Public Health Implications of Exposure to Surface and Subsurface Soil at the RTD Federal Center Intermodal Station

Lakewood, Jefferson County, Colorado

Health Consultation
7/11/2011

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

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 US 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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Summary and Statement 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 soil contamination at the Federal Center Regional Transportation District Station. Specifically, this document examines residual soil contamination that remains from activities conducted prior to the Regional Transportation District's (RTD) acquisition of the property that will become the Federal Center RTD Intermodal Station.

The Denver Federal Center (DFC) is located on West 6th Avenue and Kipling Street in Lakewood, CO (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 General Services Administration (GSA) began releasing portions of the DFC on the western border of the facility to private entities. Two of the major projects that are currently coming to fruition include the Federal Center RTD Station (Parcel A) and St. Anthony's Hospital (Parcel B). The focus of this health consultation is on the future Federal Center RTD Station, located in the west-central portion of the DFC (Figure A2). The Federal Center RTD Station will consist of light rail, bus transit, and a Park'n'Ride area that will connect public transportation between Golden and Denver. Parcel A is currently outside of the DFC boundaries and all former buildings from the DFC era have been leveled and removed. Construction crews began grading the land in the summer of 2010 and the planned opening of the Federal Center RTD Station is in the summer of 2011.

The purpose of this health consultation is to examine any residual soil contamination remaining from previous site activities at the Federal Center RTD Station property to protect the health of any current and future workers from exposure to soil.

Overview

CCPEHA has reached one conclusion regarding the public health implications of current and future exposure to residual soil contamination in the Federal Center RTD Transit Station.

Conclusion 1

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

Basis for Decision

This conclusion was reached because the estimated doses from potential exposure to soil in the Federal Center RTD Station are below a level of concern for both non-cancer and cancer health effects.

Next Steps

Based on the results of this evaluation, no further actions are necessary at this time to protect worker's health from exposure to residual contamination in soil at the Federal Center RTD Station. If necessary, CCPEHA will conduct the appropriate level of health education to address any concerns regarding the findings of this health consultation. Upon request, CCPEHA will review any additional soil data that is collected from the Federal Center RTD Transit Station 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 in the RTD Federal Center Intermodal Station (Federal Center RTD Station) in Lakewood, CO. The purpose of this document is to evaluate current and future worker exposures to surface and subsurface soil contamination at the Federal Center RTD Station.

Background

The Denver Federal Center (DFC) is located in Lakewood, Jefferson County, CO, a western suburb of Denver. 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). In December 1940, the federal government purchased the property from a rancher to build a small arms ammunition plant (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. The Denver Ordnance Plant was renamed the Denver Federal Center. The DFC is owned and managed by the 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 developing partnership with the surrounding community, the GSA began releasing portions of the DFC on the western border of the facility to private entities. Two of the major projects that are currently coming to fruition include the Federal Center RTD Station (Parcel A) and St. Anthony's Hospital (Parcel B). The focus of this health consultation is on the future Federal Center RTD Station, located in the west-central portion of the DFC (Figure A2). To clarify, the Parcel A property is the site of the future Federal Center RTD Station. Both terms describe the same plot of land and the terms will be used interchangeably throughout the document. The Federal Center RTD Station will consist of light rail, bus transit, and a Park'n'Ride that will connect the areas between Golden and Denver (Figure A3). Parcel A is currently outside of the DFC boundaries and all former buildings from the DFC era have been leveled and removed. Construction crews began grading the land in the summer of 2010 and the planned opening of the Federal Center RTD Station is in the summer of 2011.

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 2002b).

In the areas that will become the Federal Center RTD Station, phase 1 of the RCRA Facility Investigation (RFI) began in the spring of 2002. Due to the potential transfer of property to RTD, the RFI for the Parcel A property was conducted separately and in an expedited fashion in relation to the site-wide RFI. Soil 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 Focused Corrective Measures Study was conducted that addressed the soil contamination in this area, which posed unacceptable risk assuming a residential land-use scenario. The Focused Corrective Measures Study was expanded in 2004 with phase 2 of the RFI, which included the collection of additional soil samples to further delineate the extent and concentration of contamination in the Federal Center RTD parcel.

To evaluate the potential health risks to future residents from exposure to soil in this area, Parcel A was divided into lots that measured 100 ft. * 100 ft., which is typical of a residential parcel. This also helped to identify specific areas that would require remediation to achieve CDPHE's target health risk level. Based on the sampling conducted in 2002 and 2004, the lots that had contaminant levels, which 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 to definitively determine the extent and nature of the soil contamination that had previously been identified. Soil samples were collected from lots adjacent to contaminated lots 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. The same process was used to define the depth of contamination. At times, samples were collected from the base of an excavated lot to ensure soil contamination above the cleanup value was removed.

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. 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. Shortly thereafter, crews began prepping the site for the Federal Center RTD Station.

There is no exposure pathway to groundwater since groundwater sampling conducted at 10 monitoring wells during the RFI for the area did not show groundwater contamination above the state or federal standards (FEC 2006a and ECC 2006a). In addition, the water supply for the Federal Center RTD Station will be supplied by the city of Lakewood.

Three main Investigation Areas from former activities at the Denver Ordnance Plant and DFC comprise Parcel A: 1) Investigation Area 17S, 2) North Investigation Area 10W, and 3) the southwestern portion of north Investigation Area 6. 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 17S (IA17S)

All of IA17S is included in the Parcel A property that will be developed into the Federal Center RTD Station. During the Denver Ordnance Plant (DOP) era, IA17S was used for munitions powder canning and storage. IA17S contained several buildings including an empty powder case building, service magazines, powder canning houses, canned powder magazines, an office, and a locker building (FEC 2002b). Large open areas surrounded the buildings. A stockpile of acid-grade fluorspar (fluorite), contained in a concrete trough, was also present in this area that was part of the U.S. Government's Strategic Stockpile. The fluorspar pile was removed in 2002 (ECC 2006). In addition, a railroad line was present in this area that bisected IA17S from the northeast to the southwest. Coal was stored alongside the tracks for use in the train engines.

