below ground surface

Detected Compounds (0-2 ft. bgs.)	Mean (in mg/kg)	Minimum (in mg/kg)[1]	Maximum (in mg/kg)	Screening Value[2] (in mg/kg)	Detection Frequency (in percent detected)	*n*	Contaminant of Potential Concern
Strychnine**	0.00835	0.007	0.0097	NA	11.1%	18	
Tetrachloroethene	0.0016	0.00079	0.0024	0.55	6.5%	31	
Thallium	0.259	0.09	0.48	5.0	100.0%	53	
Toluene	0.00248	0.001	0.004	1,000	16.1%	31	
Uranium	1.134	0.68	2.3	200	100.0%	66	
Vanadium	71.94	45	120	5.5	100.0%	53	X
Zinc	72.79	38	170	20,000	100.0%	53	

NOTES:
N/a = Not applicable, NA = Comparison Value Not Available, *n* = Number of samples collected
* Please note that the Comparison Value displayed has been adjusted based on EPA 2010 using a Toxicity Equivalent Factor (TEF). TEFs are based on the relative toxicity of the compound in comparison to 2,3,7,8-Tetrachlorodibenzo-p-dioxin, which has a TEF of 1.0 (http://www.epa.gov/raf/files/tefs-for-dioxin-epa-00-r-10-005-final.pdf). Therefore, the appropriate CV surrogate for these compounds was calculated with the following TEFs: 1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin (0.01); 1,2,3,4,6,7,8-Heptachlorodibenzofuran (0.01); 1,2,3,7,8-Pentachlorodibenzofuran (0.03); 2,3,4,7,8-Hexachlorodibenzofuran (0.1); 2,3,7,8-Tertachlorodibenzofuran (0.1); Octachlorodibenzo-p-dioxin (0.003); and Octachlorodibenzofuran (0.003).
** Compounds do not have comparison values established by the ATSDR or EPA.
*** Calculated Screening Level based on Recommended daily allowance of essential minerals or FDA supplemental dietary mineral levels, for a 70kg adult (IOM 2011).
[1] Minimum of detected data.
[2] Please see Table A7 for additional information on the screening values used in this evaluation.

Table A3. Construction Worker Non-Cancer Hazard Quotients

Contaminant of Potential Concern	Soil Ingestion Non-cancer Hazard Quotient	Dermal Exposure to Soil Non-cancer Hazard Quotient	Combined Non-cancer Hazard Quotient
Aldrin	4.31E-04	2.58E-05	4.56E-04
Aluminum	8.58E-02	N/a	8.58E-02
Arsenic	2.05E-02	3.68E-04	2.08E-02
Chromium	1.50E-02	N/a	1.50E-02
Dieldrin	7.75E-04	4.65E-05	8.21E-04
Naphthalene	2.74E-05	6.30E-06	3.37E-05
Vanadium	5.19E-02	N/a	5.19E-02
Total Non-cancer HI	1.74E-01	4.47E-04	1.75E-01

HQ = Hazard Quotient. The hazard quotient is equal to the estimated exposure dose divided by the non-cancer health-based guideline. Values greater than 1 indicate the estimated non-cancer dose is greater than the health-based guideline.
HI= Hazard Index = Represents the cumulative HQ of multiple chemicals.
N/a = Not applicable, as per EPA RAGS Part E, dermal calculations were not performed for these contaminants

Table A4. Construction Worker Theoretical Cancer Risks

Contaminant of Potential Concern	Soil Ingestion Theoretical Cancer Risk	Dermal Exposure to Soil Theoretical Cancer Risk	Combined Theoretical Cancer Risk
Aldrin	1.57E-10	4.71E-11	2.04E-10
Arsenic	6.57E-07	5.92E-08	7.16E-07
Benz(a)anthracene	1.43E-07	5.58E-08	1.99E-07
Benz(a)pyrene	1.35E-06	5.25E-07	1.87E-06
Benz(b)fluoranthene	1.58E-07	6.17E-08	2.20E-07
Benz(k)fluoranthene	7.07E-09	2.76E-09	9.83E-09
Chromium	1.61E-06	N/a	1.61E-06
Dieldrin	1.60E-09	6.24E-10	2.22E-09
Dibenz(a,h)anthracene	2.86E-07	1.12E-07	3.98E-07
Dieldrin	4.43E-10	1.33E-10	5.76E-10
Indeno(1,2,3-cd)pyrene	8.42E-08	3.28E-08	1.17E-07
Total Cancer Risk	4.29E-06	8.50E-07	5.14E-06

Note: * = Due to their similar modes of toxicological action, theoretical cancer risks of all PAHs were combined in this evaluation. The total, combined theoretical cancer risk of all PAHs is 2.8E-06.

