Health Consultation

Evaluation of Soil Data for 33 Water Street

at the former Creese and Cook Tannery

in Danvers, Essex County, Massachusetts

EPA FACILITY ID: MAD001031574

Prepared by:
Massachusetts Department of Public Health

JUNE 11, 2015

Prepared under a Cooperative Agreement with the
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Division of Community Health Investigations
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

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

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR or ATSDR's Cooperative Agreement Partner which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

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Massachusetts Department of Public Health
Bureau of Environmental Health
Environmental Toxicology Program
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Agency for Toxic Substances and Disease Registry

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SUMMARY

Introduction: The Massachusetts Department of Public Health, Bureau of Environmental Health (MDPH/BEH), under a cooperative agreement with the U.S. Agency for Toxic Substances and Disease Registry (ATSDR), assesses the presence and nature of health hazards at sites proposed to the National Priorities List (NPL). At the request of the United States Environmental Protection Agency (US EPA) this health consultation was conducted to address community concerns relating to the potential for exposure to environmental contaminants detected in available soil samples at the Crane River East Condominium Complex at 33 Water Street located on a portion of the former Creese and Cook Superfund Site in Danvers, Massachusetts. This Health Consultation specifically focuses on a residential area of the Site where direct contact with contaminated soil is possible for residents of the Crane River East Condominium Complex. This document evaluates currently available soil data for this residential area, and as US EPA investigations proceed, MDPH will work with US EPA, the Massachusetts Department of Environmental Protection (MassDEP), and local health to determine other areas of the Creese and Cook Superfund Site where further public health evaluation is warranted and sampling data are available. The top priority of ATSDR and MDPH is to ensure that the community has the best information possible to safeguard its health.

Conclusion 1: MDPH does not have adequate data representing surface soil (0-3 inches) to conclude if eating soil containing arsenic near Buildings A, B, and C of the Crane River East Condominium Complex at 33 Water Street is expected to harm people's health. However, based on currently available soil data assuming that the concentrations

found in 0-1 foot samples are similar to concentrations in the soil closer to the surface (e.g. top 0-3 inches), it is not expected that incidentally eating soil containing arsenic at these levels would harm people's health.

This conclusion is further supported by additional sampling data that were generated by US EPA during the course of preparing this health consultation (US EPA 2014c). The ongoing US EPA phase 1 site investigation provides supplemental data from more shallow soil samples (0-6 inches). Although these data are not as numerous as the previously collected deeper soil samples (0-1 foot), results suggest that average arsenic concentrations at shallower depths are similar to or less than concentrations detected in deeper soil samples that were evaluated in this health consultation.

Basis for Decision: The average concentrations of arsenic detected in soils near Buildings A, B, and C at the Crane Creek River East Condominium Complex are similar to levels typically found in Eastern U.S. soils. Estimated exposure doses from incidental ingestion of soil with these arsenic concentrations are below levels that could cause harmful, non-cancer health effects. In addition, the estimated cancer risk from opportunities for exposure to these arsenic concentrations is less than 1×10^{-4} (that is, less than one extra cancer diagnosis in a population of 10,000). Therefore, MDPH does not consider exposure opportunities to arsenic in soils at the Crane River East Condominium Complex (near Buildings A, B, and C) to pose an unusually elevated cancer risk for children or adults.

MDPH's conclusions are based on currently available sampling data, representing the shallowest soil samples available (most commonly 0 to 1 foot), for the evaluation of potential exposures to soil at the 33 Water Street property. Individuals are less likely to have frequent contact with deep soils (i.e. 0 to 1 foot) compared to soils at shallower depths (e.g. 0 to 3 inches). Thus, conclusions about possible health impacts are based on the assumption that the concentrations found in 0-1 foot samples are similar to concentrations in the soil closer to the surface (e.g. top 0-3 inches). This assumption is further supported by supplemental data from more shallow soil samples (0-6 inches) collected in June 2014. Future sampling efforts during the course of the US EPA site investigation may provide additional data points for the 33 Water Street property.

Conclusion 2: MDPH does not have adequate data representing surface soil (0-3 inches) to conclude if eating soil containing polycyclic aromatic hydrocarbons (PAHs) near Buildings A, B, and C of the Crane River East Condominium Complex at 33 Water Street is expected to harm people’s health. However, based on currently available soil data assuming that the concentrations found in 0-1 foot samples are similar to concentrations in the soil closer to the surface (e.g. top 0-3 inches), it is not expected that incidentally eating surface soil containing PAHs at these levels would harm people’s health.

This conclusion is further supported by additional sampling data that were generated by US EPA during the course of preparing this health consultation (US EPA 2014c). The ongoing US EPA phase 1 site investigation provides supplemental data from more shallow soil samples (0-6 inches). Although these data are not as numerous as the previously collected deeper soil samples (0 -1 foot), results suggest that average PAH concentrations at shallower depths are similar to or less than concentrations detected in deeper soil samples that were evaluated in this health consultation.