After the war, IA17S was used for a variety of purposes by an assortment of different federal agencies. This includes grounds equipment maintenance and storage, equipment and materials storage; and hazardous waste storage of pesticides and herbicides (ECC 2006). The Denver Wildlife Research used the area for hazardous chemical storage. The U.S Bureau of Mines and the USGS operated a laboratory and also used the area to conduct equipment testing, storage, and maintenance. The GSA's ground maintenance crew and their equipment were also housed in this area. A number of other agencies used this area for storage of various materials including transformers containing Polychlorinated Biphenyls (PCBs) and drums of unknown contents.

North Investigation Area 10W (North IA10W)

North IA10W is located just south of IA17S along the west-central border of the DFC. All of North IA10W is included in the Parcel A property. The primary use of North IA10W has been open storage. Two buildings were constructed in this area that appear to have been sheds or barns used for housing large animals that were part of the Denver Wildlife Research Center (currently known as the National Wildlife Research Center) research (FEC 2002). Although the available information does not suggest that any experimentation actually took place in this area. Historical aerial photographs taken during the DFC era also show an unknown material pile. Over the past several years, North IA10W has been used for open storage. The topography of North IA10W was altered significantly during the construction of Center Avenue, which now runs along the southern border of this area.

North Investigation Area 6 (North IA6)

The southwestern quadrant of North IA6 is also included in the Parcel A property. This portion of North IA6 borders the southeastern corner IA17S and runs along the eastern border of North IA10W. During the DOP era, North IA6 was a munitions primer storage area. The buildings within North IA6 included primer storehouses, vacuum pump houses, and primer dry storage. A variety of potentially hazardous materials were used in the primer production that include solvents, phosphate, alkaline cleaners, sulfuric acid, soap, oil emulsions, explosives, and sodium hydroxide (FEC 2002b). During the DFC era, the facilities within this area were used by the USGS and GSA for laboratory analyses and equipment and materials storage, respectively. Materials that could have been stored in North IA6 during this time include explosives and other hazardous materials such as pesticides, nitrate film, and radionuclides. In the latter part of the DFC era, North IA6 was unoccupied.

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. In addition, no one has expressed any major concerns since construction has begun on the new RTD station.

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 the RTD Federal Center Transit Station 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

A variety of chemical constituents have been detected in surface and subsurface soil in the Parcel A property that will be the future site of the Federal Center RTD Station. The majority of these samples were collected as part of the RFI and Corrective Measures work plans. Composite and grab sampling was utilized to define the nature of contamination. Composite sampling was conducted in an "X" pattern with samples collected from the extremities and center of the pattern. These samples were homogenized and a soil sample was submitted to the laboratory for analysis. The samples were analyzed for a variety of constituents including explosives, volatile organic compounds, semi-volatile organic compound, petroleum hydrocarbons, polycyclic aromatic hydrocarbons (PAHs), Pesticides, Herbicides, Polychlorinated Biphenyls, cyanide, and

metals. Over twenty different EPA sampling methods were used to analyze the soil for contamination. As the results of the soil sampling analysis were received, the evaluation became progressively focused on contaminants that were detected and likely present in soil at the site. Therefore, 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 2010. 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. In 2010, RTD sampled areas around the former rail line, which was a focus area of remediation efforts in Parcel A. These samples contained much lower concentrations of PAHs than pre-remediation data.

Metals and Polycyclic Aromatic Hydrocarbons (PAHs) were, by and large, the most prevalent groups of contaminants found in soil at the Federal Center RTD Station parcel. Aluminum, arsenic, chromium, lead, and thallium were detected in 100% of soil samples collected at the site. These 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 metals could be slightly elevated in relation to typical background concentrations. However, this elevation does not appear significant and may not be related to former site activities. For example, the maximum detected concentration of arsenic is 11.3 parts per million with a mean concentration of 4.3 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. Table A1 and Table A2 are summaries of the soil sampling results from the depth intervals under consideration in this evaluation. As shown, the maximum concentration of all metals contaminants, with the exception of cadmium and thallium, which were only slightly higher are found in the 0-2 ft. depth interval. At this depth, chromium ranges from 4.7 – 25.5 ppm with a mean value of 15.7 ppm. Lead is found at concentrations ranging from 6.1 - 269 ppm with a mean concentration of 28.4 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 PAH compounds were detected in over 60% of all soil samples collected from the Federal Center RTD Station. 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 0.00018 – 4.6 ppm with a mean concentration of 0.16 ppm. Dibenz(a,h)anthracene ranged from 0.00042 – 1.1 ppm with a mean concentration of 0.04 ppm. There is a wide range in concentration of these contaminants that appears consistent with the other detected PAHs. PAHs were commonly detected near the center of IA17S, by the former rail line. As mentioned previously, coal was stored alongside the tracks to feed the train engines. 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.

The pesticides n-nitrosodi-n-propylamine, pentachlorophenol, dieldrin, and toxaphene were detected in soil at the Federal Center RTD Station, although the detections were infrequent and at low concentrations. These detections could be related to the grounds maintenance crew and/or pesticide storage.

Contaminants of Potential Concern

To identify contaminants of potential concern (COPCs), the soil data that was utilized in this evaluation was screened 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. 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 Federal Center RTD Station. 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. In accordance with CDPHE and EPA Region 8 guidance, if multiple contaminants exist at a site, the CV is multiplied by 0.1 (EPA 1994). Multiplying the CV by 0.1 is a protective step to reduce the potential for additive health effects from multiple chemical exposures.

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.

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
Arsenic	11.3	0.39	cancer
Benzo(a)anthracene	3.5	0.15	cancer
Benzo(a)pyrene	4.6	0.015	cancer
Benzo(b)fluoranthene	3.4	0.15	cancer
Benzo(k)fluoranthene	5.4	1.5	cancer
Chromium	25.5	0.29	cancer
Dibenz(a,h)anthracene	1.1	0.015	cancer
Ideno(1,2,3-cd)pyrene	2.5	0.15	cancer

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

As shown, the maximum detected concentration of arsenic, chromium and, 6 PAH compounds exceeded the residential screening value and were selected as contaminants of concern. In Appendix Table A1, 5 additional compounds were identified as a COPCs based on 1/10th of the

screening value. This includes aluminum, cadmium, chrysene, lead, and thallium. These COPCs were not carried further in the evaluation because the comparison of the maximum detected concentration with the CV for industrial worker derived by the EPA based on the exposure frequency of 250 days per year over the exposure duration of 25 years (Appendix Table B3).