Table A5. Maintenance Worker Non-Cancer Hazard Quotients

Contaminant of Potential Concern	Soil Ingestion Non-cancer Hazard Quotient	Dermal Exposure to Soil Non-cancer Hazard Quotient	Combined Non-cancer Hazard Quotient
Aldrin	6.52E-05	4.31E-05	1.08E-04
Arsenic	2.57E-03	5.09E-04	3.08E-03
Chromium	1.80E-03	N/a	1.80E-03
Dieldrin	9.39E-05	6.20E-05	1.56E-04
Naphthalene	7.83E-06	1.41E-05	2.19E-05
Vanadium	5.93E-03	N/a	5.93E-03
Total Non-cancer HI	1.05E-02	6.28E-04	1.11E-02

HQ = Hazard Quotient. The hazard quotient is equal to the estimated exposure dose divided by the non-cancer health-based guideline. Values greater than 1 indicate the estimated non-cancer dose is greater than the health-based guideline.
HI= Hazard Index = Represents the cumulative HQ of multiple chemicals.
N/a = Not applicable, as per EPA RAGS Part E, dermal calculations were not performed for these contaminants

Table A6. Maintenance Worker Theoretical Cancer Risks

Contaminant of Potential Concern	Soil Ingestion Theoretical Cancer Risk	Dermal Exposure to Soil Theoretical Cancer Risk	Combined Theoretical Cancer Risk
Aldrin	1.19E-10	7.84E-11	1.97E-10
Arsenic	4.13E-07	8.18E-08	4.95E-07
Benz(a)anthracene	1.48E-07	1.27E-07	2.75E-07
Benz(a)pyrene	1.38E-06	1.18E-06	2.56E-06
Benz(b)fluoranthene	1.63E-07	1.40E-07	3.03E-07
Benz(k)fluoranthene	7.14E-09	6.13E-09	1.33E-08
Chromium	9.62E-07	N/a	9.62E-07
Dieldrin	1.63E-09	1.40E-09	3.03E-09
Dibenz(a,h)anthracene	2.96E-07	2.54E-07	5.50E-07
Dieldrin	2.68E-10	1.77E-10	4.46E-10
Indeno(1,2,3-cd)pyrene	8.57E-08	7.35E-08	1.59E-07
Total Cancer Risk	3.46E-06	1.87E-06	5.32E-06

Note: * = Due to their similar modes of toxicological action, theoretical cancer risks of all PAHs were combined in this evaluation. The total, combined theoretical cancer risk of all PAHs is 3.9E-06.

Table A7. Screening Values used for Contaminant of Potential Concern Selection

Detected Compounds	ATSDR CV (in mg/kg)	Source	EPA Regional Screening Level (in mg/kg)	Source	Notes
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	NA	N/a	NA	N/a	
1,2,3,4,6,7,8-HpCDF	NA	N/a	NA	N/a	
1,1,1-Trichloroethane	1.00E+05	RMEG	**8.70E+03**	non-cancer	
1,2,4-Trimethylbenzene	NA	N/a	**6.20E+01**	non-cancer	
1,2-Dichloropropane	5.00E+03	cEMEG	**8.90E-01**	cancer	
1,3,5-Trimethylbenzene	NA	N/a	**7.80E+02**	non-cancer	
1-Methylnaphthalene	4.00E+03	cEMEG	**2.20E+01**	cancer	
2,4-Dichlorophenoxyacetic acid	NA	N/a	**6.90E+02**	non-cancer	
2,4-Dinitrotoluene	1.00E+02	cEMEG	**1.60E+00**	cancer	
2,6-Dinitrotoluene	2.00E+02	iEMEG	**6.10E+01**	non-cancer	
2-Methylnaphthalene	**2.00E+02**	RMEG	3.10E+02	non-cancer	
Acenaphthene	**3.00E+03**	RMEG	3.40E+03	non-cancer	
Acenaphthylene					
Acetone	**5.00E+04**	RMEG	6.10E+04	non-cancer	
Aldrin	2.00E+00	cEMEG	**2.90E-02**	cancer	
Aluminum	**5.00E+04**	cEMEG	7.70E+04	non-cancer	
Anthracene	2.00E+04	cRMEG	**1.70E+04**	non-cancer	
Antimony	**2.00E+01**	cRMEG	3.10E+01	non-cancer	Metallic Antimony
Aroclor 1254	1.00E+00	cChild EMEG	**2.20E-01**	cancer	
Aroclor 1260			**2.20E-01**	cancer	
Arsenic	2.00E+01	cChild EMEG	**3.90E-01**	cancer	
Azinphos-methyl	1.00E+02	cChild EMEG	NA	N/a	
Barium	**1.00E+04**	cChild EMEG	1.50E+04	non-cancer	
Benzene	3.00E+01	cEMEG	**1.10E+00**	cancer	
Benzo(a)anthracene	NA	N/a	**1.50E-01**	cancer	
Benzo(a)pyrene	1.00E-01	CREG	**1.50E-02**	cancer	
Benzo(b)fluoranthene	NA	N/a	**1.50E-01**	cancer	
Benzo(g,h,i)perylene	NA	N/a	NA	N/a	
Benzo(k)fluoranthene	NA	N/a	**1.50E+00**	cancer	
Beryllium	**1.00E+02**	cEMEG	1.60E+02	non-cancer	
Bis(2-ethylhexyl)phthalate	NA	N/a	**3.50E+01**	cancer	
Boron	**1.00E+04**	RMEG	1.60E+04	non-cancer	
Butyl Benzyl Phthalate	1.00E+04	RMEG	2.60E+02	cancer	
Cadmium	**5.00E+00**	cEMEG	7.10E+01	non-cancer	
Carbazole	NA	N/a	NA	N/a	
Carbon disulfide	5.00E+03	RMEG	**8.20E+02**	non-cancer	
Chloroform	5.00E+02	cEMEG	**2.90E-01**	cancer	

Chromium	5.00E+01	cEMEG (Chromium VI)	**2.90E-01**	cancer	Value for Chromium VI
Chrysene	NA	N/a	**1.50E+01**	cancer	
Cobalt	5.00E+02	iEMEG	**2.30E+01**	non-cancer	
Copper	**5.00E+02**	cEMEG	3.10E+03	non-cancer	
Cyanide, total	**1.00E+03**	RMEG	1.60E+03	non-cancer	