Basis for Decision: The maximum estimated cancer risk to children (1 excess cancer diagnosis in a population of ten thousand) from incidental ingestion of soil containing polycyclic aromatic hydrocarbons (PAHs) found at the Crane River East Condominium Complex is similar to what would be expected from exposure to the concentrations of PAHs typically found in soils in U.S. urban areas. The actual cancer risks for children are likely to be lower than estimated in this consult because of the conservative, health-protective exposure assumptions used in calculating the estimated cancer risk. For adults, the estimated cancer risk from incidental ingestion of PAH-contaminated soil is less than 1×10^{-4} (that is, less than 1 additional cancer diagnosis in a population of 10,000). For these reasons, MDPH does not consider exposures to PAHs in soils at the Crane River East Condominium Complex (near Buildings A, B, and C) to pose an unusually elevated cancer risk for children or adults.

Conclusions about possible health impacts are based on currently available sampling data with the assumption that the concentrations found in 0-1 foot samples are similar to concentrations in the soil closer to the surface (e.g. top 0-3 inches). Soil data used for the evaluation of PAHs in soil at the 33 Water Street property were limited by the small number of sample points representing the site area, an outlier sample not consistent with other sample points, and soil depths greater than typically used in public health evaluations to characterize exposure to soil at the surface where frequent contact is likely. Existing grass coverage at the site will minimize direct exposure to soil contamination at the site and it is less likely that residents will have frequent contact with deeper soils at the site. However, a more thorough characterization of PAH concentrations in surface soil is warranted to further evaluate whether the concentrations of PAHs in site soil are similar to the concentrations typically found in urban environments. MDPH has recommended additional surface soil sampling to better characterize the levels of PAHs in surface soils across the 33 Water Street property; future sampling efforts during the course of the US EPA site investigation may provide additional data points for the 33 Water Street property.

Next Steps:

- MDPH recommends that US EPA conduct additional soil sampling at shallower depths (0-3 inches) and in more representative locations (including the garden area located along the tree line behind building A and in front of Building C in the vicinity of sample SS-18A), during future investigations, to better characterize the levels of PAHs and arsenic in surface soils across the 33 Water Street property. The resulting data will allow MDPH to more thoroughly evaluate potential health risks from exposure to contaminants in the property's surface soils.
- MDPH recommends that residents, particularly children, of the Crane River East Condominium Complex, take steps to reduce their potential exposure to contaminants in soils at the complex until further sampling is completed. These steps include:
  - Avoiding direct contact with bare soil, especially in front of Building C (where higher levels of PAHs were found);
  - Minimizing tracking soil into the house (e.g. wiping shoes on a door mat before entering the house);
  - Washing hands before eating and after playing outside; and
  - Avoiding digging or playing in areas with bare soil.

- MDPH recommends periodic inspection of the restricted, potentially-contaminated areas between the 33 Water Street property and the Crane River, including the Massachusetts Bay Transportation Authority Right of Way (MBTA ROW), to ensure that warning signs are posted and clearly visible.
- MDPH will work with federal, state and local health agencies to determine how public health concerns can be most effectively addressed, as new data are generated during the upcoming US EPA site investigations.

For More Information: If you have concerns about your health, you should contact your health care provider. You may also call ATSDR at 1-800-CDC-INFO or MDPH at 617-624-5757 and ask for information on the Former Creese and Cook Tannery Superfund Site.

PURPOSE

The former Creese & Cook Tannery Site has been proposed for inclusion on the National Priorities List (NPL) and the United States Environmental Protection Agency (US EPA) has determined that concentrations of arsenic, chromium, and dioxins have been detected at levels above health based standards (US EPA 2013c). The Massachusetts Department of Public Health, Bureau of Environmental Health (MDPH/BEH), under a cooperative agreement with the U.S. Agency for Toxic Substances and Disease Registry (ATSDR), assesses the presence and nature of health hazards at sites proposed to the NPL. As part of this agreement, MDPH/BEH evaluated the public health implications of the contamination at the former Creese & Cook Tannery Site. This Health Consultation specifically focuses on a residential area of the Site located at 33 Water Street (near buildings A, B, and C) where direct contact with contaminated soil is possible for residents of the Crane River East Condominium Complex.

This health consultation was conducted to address community concerns at the Crane River East Condominiums by evaluating soil data that are currently available. Sampling data for other areas of the site are limited at this time; however, US EPA has plans to conduct additional sampling to further characterize the nature and extent of contamination. As data become available or upon request, MDPH will work with US EPA, the Massachusetts Department of Environmental Protection (MassDEP), and local health to determine other areas of the Creese and Cook Tannery Site where further public health evaluation is warranted.