Exposure Evaluation

The objective of the exposure evaluation is to determine if and how individuals may come into contact with residual soil contaminants at the RTD Federal Center Intermodal Station. 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 of composition, the activity at the site is almost entirely associated with land grading, laying utilities, and making other preparations for the construction of the Federal Center RTD Station. All of the former DFC era buildings have been demolished and removed. Construction workers are currently onsite building the Federal Center Station. Due to the nature of their work, they will 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 Federal Center Station are constructed. Therefore, it was assumed in this evaluation that construction workers could be exposed to soil contaminants at the Federal Center Station for 250 days per year over a period of 5 years.

Groundskeepers and maintenance workers will also likely be exposed to soil contaminants at the Federal Center Station 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 225 days per year over a period of 25 years. The assumed exposure frequency and duration for construction workers is based on professional judgment and site-specific circumstances. The assumed exposure frequency and duration for maintenance workers is the standard default assumption provided in the EPA and/or ATSDR risk assessment guidance.

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	RTD Federal Center Intermodal Station	Surface and subsurface soil	Maintenance Workers (groundskeepers) and Construction Workers	Current and Future (potential)	1) Incidental Ingestion and Dermal Exposure to Soil

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

As discussed in the Environmental Data section of this document, soil samples collected from the Federal Center RTD Station 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 from the Federal Center RTD Station 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 is a high-end arithmetic mean concentration 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 the Federal Center RTD Station parcel at a depth of 0-2 ft. bgs. The exposure unit for construction workers is soil within the Federal Center RTD Station 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. 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 the Federal Center RTD Station, non-cancer and cancer exposure doses were calculated for both receptors and compared to health-based reference values. Dose calculations are unique for each type of worker based on the frequency, duration, and intensity of the particular exposure scenario. 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 document and the resulting exposure doses are available in Appendix B of this document.

Metals and polycyclic aromatic hydrocarbons (PAHs) are the contaminants of concern found in soil at the Federal Center RTD Station. Both groups of contaminants were found at low levels. Non-cancer health-based guidelines such as the ATSDR Minimal Risk Level (MRL) and EPA Reference Dose (RfD) are doses at which no adverse health effects are thought to occur. In general, chronic exposure to low levels of metals have resulted in a variety of health effects including skin abnormalities, changes in blood constituents, and nausea and vomiting. Chronic, low level exposure to PAHs has primarily been associated with cancer. For additional information on the toxic potential of site-related COPCs, please see Appendix C.

Construction Worker

At this time, the construction worker is the main receptor that is coming into contact with soil contaminants at the Federal Center RTD Station. 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 are contaminants of concern, which all have a similar toxicological mode of action. It is recommended to combine the estimated cancer doses for all PAH contaminants of concern to produce a total combined theoretical cancer risk from exposure to PAHs. In addition, cancer is thought to be the most sensitive health end-point from exposure to PAHs. Therefore, non-cancer health risks are typically not evaluated for PAHs and non-cancer health-based guidelines do not exist from the ATSDR or EPA. Dermal exposure to chromium is also not evaluated in this health consultation because there is very limited data to suggest that dermal exposure to chromium is a significant pathway of exposure.

The estimated non-cancer doses for construction workers from incidental ingestion of soil and dermal exposure to soil are well below the non-cancer health-based guidelines for arsenic and chromium (Table A3). For arsenic, the estimated dose from incidental ingestion is $1.38 * 10^{-5}$ mg/kg-day and the estimated dose from dermal exposure is $1.24 * 10^{-6}$ mg/kg-day. This equates to a combined non-cancer dose of arsenic at $1.50 * 10^{-5}$ mg/kg-day. The non-cancer health-based guideline for arsenic is $3.0 * 10^{-4}$ mg/kg-day. Therefore, the estimated non-cancer dose of arsenic for construction workers is 20 times less than the health-based guideline. For chromium, the estimated exposure dose for incidental ingestion during construction work is $4.91 * 10^{-5}$ mg/kg-day, which is 61 times less than the health-based guideline for hexavalent chromium of $3.0 * 10^{-3}$ mg/kg-day. The combined hazard index for arsenic and chromium is also significantly below (14-fold) the acceptable level of one (Table A3). This indicates a very low risk of construction workers developing non-cancer adverse health effects, based on the assumption of additivity for multiple chemicals, from exposure to soil in the Federal Center RTD Station property. It should be noted that the toxicity values for hexavalent chromium (the most toxic form of chromium) were used in this evaluation to assess the health risks of chromium in soil at the Federal Center RTD Station. This is a conservative assumption because the type of chromium found in soil at the Federal Center RTD Station is not likely to be all hexavalent chromium (chromium VI). In lieu of site-specific speciation data, the toxicity values for hexavalent chromium were used to be prudent of public health.

The estimated theoretical cancer risks for construction workers are at the low end of the acceptable cancer risk range (Table A5). Cancer doses were estimated for arsenic, chromium, and the 6 PAHs selected as contaminants of concern (benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene). The combined estimated cancer dose of arsenic is $1.07 * 10^{-6}$ mg/kg-day, which equates to a cancer risk of 1.61 excess cancer cases per million exposed individuals. The acceptable cancer risk range is 1 excess cancer case per million exposed individuals to 100 excess cancer cases per million exposed individuals. Thus, the estimated theoretical cancer risk from exposure to arsenic is at the low-end of the acceptable cancer risk range. For chromium, the estimated cancer dose is 3.51 mg/kg-day, which equates to a theoretical cancer risk that is also at the low-end of the acceptable cancer risk range at 1.75 excess cancer cases per million exposed individuals. It should be noted that for this evaluation it was assumed that all chromium is hexavalent chromium, which is a conservative assumption in that it is not likely that the chromium found in soil at the Federal Center RTD Station is hexavalent chromium. However, without chemical speciation to determine the chemical form of chromium, it is not possible to definitively make this claim. Therefore, the theoretical cancer risk attributable to exposure to chromium could be an overestimation of actual risk. The total combined cancer dose of all PAH compounds is $4.42 * 10^{-7}$ mg/'kg-day, which equates to an estimated theoretical cancer risk of 1.02 excess cancer cases per million exposed individuals. The estimated cancer risk from each COC is at the low-end of the acceptable cancer risk range. This indicates a very low increased risk of developing cancer from contacting soil during construction work at the Federal Center RTD Station. If the estimated theoretical cancer risk from arsenic, chromium, and PAHs is combined, the overall theoretical cancer risk for construction workers is 4.38 excess cancer cases per million exposed individuals. This is also at the low-end of the acceptable cancer risk range and indicates a very low increased risk of developing cancer from construction workers contacting soil at the Federal Center RTD Station. It should, however, be noted that the finding of cumulative cancer risk is associated with a large uncertainty (i.e., overestimation of risk) because of the assumption of hexavalent chromium in soil instead of total chromium or trivalent chromium, and the inclusion of pre- and post-remediation data in the estimation of exposure point concentration. Furthermore, the estimated risks for arsenic are similar to the cancer risks associated with background levels of arsenic in soil.