Table A7 (continued). Screening Values used for Contaminant of Potential Concern Selection

Detected Compounds	ATSDR CV (in mg/kg)	Source	EPA Regional Screening Level (in mg/kg)	Source	Notes
Dibenz(a,h)anthracene	NA	N/a	**1.50E-02**	cancer	
Dichlorodiphenyldichloroethane	NA	N/a	NA	N/a	
Dichlorodiphenyldichloroethylene	NA	N/a	NA	N/a	
Dichlorodiphenyltrichloroethane	NA	N/a	NA	N/a	
Dichlorvos	3.00E+01	cEMEG	**1.70E+00**	cancer	
Dieldrin	3.00E+00	cEMEG	**3.00E-02**	cancer	
Di-n-Butyl phthalate	**5.00E+03**	RMEG	6.10E+03	non-cancer	
Endosulfan I	NA	N/a	NA	N/a	
Endosulfan Sulfate	NA	N/a	NA	N/a	
Endrin ketone	NA	N/a	NA	N/a	
Fluoranthene	**2.00E+03**	RMEG	2.30E+03	non-cancer	
Fluorene	**2.00E+03**	RMEG	2.30E+03	non-cancer	
Fluoride	NA	N/a	**3.10E+03**	non-cancer	
Formaldehyde	**1.00E+04**	cEMEG	1.20E+04	non-cancer	
Heptachlor epoxide	8.00E-02	CREG	**5.30E-02**	cancer	
Indeno(1,2,3-cd)pyrene	NA	N/a	**1.50E-01**	cancer	
Iron	NA	N/a	**5.50E+04**	non-cancer	
Lead	NA	N/a	**4.00E+02**	non-cancer	
Lithium	NA	N/a	**1.60E+02**	non-cancer	
Manganese	3.00E+03	RMEG	**1.80E+03**	non-cancer	
Mercury	NA	N/a	**5.60E+00**	non-cancer	Value for elemental Hg
Methoxychlor	**3.00E+02**	RMEG	3.10E+02	non-cancer	
Methylene chloride	3.00E+03	cEMEG	**1.10E+01**	cancer	
Molybdenum	**3.00E+02**	RMEG	3.90E+02	non-cancer	
Naphthalene	1.00E+03	RMEG	**3.60E+00**	cancer	
Nickel	**1.00E+03**	RMEG	1.50E+03	non-cancer	Nickel Soluble Salts
N-Nitrosodi-n-propylamine	1.00E-01	CREG	**6.90E-02**	cancer	
Pentachlorophenol	5.00E+01	cEMEG	**8.90E-01**	cancer	
Phenanthrene	NA	N/a	NA	N/a	
Pyrene	2.00E+03	cRMEG	**1.70E+03**	non-cancer	
Selenium	**3.00E+02**	cEMEG	3.90E+02	non-cancer	
Silver	**3.00E+02**	RMEG	3.90E+02	non-cancer	
Strontium	**3.00E+04**	RMEG	4.70E+04	non-cancer	
Styrene	1.00E+04	RMEG	**6.30E+03**	non-cancer	

Sulfate	NA	N/a	NA	N/a	
Tetrachloroethene	5.00E+02	RMEG	**5.50E-01**	cancer	
Thallium	5.00E+00	RMEG (Thallium acetate)	NA	N/a	
Toluene	**1.00E+03**	iEMEG	5.00E+03	non-cancer	
Toxaphene	6.00E-01	CREG	**4.40E-01**	cancer	
Trichloroethene	4.00E+02	PICA	**2.80E+00**	cancer	

Table A7 (continued). Screening Values used for Contaminant of Potential Concern Selection

Detected Compounds	**ATSDR CV (in mg/kg)**	**Source**	**EPA Regional Screening Level (in mg/kg)**	**Source**	**Notes**
Uranium	**2.00E+02**	iEMEG (soluble salts)	2.30E+02	non-cancer	Uranium soluble salts
Vanadium	5.00E+02	iEMEG	**5.50E+00**	non-cancer	metallic vanadium
Zinc	**2.00E+04**	cEMEG	2.30E+04	non-cancer	metallic zinc

NOTE: mg/kg = milligram analyte per kilogram soil, **bolded** comparison values were used for COPC selection, NA = Not Available, N/a = Not applicable, cEMEG = chronic Environmental Media Evaluation Guide, iEMEG = intermediate Environmental Media Evaluation Guide , CREG = Cancer Risk Evaluation Guide , OSWER = 0ffice of Solid Waste and Emergency Response, RMEG = Reference Dose Media Evaluation Guide

APPENDIX B. Additional Exposure Assessment Information

The first step to determine if adverse health effects are likely to occur from exposure to residual soil contamination found in soil at the Parcel B/St. Anthony's property is to estimate exposure doses for the people that are likely to come into contact with site-related contamination. The estimated exposure doses are designed to be conservative estimations of actual contaminant intake, accounting for the majority of potential exposures at the site. As mentioned previously in the document, exposure doses are only estimated for Contaminants of Potential Concern (COPC), which have exceeded the comparison values (CVs) and other screening parameters. Estimating the exposure dose requires assumptions to be made regarding various exposure parameters such as the frequency of a particular activity, duration of exposure to site-related contamination, and the amount of a particular substance that is taken in by an individual during a given activity. Site-specific exposure information is always preferable when estimating exposure doses. However, site-specific information is rarely available due to limited time, a lack of data, and financial constraints. In lieu of site-specific information, default exposure parameters that are established by the U.S. Environmental Protection Agency (EPA) and Agency for Toxic Substances and Disease (ATSDR) are used in the exposure dose estimation. At times, professional judgment is used when default values are not available or seem unreasonable for a particular site.