Overall, this evaluation indicates that it is unlikely that construction workers would experience significant non-cancer or cancer health effects from contacting soil at the Federal Center RTD Station.

Maintenance Worker

The estimated non-cancer doses for maintenance workers from incidental ingestion of soil and dermal exposure to soil are well below the non-cancer health-based guidelines for arsenic and chromium (Table A6). For arsenic, the estimated dose from incidental ingestion is $5.44 * 10^{-6}$ mg/kg-day and the estimated dose from dermal exposure is $1.08 * 10^{-6}$ mg/kg-day. This equates to a combined non-cancer dose of arsenic of $6.52 * 10^{-6}$ mg/kg-day. The non-cancer health-based guideline for arsenic is $3.0 * 10^{-4}$ mg/kg-day. Therefore, the estimated non-cancer dose of arsenic for maintenance workers is 50 times less than the health-based guideline. For chromium, the estimated non-cancer dose of chromium is $1.46 * 10^{-5}$ mg/kg-day. The non-cancer health-based

guideline for chromium VI is $3.0 * 10^{-3}$. Thus, the estimated non-cancer dose of chromium for maintenance workers is over 200 times less than the health-based guideline for chromium VI. The combined hazard index for arsenic and chromium is also significantly below (33 times lower) the acceptable level of one (Table A6). This indicates a very low risk of maintenance workers developing non-cancer adverse health effects, based on the assumption of additivity, from exposure to arsenic and chromium in soil at the Federal Center RTD Station property.

The estimated theoretical cancer risks for maintenance workers are also at the low end of the acceptable cancer risk range (Table A7). The combined estimated cancer dose of arsenic is $2.33 * 10^{-6}$ mg/kg-day, which equates to a cancer risk at the low-end of the acceptable risk range of 3.49 excess cancer cases per million exposed individuals. For chromium, the estimated cancer dose from incidental ingestion of soil is $5.22 * 10^{-6}$ mg/kg-day, which equates to a theoretical cancer risk that is also at the low-end of the acceptable cancer risk range at 2.61 excess cancer cases per million exposed individuals. The total combined cancer dose of all PAH compounds is $1.03 * 10^{-6}$ mg/kg-day, which equates to an estimated theoretical cancer risk of 2.37 excess cancer cases per million exposed individuals. The estimated cancer risk from each COC is at the low-end of the acceptable cancer risk range. This indicates a very low increased risk of developing cancer from contacting soil during maintenance work at the Federal Center RTD Station. If the estimated theoretical cancer risk from arsenic, chromium, and PAHs is combined, the overall theoretical cancer risk for maintenance workers is 8.47 excess cancer cases per million exposed individuals. This is also at the low-end of the acceptable cancer risk range, which indicates a very low increased risk of maintenance workers developing cancer from contacting soil at the Federal Center RTD Station. It should, however, be noted that the estimated cumulative cancer risk is associated with a large uncertainty (i.e. overestimation of risk) because of the assumption of hexavalent chromium in soil instead of total chromium or trivalent chromium, and the inclusion of pre- and post-remediation data in the estimation of exposure point concentration. Furthermore, the estimated cancer risks for arsenic are similar to the cancer risks associated with background levels of arsenic in soil.

Overall, this evaluation indicates that it is unlikely that maintenance workers would experience significant non-cancer or cancer health effects from contacting soil at the Federal Center RTD Station.

Uncertainty

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 potential 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 2010 for estimating the exposure point concentration for workers. This assumption has resulted in 3-4 fold overestimation of risk based on the comparison of EPCs estimated using all data (2002-2010) and only post-remediation data collected in 2010 (Table A7).

- 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 the Federal Center RTD Station. 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. Limited soil samples collected post-remediation in 2010 from areas around the former rail line, where the majority of excavation took place, had much lower concentrations of PAHs than the pre-remediation data. If this pattern is consistent across the Parcel A property, which it likely is, than the risks identified in this evaluation are likely an overestimation (by approximately 3-4 fold as shown in Table A7).

- As discussed previously, there are no available non-cancer toxicity values for PAHs. However, this appears to be a minor source of uncertainty due to the fact that cancer appears to be the most sensitive health endpoint of exposure to PAH compounds. This means that the potential health hazards associated with PAH exposure would become a concern based on carcinogenic risk well before the exposure would become a concern based on non-cancer health hazards. Nonetheless, it is a small source of uncertainty that would likely elevate the non-cancer health hazards identified in this evaluation if non-cancer toxicity values for PAHs were available.

- 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.

In this evaluation, child exposures were not considered because children are not expected to come into contact with any site-related soil contamination.

Conclusions

Based on the soil data and exposure pathways evaluated in this health consultation, CCPEHA has reached one conclusion regarding current and future exposures to residual soil contamination in the Federal Center RTD Station:

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 Federal Center RTD Station are below a level of concern for non-cancer and cancer health effects. Specifically, the estimated cancer risks from PAHs which are considered the site-related contaminants of potential concern are just above (i.e., 1 or 2 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 4.38E-06 and 8.47E-06 for construction and maintenance workers, respectively are associated with a large uncertainty (i.e., overestimation of risk) and are driven by the cancer risks for arsenic which are similar to cancer risks associated with background levels of arsenic in soil and the overly conservative assumption of all hexavalent chromium in soil.

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 the Federal Center RTD Station.

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 Federal Center RTD Transit Station and update the health consultation accordingly.

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Appendix A. Tables and Figures

Table A1. Screened Soil Contaminant Data Summary Statistics (0-2 ft. below ground surface)

Contaminant	Minimum[1] (in mg/kg)	Maximum (in mg/kg)	Mean[2] (in mg/kg)	% detected	*n*	Screening Value (in mg/kg)	COPC	COPC (1/10th CV)
Aluminum	9,000	41,100	27,383	100%	36	50,000		X
Aroclor 1254*	0.008	0.021	0.013	12%	34	0.22		
Aroclor 1260**	0.083	0.23	N/a	6%	34	0.22	**X**	
Arsenic	**0.33**	**11.3**	**4.3**	**100%**	**55**	**0.39**	**X**	
Benz(a)anthracene	**0.00017**	**3.5**	**0.14**	**87%**	**145**	**0.15**	**X**	
Benz(a)pyrene	**0.00018**	**4.6**	**0.16**	**81%**	**145**	**0.015**	**X**	
Benz(b)fluoranthene	**0.0002**	**3.4**	**0.18**	**86%**	**145**	**0.15**	**X**	
Benz(k)fluoranthene	**0.00022**	**5.4**	**0.15**	**80%**	**145**	**1.5**	**X**	
Cadmium	0.051	2.3	0.58	44%	55	5.0		X
Chromium	**4.7**	**25.5**	**15.7**	**100%**	**55**	**0.29**	**X**	
Chrysene*	0.00025	4.9	0.19	88%	145	15		X
Dibenz(a,h)anthracene	**0.00042**	**1.1**	**0.04**	**62%**	**145**	**0.015**	**X**	
Dieldrin*	0.0028	0.025	0.0066	24%	17	0.03		
2,4-Dinitrotoluene*	N/a	N/a	N/a	0%	36	1.6		
Ideno(1,2,3-cd)pyrene	**0.0017**	**2.5**	**0.11**	**75%**	**145**	**0.15**	**X**	
Lead	6.1	269	28.4	100%	72	400		X
Naphthalene*	0.00039	0.33	0.01	27%	164	3.6		
N-nitrosodi-n-propylamine*	N/a	0.047	N/a	3%	36	0.069		
Pentachlorophenol*	0.00074	0.042	0.02	6%	36	0.89		
Thallium	0.15	0.66	0.34	100%	36	5.0		X
Toxaphene	0.23	0.86	0.32	18%	17	0.44		

NOTES: N/a = Not applicable

[1] Minimum of detected data.

[2] Calculated using ProUCL 4.1.00 recommended method

* Reporting Limit exceeds screening value but the detection limit is significantly lower than the screening value

** Was not selected as a COPC because the contaminant was detected just at the residential CV and lower than the industrial CV.

Table A2. Screened Soil Contaminant Data Summary Statistics (0-12 ft. below ground surface)

Contaminant	Minimum[1] (in mg/kg)	Maximum (in mg/kg)	Mean[2] (in mg/kg)	% detected	*n*	Screening Value (in mg/kg)	COPC[3]	1/10th CV COPC
Aluminum	9,000	41,100	27,383	100%	81	50,000		X
Aroclor 1254	0.008	0.021	0.01	5%	76	0.22		
Aroclor 1260	0.083	0.23	N/a	3%	76	0.22		
Arsenic	**0.33**	**11.3**	**3.2**	**100%**	**110**	**0.39**	**X**	
Benz(a)anthracene	**0.00013**	**3.5**	**0.11**	**71%**	**212**	**0.15**	**X**	
Benz(a)pyrene	**0.00018**	**4.6**	**0.13**	**64%**	**212**	**0.015**	**X**	
Benz(b)fluoranthene	**0.0002**	**3.4**	**0.15**	**68%**	**212**	**0.15**	**X**	
Benz(k)fluoranthene	**0.00022**	**5.4**	**0.12**	**62%**	**212**	**1.5**	**X**	
Cadmium	0.051	2.8	0.76	57%	110	5.0		X
Chromium	**4.7**	**25.5**	**14.5**	**100%**	**110**	**0.29**	**X**	
Chrysene*	0.0002	4.9	0.15	71%	212	15		X
Dibenz(a,h)anthracene	**0.00042**	**1.1**	**0.03**	**48%**	**212**	**0.015**	**X**	
2,4-Dinitrotoluene*	N/a	N/a	N/a	0%	N/a	1.6		
Ideno(1,2,3-cd)pyrene	**0.00088**	**2.50**	**0.09**	**58%**	**212**	**0.15**	**X**	
Lead	4.2	269	22.1	100%	127	400		X
Naphthalene*	0.00034	0.33	0.01	21%	241	3.6		
N-nitrosodi-n-propylamine*	0.047	0.047	N/a	1%	81	0.069		
Pentachlorophenol*	0.00074	0.042	N/a	2%	81	0.89		
Thallium	0.11	0.78	0.37	100%	81	5.0		X

NOTES:
[1] Minimum of detected data.
[2] Calculated using ProUCL 4.1.00 recommended method
[3] Contaminants that were detected in less than 5% of all samples were not included as Contaminants of Potential Concern (COPCs).
N/a = Not applicable

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
Arsenic	4.60E-02	4.14E-03	5.01E-02
Chromium	1.64E-02	N/a	1.64E-02
Total Non-cancer HI	6.24E-02	4.14E-03	6.65E-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

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
Arsenic	1.48E-06	1.33E-07	1.61E-06
Benz(a)anthracene	4.04E-08	1.58E-08	5.62E-08
Benz(a)pyrene	5.05E-07	1.97E-07	7.02E-07
Benz(b)fluoranthene	5.39E-08	2.10E-08	7.49E-08
Benz(k)fluoranthene	5.05E-09	1.97E-09	7.02E-09
Chromium	1.75E-06	N/a	1.75E-06
Dibenz(a,h)anthracene	1.01E-07	2.70E-09	1.40E-07
Indeno(1,2,3-cd)pyrene	2.69E-08	1.05E-07	3.74E-08
Total Cancer Risk	3.96E-06	4.76E-07	4.38E-06*