Construction workers and maintenance workers are the two primary receptors that were identified in this evaluation who are likely to come into contact with site-related contamination now and in the future.

The primary exposure pathways evaluated in this health consultation are exposure to residual soil contamination through incidental ingestion and dermal exposure (skin contact). The dose estimations calculated for the construction workers assumed that they will be exposed to residual soil contamination for 250 days per year over 5 years. For maintenance workers, it is assumed that they will be exposed to soil for 100 days per year over a period of 25 yrs. The major exposure factors used for each receptor are listed below in Table B1.

Two routes of exposure exist for these exposure pathway scenarios: 1) incidental ingestion of soil contaminants and 2) dermal exposure to soil contaminants. Since both routes of exposure occur at the same time, the estimated doses for each exposure route are combined to form a total dose for each contaminant. In this health consultation, a number of COPCs were PAHs, which have a similar mode of action. Therefore, the total dose for each PAH was combined to produce the total dose from exposure to PAHs in soil.

Non-cancer and cancer health endpoints are evaluated differently so the estimation of exposure dose also differs slightly (non-cancer doses are averaged over the timeframe of exposure and cancer doses are averaged over a lifetime). Thus, non-cancer and cancer exposure doses were estimated for both pathways. The exposure dose equations used in this evaluation are presented below (Equations 1-4).

Table B1. Exposure Factors

Receptor	Maintenance Worker	Source of Exposure Factor	Construction Worker	Source of Exposure Factor
Exposure Frequency (days/year)	100	Site-specific Professional Judgment	250	Default Value (PHAGM 2005)
Exposure Duration (years)	25	Default Value (EPA 2002)	5	Site-specific Professional Judgment
Soil Ingestion Rate (mg/day)	100	Default Value (EPA 2002)	330	Default Value (EPA 2002)
Surface Area Exposed (cm^2)	3,300	Default Value (EPA 2004)	3,300	Default Value (EPA 2004)
Adherence Factor (mg/cm^2)	0.2	Default Value (EPA 2004)	0.3	Default Value (EPA 2004)
Body Weight (kg)	70	Default Value (PHAGM 2005)	70	Default Value (PHAGM 2005)
Non-Cancer Averaging Time (days)	9,125	Default Value (PHAGM 2005)	1,825	Default Value (PHAGM 2005)
Cancer Averaging Time (days)	25,550	Default Value (EPA 1997)	25,550	Default Value (EPA 1997)

$cm.^2$ = square centimeters, kg. = kilogram, mg. = milligram, µg. = microgram
EPA (1997) = Environmental Protection Agency, Exposure Factors Handbook
EPA (2002) = Environmental Protection Agency, Supplemental Guidance for Developing Soil Screening Levels at Superfund Sites
EPA (2004) = Environmental Protection Agency, Risk Assessment Guidance for Superfund, Part E. Supplemental Guidance for Dermal Exposure
PHAGM (2005) = Agency for Toxic Substances and Disease Registry, Public Health Assessment Guidance Manual

Table B2. Chemical Specific Dermal Exposure Factors (EPA RAGS, Part E 2004)

COPC	Dermal Absorption Fraction (ABS_d)
Aldrin	0.1
Arsenic	0.03
Benz(a)anthracene	0.13
Benz(a)pyrene	0.13
Benz(b)fluoranthene	0.13
Benz(k)fluoranthene	0.13
Chrysene	0.13
Dibenz(a,h)anthracene	0.13
Dieldrin	0.10
Indeno(1,2,3-cd)pyrene	0.13
Naphthalene	0.13

Another critical component of the exposure dose estimation is the concentration of chemicals of potential concern that individuals are likely to be exposed to in a particular medium, which is referred to as the Exposure Point Concentration (EPC).

Table B3. Parcel B Estimated Soil Exposure Point Concentrations for Construction Workers (soil data collected from 0-12 ft. bgs.)

Contaminant of Potential Concern	Max. Detected Conc. (in mg/kg)	Mean Conc. (in mg/kg)	EPC (in mg/kg)	ProUCL 4.1.00 Recommended Exposure Point Concentration Statistical Method	CV (in mg/kg)
Aldrin	0.03	0.03	0.04	95% KM (t) UCL	
Aluminum	51,000	25,367	26,582	95% Student's-t UCL	
Arsenic	3.5	1.8	1.9	95% Student's-t UCL	
Benzo(a)anthracene	48.0	0.2	0.9	97.5% KM (Chebyshev) UCL	
Benzo(a)pyrene	43.0	0.2	0.8	97.5% KM (Chebyshev) UCL	
Benzo(b)fluoranthene	50.0	0.3	0.9	97.5% KM (Chebyshev) UCL	
Benzo(k)fluoranthene	23.0	0.1	0.4	97.5% KM (Chebyshev) UCL	
Chromium	24.0	13.4	13.9	95% Approximate Gamma UCL	
Chrysene	52.0	0.3	0.9	97.5% KM (Chebyshev) UCL	
Dibenz(a,h)anthracene	9.2	0.05	0.2	97.5% KM (Chebyshev) UCL	
Dieldrin	0.13	0.01	0.01	95% KM (Chebyshev) UCL	
Ideno(1,2,3-cd)pyrene	26.0	0.2	0.5	97.5% KM (Chebyshev) UCL	
Lead	1,600	51	113	95% Chebyshev (Mean, Sd) UCL	
Naphthalene	13.0	0.05	0.2	95% KM (Chebyshev) UCL	
Vanadium	160	77	80	95% Approximate Gamma UCL	

NOTES: All contaminants with exposure point concentrations less than the residential and/or industrial comparison value(s) were not carried forward in this evaluation.
NA = Not Available

Table B4. Parcel B Estimated Soil Exposure Point Concentrations for Maintenance Workers (soil data collected from 0-2 ft. bgs.)

Contaminant of Potential Concern	Max. Detected Conc. (in mg/kg)	Mean Conc. (in mg/kg)	EPC (in mg/kg)	ProUCL 4.1.00 Recommended Exposure Point Concentration Statistical Method	CV (in mg/kg)
Aldrin	0.03	0.004	0.005	95% KM (t) UCL	
Arsenic	3.5	1.8	2.0	95% Student's-t UCL	
Benzo(a)anthracene	48.0	0.3	1.5	97.5% KM (Chebyshev) UCL	
Benzo(a)pyrene	43.0	0.3	1.4	97.5% KM (Chebyshev) UCL	
Benzo(b)fluoranthene	50.0	0.4	1.6	97.5% KM (Chebyshev) UCL	
Benzo(k)fluoranthene	23.0	0.2	0.7	97.5% KM (Chebyshev) UCL	
Chromium	23.0	13.0	13.8	95% Approximate Gamma UCL	
Chrysene	52.0	0.4	1.6	97.5% KM (Chebyshev) UCL	
Dibenz(a,h)anthracene	9.2	0.08	0.3	97.5% KM (Chebyshev) UCL	
Dieldrin	0.13	0.01	0.01	95% KM (Chebyshev) UCL	
Ideno(1,2,3-cd)pyrene	26.0	0.15	0.5	97.5% KM (Chebyshev) UCL	
Lead	1,600	51	113	95% Chebyshev (Mean, Sd) UCL	
Naphthalene	13.0	0.05	0.2	95% KM (Chebyshev) UCL	
Vanadium	160	77	80	95% Approximate Gamma UCL	

NOTES: All contaminants with exposure point concentrations less than the residential and/or industrial comparison value(s) were not carried forward in this evaluation.
NA = Not Available

Equation 1. Non-Cancer Soil Ingestion Dose

$$\textbf{Non-Cancer Dose} = (C_s * IRS * CF * EF * ED) / BW * AT_{NC}$$

Where:
C_s = Chemical Concentration in Soil (in mg/kg or milligrams contaminant per kilogram of soil)
IRS = Ingestion Rate of Soil (in milligrams of soil per day)
CF = Conversion Factor (in kilograms per milligram)
EF = Exposure Frequency (in days per year)
ED = Exposure Duration (in years)
BW = Body Weight (in kilograms)
AT_{NC} = Non-Cancer Averaging Time (in days)

Example: Non-cancer construction worker ingestion dose of Arsenic (Table B6) =>
(4.27 mg/kg * 330 mg/day * 1* 10^{-6} kg/mg * 250 days per year * 5 years) / (70 kg. * 1,825 days)
= **$1.38 * 10^{-5}$ mg/kg-day**

Equation 2. Cancer Soil Ingestion Dose

$$\textbf{Cancer Dose} = (C_s * CF * IRS * EF * ED) / (BW * AT_C)$$

Where:
C_s = Chemical Concentration in Soil (in mg/kg or millgrams contaminant per kilogram of soil)
CF = Conversion Factor (in kilograms per milligram)
IRS = Ingestion Rate of Soil (in milligrams of soil per day)
EF = Exposure Frequency (in days per year)
ED = Exposure Duration (in years)
BW = Body Weight (in kilograms)
AT_C = Cancer Averaging Time (in days)

Example: Cancer construction worker ingestion dose of Benz(a)pyrene (Table B8) =>
(0.29 mg/kg * 10^{-6} kg/mg * 330 mg/day * 250 days/year * 5 years) / (70kg * 25,550 days
= $6.69 * 10^{-8}$ mg/kg/day

Equation 3. Non-Cancer Dermal Absorbed Dose from Soil

$$\textbf{DA event (DAev)} = C_s * CF * AF * ABS_d$$

$$\textbf{DAD (mg/cm}^2\textbf{-event)} = \frac{DAev * EF * ED * SA}{BW * AT_{NC}}$$

Where:
DAev = Absorbed dose per event (in milligrams per square centimeter event)
$\mathbf{C_s}$ = Chemical concentration in soil (in milligrams contaminant per kilogram soil)
CF = Conversion factor (in kilograms per milligram)
AF = Adherence Factor (milligram per square centimeter event)
$\mathbf{ABS_d}$ = Dermal Absorption Fraction
EF = Exposure Frequency (in days per year)
ED = Exposure Duration (in years)
SA = Skin Surface Area (in square centimeters)
BW = Body Weight (in kilograms)
$\mathbf{AT_{NC}}$ = Non-Cancer Averaging Time (in days)

Example: Non-cancer maintenance worker dermal absorbed dose of Arsenic (Tables B5 & B7) =>