Note: * = Combined risk from PAHs alone is 1.02E-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
Arsenic	1.81E-02	3.59E-03	2.17E-02
Chromium	4.87E-03	N/a	4.87E-03
Total Non-cancer HI	2.30E-02	3.59E-03	2.66E-02

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
Arsenic	2.92E-06	5.77E-07	3.49E-06
Benz(a)anthracene	7.35E-08	6.30E-08	1.37E-07
Benz(a)pyrene	8.95E-07	7.68E-07	1.66E-06
Benz(b)fluoranthene	8.95E-08	7.68E-08	1.66E-07
Benz(k)fluoranthene	9.18E-09	7.88E-09	1.71E-08
Chromium	2.61E-06	N/a	2.61E-06
Dibenz(a,h)anthracene	1.61E-07	9.44E-09	2.99E-07
Indeno(1,2,3-cd)pyrene	4.59E-08	3.94E-07	8.53E-08
Total Cancer Risk	6.80E-06	1.90E-06	8.47E-06*

Note: * = Combined risk from PAHs alone is 2.37E-06

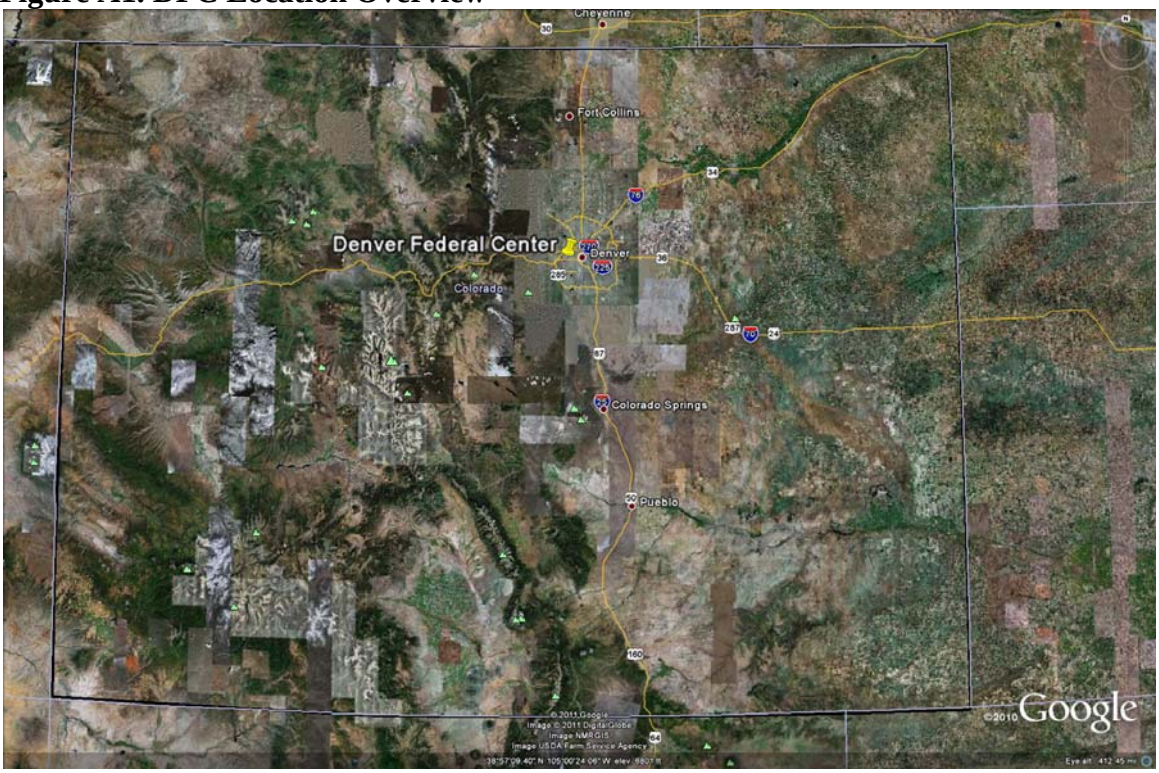
Table A7. Soil Exposure Point Concentrations for Maintenance Workers (0-2 ft. bgs.) Compares the EPCs for all data (from 2002 to 2010) including pre- and post-remediation periods vs. EPC based on the 2010 RTD Soil Samples Collected Post-Remediation.

COPC	Exposure Point Concentration (in mg/kg)	Residential Screening Value (in mg/kg)	Industrial Screening Value (in mg/kg)
Arsenic	All Data: 6.18	0.39	1.6
	2010 data: 8.81 (increase)		
Benzo(a)anthracene	All Data: 0.32	0.15	21
	2010 data: 0.0965 (decrease)		
Benzo(a)pyrene	All Data: 0.39	0.015	0.21
	2010 data: 0.0941 (decrease)		
Benzo(b)fluoranthene	All Data: 0.39	0.15	2.1
	2010 data: 0.11 (decrease)		
Benzo(k)fluoranthene	All Data: 0.40	1.5	21
	2010 data: 0.096 (decrease)		
Chromium	All Data: 16.6	0.29	5.6
	2010 data: 17.1 (increase)		
Dibenz(a,h)anthracene	All Data: 0.07	0.015	0.21
	2010 data: 0.0513* (decrease)		
Ideno(1,2,3-cd)pyrene	All Data: 0.20	0.15	2.1
	2010 data: 0.0831 (decrease)		

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
* Based on 4/19 detected values
2010 soil EPCs are based on 19 samples