DA_{ev} = 6.18 mg/kg * 10^{-6} kg/mg * 0.2 mg/cm^2-event * 0.03 = **3.71 * 10^{-8} mg/cm^2-event**

DAD = (3.71 * 10^{-8} mg/cm^2-event * 225 days * 25 years * 3,300 cm^2) / (70 kg. * 9,125 days) = **1.08 * 10^{-6} mg/kg-day**

Table B5. Dermal Absorbed Dose Per Event (DA_{ev})

Contaminant of Potential Concern	Construction Worker (in mg/cm^2-event)	Maintenance Worker (in mg/cm^2-event)
DA_{ev} for Aldrin	1.20E-10	1.00E-10
DA_{ev} for Arsenic	1.71E-08	1.18E-08
DA_{ev} for Benz(a)anthracene	3.32E-08	3.77E-08
DA_{ev} for Benz(a)pyrene	3.12E-08	3.51E-08
DA_{ev} for Benz(b)fluoranthene	3.67E-08	4.16E-08
DA_{ev} for Benz(k)fluoranthene	1.64E-08	1.82E-08
DA_{ev} for Chrysene	3.71E-08	4.16E-08
DA_{ev} for Dibenz(a,h)anthracene	6.63E-09	7.54E-09
DA_{ev} for Dieldrin	3.60E-10	2.40E-10
DA_{ev} for Indeno(1,2,3-cd)pyrene	1.95E-08	2.18E-08
DA_{ev} for Naphthalene	7.29E-05	1.72E-04

Equation 4. Cancer Dermal Absorbed Dose from Soil

$$\text{DA event (DAev)} = C_s * CF * AF * ABS_d$$

$$\text{DAD (mg/cm}^2\text{-event)} = \frac{DAev * EF * ED * SA}{AT_C * BW}$$

Where:
DAev = Absorbed dose per event (in milligrams per square centimeter event)
IRW_{adj} = Age-adjusted dermal absorption factor (in square centimeter-year per kilogram)
EF = Exposure Frequency (in days)
SA = Skin Surface Area (in square centimeters)
AT_C = Cancer Averaging Time (in days)
BW = Body Weight (in kilograms)

NOTE: The DA event calculation for non-cancer and cancer dermal absorbed dose equations is the same (DA_{ev} only needs to be calculated once).

Example: Theoretical Cancer Dermal Dose for Maintenance Workers from Benz(a)anthracene (Tables B5 & B9) =>

DA_{ev} = 0.31 mg/kg * 10^{-6} kg/mg * 0.2 mg/cm^2-event * 0.13 = **8.06* 10^{-9} mg/cm^2-event**

DAD = (8.06*10^{-9} mg/cm^2-event * 225 days * 25 years * 3,300 cm^2)/ (70 * 25550 days) = **8.37*10^{-8} mg/kg-day**

Table B6. Construction Worker Non-Cancer Exposure Doses

Contaminant of Potential Concern	Ingestion Dose (mg/kg-day)	Dermal Absorbed Dose (mg/kg-day)	Combined Dose (mg/kg-day)	Health-based Guideline (mg/kg-day)
Aldrin	1.29E-08	7.75E-10	1.37E-08	3.00E-05
Aluminum	8.58E-02	N/a	8.58E-02	1.00E+00
Arsenic	6.14E-06	1.10E-07	6.25E-06	3.00E-04
Chromium	4.50E-05	N/a	4.50E-05	3.00E-03
Dieldrin	3.87E-08	2.32E-09	4.11E-08	5.00E-05
Naphthalene	5.49E-07	1.26E-07	6.75E-07	2.00E-02
Vanadium	2.60E-04	N/a	2.60E-04	5.00E-03

NOTE: mg/kg-day = milligram per kilogram body weight a day, N/a = Not applicable (Dermal Dose is not calculated for chromium as per EPA RAGS E, 2004)

Table B7. Construction Worker Cancer Exposure Doses

Contaminant of Potential Concern	Soil Ingestion Cancer Dose (in mg/kg-day)	Dermal Exposure to Soil Cancer Dose (in mg/kg-day)	Combined Cancer Dose (in mg/kg-day)
Aldrin	9.23E-10	2.77E-10	1.20E-09
Arsenic	4.38E-07	3.94E-08	4.78E-07
Benz(a)anthracene	1.96E-07	7.65E-08	2.73E-07
Benz(a)pyrene	1.85E-07	7.20E-08	2.56E-07
Benz(b)fluoranthene	2.17E-07	8.46E-08	3.01E-07
Benz(k)fluoranthene	9.69E-08	3.78E-08	1.35E-07
Chromium	3.21E-06	N/a	3.21E-06
Dieldrin	2.19E-07	8.55E-08	3.05E-07
Dibenz(a,h)anthracene	3.92E-08	1.53E-08	5.45E-08
Dieldrin	2.77E-09	8.30E-10	3.60E-09

Indeno(1,2,3-cd)pyrene	1.15E-07	4.50E-08	1.60E-07

Note: * = Due to their similar modes of toxicological action, theoretical cancer risks of all PAHs were combined in this evaluation. The total, combined theoretical cancer risk of all PAHs is 2.8E-06.

Table B8. Maintenance Worker Non-Cancer Exposure Doses

Contaminant of Potential Concern	Ingestion Dose (mg/kg-day)	Dermal Absorbed Dose (mg/kg-day)	Combined Dose (mg/kg-day)	Health-based Guideline (mg/kg-day)
Aldrin	1.96E-09	1.29E-09	3.25E-09	3.00E-05
Arsenic	7.71E-07	1.53E-07	9.24E-07	3.00E-04
Chromium	5.39E-06	N/a	5.39E-06	3.00E-03
Dieldrin	4.70E-09	3.10E-09	7.80E-09	5.00E-05
Naphthalene	1.57E-07	2.82E-07	4.39E-07	2.00E-02
Vanadium	2.96E-05	N/a	2.96E-05	5.00E-03

NOTE: mg/kg-day = milligram per kilogram body weight a day, N/a = Not applicable (Dermal Dose is not calculated for chromium and vanadium as per EPA RAGS E, 2004)

Table B9. Maintenance Worker Cancer Exposure Doses

Contaminant of Potential Concern	Ingestion Dose (mg/kg-day)	Dermal Absorbed Dose (mg/kg-day)	Combined Dose (mg/kg-day)
Aldrin	6.99E-10	4.61E-10	1.16E-09
Arsenic	2.75E-07	5.45E-08	3.30E-07
Benz(a)anthracene	2.03E-07	1.74E-07	3.77E-07
Benz(a)pyrene	1.89E-07	1.62E-07	3.51E-07
Benz(b)fluoranthene	2.24E-07	1.92E-07	4.16E-07
Benz(k)fluoranthene	9.78E-08	8.40E-08	1.82E-07
Chromium	1.92E-06	N/a	1.92E-06
Chrysene	2.24E-07	1.92E-07	4.16E-07
Dibenz(a,h)anthracene	4.05E-08	3.48E-08	7.53E-08

Dieldrin	1.68E-09	1.11E-09	2.78E-09
Indeno(1,2,3-cd)pyrene	1.17E-07	1.01E-07	2.18E-07

Note: * = Due to their similar modes of toxicological action, theoretical cancer risks of all PAHs were combined in this evaluation. The total, combined theoretical cancer risk of all PAHs is 3.9E-06.

APPENDIX C. Toxicological Evaluation

The basic objective of a toxicological evaluation is to identify what adverse health effects a chemical causes, and how the appearance of these adverse effects depends on dose. The toxic effects of a chemical also depend on the route of exposure (oral, inhalation, dermal), the duration of exposure (acute, subchronic, chronic or lifetime), the health condition of the person, the nutritional status of the person, and the life style and family traits of the person. In this evaluation, chronic oral exposures were evaluated.

The U.S. Environmental Protection Agency (EPA) and the Agency for Toxic Substances and Disease (ATSDR) have established oral reference doses (RfD) and minimal risk levels (MRL) for non-cancer effects. An RfD is the daily dose in humans (with uncertainty spanning perhaps an order of magnitude), including sensitive subpopulations, that is likely to be without an appreciable risk of non-cancer adverse health effects during a lifetime of exposure to a particular contaminated substance. An MRL is the dose of a compound that is an estimate of daily human exposure that is likely to be without an appreciable risk of adverse non-cancer effects of a specified duration of exposure. The acute, intermediate, and chronic MRLs address exposures of 14 days or less, 14 days to 365 days, and 1-year to lifetime, respectively. The health-based guidelines for the contaminants of potential concern for this evaluation are listed below in Table C1 and C2.

Table C1. Non-Cancer Health-based Guidelines for Contaminants of Potential Concern

Contaminant of Potential Concern	ATSDR Minimal Risk Level (in mg/kg-day)	ATSDR Source	EPA Reference Dose (in mg/kg-day)	EPA Source
Arsenic	0.0003	Chronic Oral	0.0003	IRIS
Benz(a)anthracene	NA	NA	NA	NA
Benz(a)pyrene	NA	NA	NA	NA
Benz(b)fluoranthene	NA	NA	NA	NA
Benz(k)fluoranthene	NA	NA	NA	NA
Chromium*	0.001	Chronic Oral (Hexavalent)	0.003	IRIS (Hexavalent)
Dibenz(a,h)anthracene	NA	NA	NA	NA
Ideno(1,2,3-cd)pyrene	NA	NA	NA	NA

NOTES:
IRIS = Integrated Risk Information System
NA = Not available
*= Total chromium (ratio of 1:6 Cr VI:CrIII) is a more reasonable assumption. An oral RfD for Total chromium is 1.5 mg/kg/day (EPA IRIS).

Table C2. Cancer Toxicity Values for Contaminants of Potential Concern

Contaminant of Potential Concern	Oral Slope Factor (in mg/kg-day^{-1})	Source
Arsenic	1.5	IRIS
Benz(a)anthracene	0.73	Environmental Criteria and Assessment Office
Benz(a)pyrene	7.3	IRIS
Benz(b)fluoranthene	0.73	Environmental Criteria and Assessment Office
Benz(k)fluoranthene	0.073	Environmental Criteria and Assessment Office
Hexavalent Chromium *	0.5	New Jersey
Dibenz(a,h)anthracene	7.3	Environmental Criteria and Assessment Office
Ideno(1,2,3-cd)pyrene	0.73	Environmental Criteria and Assessment Office

NOTES: * = Total chromium (ratio of 1:6 of Cr VI to Cr III) is a more reasonable assumption, but no oral slope factor is available for total chromium, IRIS = EPA Integrated Risk Information System.

APPENDIX D. Agency for Toxic Substances and Disease Registry's ToxFAQs

This fact sheet answers the most frequently asked health questions about polycyclic aromatic hydrocarbons (PAHs). For more information, you may call the ATSDR Information Center at 1-888-422-8737. This fact sheet is one in a series of summaries about hazardous substances and their health effects. This information is important because this substance may harm you. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present.