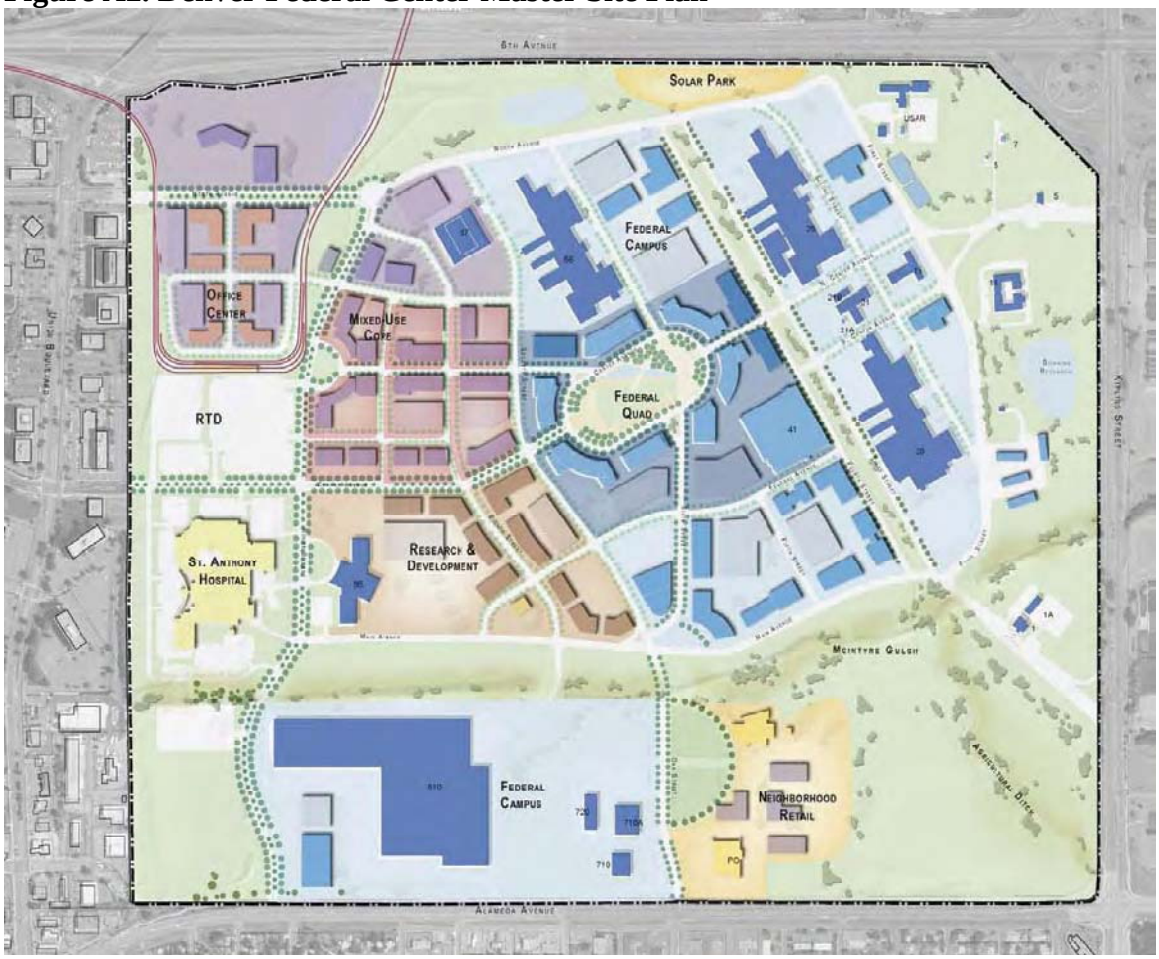
Figures

Figure A1. DFC Location Overview



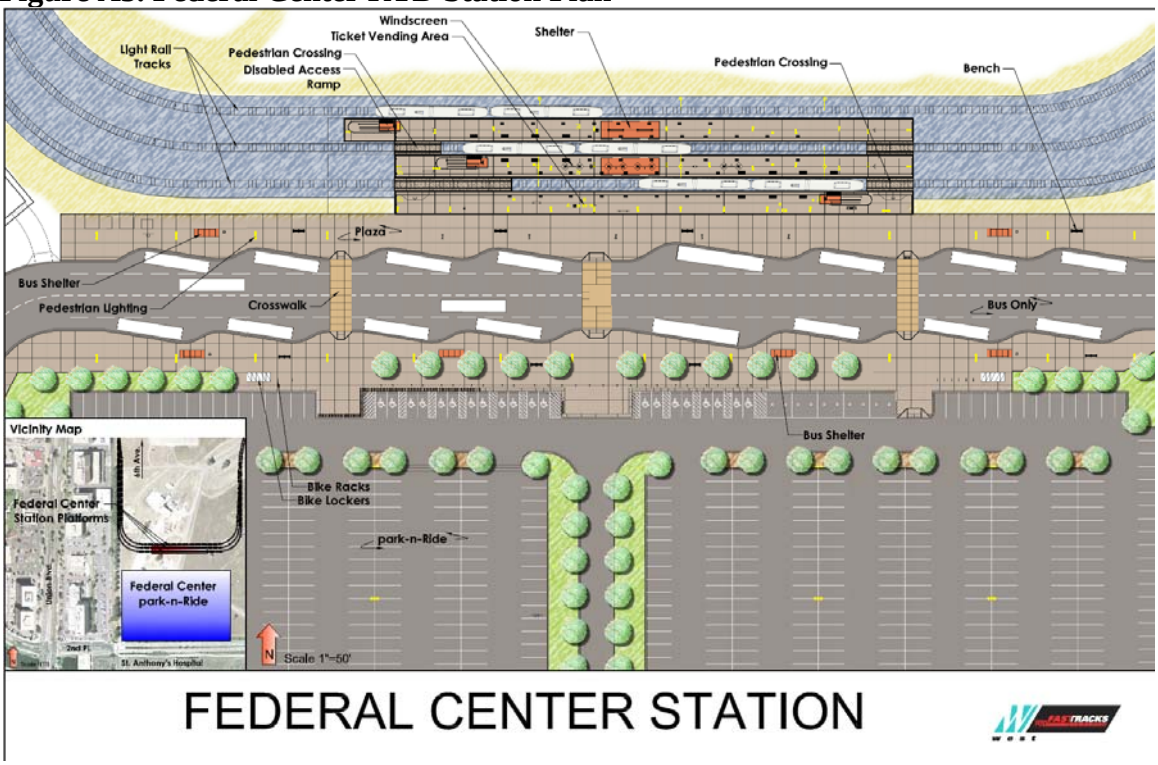
Source: Google Earth 2011

Figure A2. Denver Federal Center Master Site Plan



SOURCE: General Services Administration
http://www.gsa.gov/graphics/regions/masterplan_factsheet_508.pdf

Figure A3. Federal Center RTD Station Plan



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 Federal Center RTD Transit Station 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 Concern (COC), 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 in the RTD Station for 250 days per year over 5 years. For maintenance workers, it is assumed that they will be exposed to soil in the RTD Station for 225 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 COCs 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)	225	Default Value (EPA 2002)	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)
Arsenic	0.03
Benz(a)anthracene	0.13
Benz(a)pyrene	0.13
Benz(b)fluoranthene	0.13
Benz(k)fluoranthene	0.13
Dibenz(a,h)anthracene	0.13
Indeno(1,2,3-cd)pyrene	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. Soil Exposure Point Concentrations and Screening Levels for Maintenance Workers (0-2 ft. bgs.)

COPC	Exposure Point Concentration (in mg/kg)	Residential Screening Value (in mg/kg)	Industrial Screening Value (in mg/kg)	EPC Method
Aluminum	29,458	50,000	990,000	95% Student's-t UCL
Arsenic	6.18	0.39	1.6	95% Chebyshev (Mean, Sd) UCL
Benzo(a)anthracene	0.32	0.15	21	97.5% KM (Chebyshev) UCL
Benzo(a)pyrene	0.39	0.015	0.21	97.5% KM (Chebyshev) UCL
Benzo(b)fluoranthene	0.39	0.15	2.1	97.5% KM (Chebyshev) UCL
Benzo(k)fluoranthene	0.40	1.5	21	97.5% KM (Chebyshev) UCL
Cadmium	0.73	5.0	800	95% KM (percentile bootstrap) UCL
Chromium	16.6	0.29	5.6	95% Student's-t UCL
Dibenz(a,h)anthracene	0.07	0.015	0.21	95% KM (Chebyshev) UCL
Ideno(1,2,3-cd)pyrene	0.20	0.15	2.1	95% KM (Chebyshev) UCL
Lead	31.5	400	800	95% H-UCL
Thallium	0.36	5.0	NA	95% Student's-t UCL
Toxaphene	0.44	0.44	1.6	95% KM (t) 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. Soil Exposure Point Concentrations and Screening Levels for Construction Workers (0-12 ft. bgs.)

COPC	Exposure Point Concentration (in mg/kg)	Residential Screening Value (in mg/kg)	Industrial Screening Value (in mg/kg)	EPC Method
Aluminum	28,733	50,000	990,000	95% Student's-t UCL
Arsenic	4.27	0.39	1.6	95% Chebyshev (Mean, Sd) UCL
Benzo(a)anthracene	0.24	0.15	21	97.5% KM (Chebyshev) UCL
Benzo(a)pyrene	0.30	0.015	0.21	97.5% KM (Chebyshev) UCL
Benzo(b)fluoranthene	0.32	0.15	2.1	97.5% KM (Chebyshev) UCL
Benzo(k)fluoranthene	0.30	1.5	21	97.5% KM (Chebyshev) UCL
Cadmium	0.86	5.0	800	95% KM (percentile bootstrap) UCL
Chromium	15.2	0.29	5.6	95% Student's-t UCL
Dibenz(a,h)anthracene	0.06	0.015	0.21	95% KM (Chebyshev) UCL
Ideno(1,2,3-cd)pyrene	0.16	0.15	2.1	95% KM (Chebyshev) UCL
Lead	32.3	400	800	95% (Mean, Sd) UCL
Thallium	0.40	5.0	NA	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 Arsenic	3.84E-08	3.71E-08
DA_{ev} for Benz(a)anthracene	9.36E-09	8.32E-09
DA_{ev} for Benz(a)pyrene	1.17E-08	1.01E-08
DA_{ev} for Benz(b)fluoranthene	1.25E-08	1.01E-08
DA_{ev} for Benz(k)fluoranthene	1.17E-08	1.04E-08
DA_{ev} for Dibenz(a,h)anthracene	2.34E-09	1.82E-09
DA_{ev} for Indeno(1,2,3-cd)pyrene	6.24E-09	5.20E-09

Equation 4. Cancer Dermal Absorbed Dose from Soil

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

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

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 Dose Results

COPC	Ingestion Dose (mg/kg-day)	Dermal Absorbed Dose (mg/kg-day)	Combined Dose (mg/kg-day)	Health-based Guideline (mg/kg-day)
Arsenic	1.38E-05	1.24E-06	1.50E-05	3.0E-04
Chromium	4.91E-05	N/a	4.91E-05	3.0E-03

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

Table B7. Maintenance Worker Non-Cancer Exposure Dose Results

COPC	Ingestion Dose (mg/kg-day)	Dermal Absorbed Dose (mg/kg-day)	Combined Dose (mg/kg-day)	Health-based Guideline (mg/kg-day)
Arsenic	5.44E-06	1.08E-06	6.52E-06	3.0E-04
Chromium	1.46E-05	N/a	1.46E-05	3.0E-03

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

Table B8. Construction Worker Cancer Exposure Dose Results

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)
Arsenic	9.85E-07	8.86E-08	1.07E-06
Benz(a)anthracene	5.54E-08	2.16E-08	7.69E-08
Benz(a)pyrene	6.92E-08	2.70E-08	9.62E-08
Benz(b)fluoranthene	7.38E-08	2.88E-08	1.03E-07
Benz(k)fluoranthene	6.92E-08	2.70E-08	9.62E-08
Chromium	3.51E-06	N/a	3.51E-06
Dibenz(a,h)anthracene	1.38E-08	5.40E-09	1.92E-08
Indeno(1,2,3-cd)pyrene	3.69E-08	1.44E-08	5.13E-08

Table B9. Maintenance Worker Cancer Exposure Dose Results

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)
Arsenic	1.94E-06	3.85E-07	2.33E-06
Benz(a)anthracene	1.01E-07	8.64E-08	1.87E-07
Benz(a)pyrene	1.23E-07	1.05E-07	2.28E-07
Benz(b)fluoranthene	1.23E-07	1.05E-07	2.28E-07
Benz(k)fluoranthene	1.26E-07	1.08E-07	2.34E-07
Chromium	5.22E-06	N/a	5.22E-06
Dibenz(a,h)anthracene	2.20E-08	1.89E-08	4.09E-08
Indeno(1,2,3-cd)pyrene	6.29E-08	5.40E-08	1.17E-07

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.

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.

Appendix D. ATSDR ToxFAQs on Polycyclic Aromatic Hydrocarbons

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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