Highlights

Exposure to polycyclic aromatic hydrocarbons usually occurs by breathing air contaminated by wild fires or coal tar, or by eating foods that have been grilled. PAHs have been found in at least 600 of the 1,430 National Priorities List sites identified by the Environmental Protection Agency (EPA).

What are polycyclic aromatic hydrocarbons (PAHs)?

Polycyclic aromatic hydrocarbons (PAHs) are a group of over 100 different chemicals that are formed during the incomplete burning of coal, oil and gas, garbage, or other organic substances like tobacco or charbroiled meat. PAHs are usually found as a mixture containing two or more of these compounds, such as soot.

Some PAHs are manufactured. These pure PAHs usually exist as colorless, white, or pale yellow-green solids. PAHs are found in coal tar, crude oil, creosote, and roofing tar, but a few are used in medicines or to make dyes, plastics, and pesticides.

What happens to polycyclic aromatic hydrocarbons (PAHs) when they enter the environment?

PAHs enter the air mostly as releases from volcanoes, forest fires, burning coal, and automobile exhaust. PAHs can occur in air attached to dust particles. Some PAH particles can readily evaporate into the air from soil or surface waters. PAHs can break down by reacting with sunlight and other chemicals in the air, over a period of days to weeks. PAHs enter water through discharges from industrial and wastewater treatment plants. Most PAHs do not dissolve easily in water. They stick to solid particles and settle to the bottoms of lakes or rivers. Microorganisms can break down PAHs in soil or water after a period of weeks to months.

In soils, PAHs are most likely to stick tightly to particles; certain PAHs move through soil to contaminate underground water. PAH contents of plants and animals may be much higher than PAH contents of soil or water in which they live.

How might I be exposed to polycyclic aromatic hydrocarbons (PAHs)?

- Breathing air containing PAHs in the workplace of coking, coal-tar, and asphalt production plants; smokehouses; and municipal trash incineration facilities.
- Breathing air containing PAHs from cigarette smoke, wood smoke, vehicle exhausts, asphalt roads, or agricultural burn smoke.
- Coming in contact with air, water, or soil near hazardous waste sites.
- Eating grilled or charred meats; contaminated cereals, flour, bread, vegetables, fruits, meats; and processed or pickled foods.
- Drinking contaminated water or cow's milk.
- Nursing infants of mothers living near hazardous waste sites may be exposed to PAHs through their mother's milk.

How can polycyclic aromatic hydrocarbons (PAHs) affect my health?

Mice that were fed high levels of one PAH during pregnancy had difficulty reproducing and so did their offspring. These offspring also had higher rates of birth defects and lower body weights. It is not known whether these effects occur in people.

Animal studies have also shown that PAHs can cause harmful effects on the skin, body fluids, and ability to fight disease after both short- and long-term exposure. But these effects have not been seen in people.

How likely are polycyclic aromatic hydrocarbons (PAHs) to cause cancer?

The Department of Health and Human Services (DHHS) has determined that some PAHs may reasonably be expected to be carcinogens.

Some people who have breathed or touched mixtures of PAHs and other chemicals for long periods of time have developed cancer. Some PAHs have caused cancer in laboratory animals when they breathed air containing them (lung cancer), ingested them in food (stomach cancer), or had them applied to their skin (skin cancer).

Is there a medical test to show whether I've been exposed to polycyclic aromatic hydrocarbons (PAHs)?

In the body, PAHs are changed into chemicals that can attach to substances within the body. There are special tests that can detect PAHs attached to these substances in body tissues or blood. However, these tests cannot tell whether any health effects will occur or find out the extent or source of your exposure to the PAHs. The tests aren't usually available in your doctor's office because special equipment is needed to conduct them.

Has the federal government made recommendations to protect human health?

The Occupational Safety and Health Administration (OSHA) has set a limit of 0.2 milligrams of PAHs per cubic meter of air (0.2 mg/m3). The OSHA Permissible Exposure Limit (PEL) for mineral oil mist that contains PAHs is 5 mg/m3 averaged over an 8-hour exposure period.

The National Institute for Occupational Safety and Health (NIOSH) recommends that the average workplace air levels for coal tar products not exceed 0.1 mg/m3 for a 10-hour workday, within a 40-hour workweek. There are other limits for workplace exposure for things that contain PAHs, such as coal, coal tar, and mineral oil.

Glossary

Carcinogen: A substance that can cause cancer.
Ingest: Take food or drink into your body.

References

Agency for Toxic Substances and Disease Registry (ATSDR). 1995. Toxicological Profile for Polycyclic Aromatic Hydrocarbons (PAHs). Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Where can I get more information?

If you have questions or concerns, please contact your community or state health or environmental quality department or:

For more information, contact:
Agency for Toxic Substances and Disease Registry
Division of Toxicology and Environmental Medicine
1600 Clifton Road NE, Mailstop F-62
Atlanta, GA 30333
Phone: 1-800-CDC-INFO · 888-232-6348 (TTY)
Fax: 1-770-488-4178
Email: cdcinfo@cdc.gov

ATSDR can also tell you the location of occupational and environmental health clinics. These clinics specialize in recognizing, evaluating, and treating illnesses resulting from exposure to hazardous substances.

Information line and technical assistance:
Phone: 888-422-8737
FAX: (770)-488-4178

To order toxicological profiles, contact:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Phone: 800-553-6847 or 703-605-6000

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