BACKGROUND AND STATEMENT OF ISSUES

The former Creese & Cook Tannery Site is an approximately 17 acre site located along the east and west banks of the Crane River in Danvers, Massachusetts (US EPA 2013c). The Site is located in an area with both commercial and residential properties (MassDEP 2011) and currently comprise the 33 Water Street parcel, the 20 Cheever Street parcel and a Massachusetts Bay Transportation Authority (MBTA) Right of Way (ROW), all east of the River; the 55 Clinton Street parcel west of the River and the Crane River itself

(See Figure 1 for site areas).[1] According to site history, the original tannery and finishing operations for Creese and Cook began in 1903 at 33 Water Street where they used raw animal hides to produce shoes, handbags, and other leather products. In 1914, the Creese and Cook Tannery was said to have expanded the hide processing operations to a larger area across the Crane River (55 Clinton Street parcel) (MassDEP 2011; US EPA 2013b; Weston Solutions Inc. 2011). According to US EPA, wastes from the facility were disposed of in on-site landfills, liquid effluent was discharged to the Crane River and later into sewers, and sludge waste was deposited into onsite lagoons (US EPA 2013c). Operations at the Creese and Cook Facility ceased in the early 1980's when the company went bankrupt, and in 1986 the 33 Water Street parcel was redeveloped into a 28 unit condominium complex called the Crane River East Condominiums (MassDEP 2011 and US EPA 2013b).

This Health Consultation evaluates available soil data for a residential area of the Site where direct contact with contaminated soil is possible for residents of the Crane River East Condominium Complex (33 Water Street). The Water Street parcel is located east of the Crane River and consists of four condo buildings (A, B, C and D), an access road and parking lot, grassy lawn area and an MBTA ROW that runs west of the condo complex along the River. Contamination in the area of the MBTA ROW is not well characterized, however historical use and preliminary sampling suggests contamination (US EPA 2013a). According to US EPA, the MBTA ROW area is currently fenced to prevent public access to the area and to the River from the condo complex and warning signs are posted (EPA 2013a). Soil sampling near building D (northern most portion of the parcel) showed elevated levels of arsenic resulting in a US EPA removal action completed in June of 2012; contaminated soils were removed and brought to an off-site disposal facility (US EPA 2013b). Therefore, soil samples associated with the area near Building D are not evaluated in this report. Based on discussions with US EPA and ATSDR staff,

[1] Additional site investigations are underway to determine the nature and extent of contamination at the Creese and Cook Tannery Site in Danvers. Therefore, additional properties (e.g. 12 Cheever St and 45 Water St.) may be sampled in the US EPA investigation/study area and site boundaries currently described in this report may be expanded as data become available.

the MDPH focused this Health Consultation on current site conditions at the Water Street parcel including areas near Buildings A, B, and C. The MBTA ROW and past and present soil conditions near Building D are beyond the scope of this report. Recent soil investigations from April and October of 2011 for the eastern portion of the site (i.e. 33 Water Street, 20 Cheever Street, and the MBTA ROW) are summarized in reports by Weston Solutions, Inc and focus primarily on the 33 Water Street property, with limited sampling at 20 Cheever Street and the MBTA ROW (Weston Solutions 2011, 2012). Additionally, there is one historical investigation from 1984 that provides limited soil data for 33 Water Street and 20 Cheever Street properties (US EPA 2012). The four soil samples collected in 1984 at the 33 Water Street property were prior to condo construction and therefore would unlikely represent present site conditions. Historical investigations for the western portion of the site date back to 1981 when the site was still operational. Subsequent investigations by R.E.W. Consultants, Woodard and Curran, Weston Solutions and others summarize sampling for specific source areas on-site (e.g. leather scrap pile, former landfill areas, former lagoons, former beam house, on-site containment area) and other contaminated soils. The most recent investigation was a Site Reassessment by US EPA including Crane River sediment sampling and source sampling for the western portion of the site. Investigations to establish the full nature and extent of contamination at the Creese and Cook Tannery site are underway and sampling for the eastern portion of the site is estimated to start in June 2014 (US EPA 2014b).

In June of 2013, MDPH staff conducted a site visit to the 33 Water Street parcel in Danvers to observe current site conditions. The grassy lawn area associated with the rear of the Condo Complex was well maintained and easily accessible for recreational use. Children’s toys were not observed, however there were young children seen in the vicinity of the complex. A patio was observed on the northern portion of the site behind building C and along the fence which restricts access to the MBTA ROW (which is believed to have been constructed sometime after September 2010[2]). A small garden was observed behind Building A along the dense tree line that separates 33 Water Street with an adjacent property (35 Water Street).

METHODS

Soil Sampling

On April 18-22, 2011, the Superfund Technical Assessment and Response Team (START) conducted sampling of the 33 Water Street property, with sampling focused on the footprint of the former tannery building (vicinity of Buildings A-C) (Weston Solutions Inc. 2011). On October 17-18, 2011, START personnel collected additional samples in a 50x50 foot grid like pattern over the 33 Water Street property. See Figure 2 for sample locations and depictions of the former tannery footprint and current buildings located at the site. Soil samples were collected from soil borings, using a hand auger, at depths of 0 to 1 foot below ground surface.[3] Typically, surface soil samples taken from the top 0–3 inches of soil are of most importance for public health evaluation. This is because it is likely that individuals would have more frequent contact with surface soil than with deeper soils. Because there are limited data available for soil at shallower depths, this health consultation considers potential exposures to the shallowest soil samples available for each sampling location (i.e. 0 to 1 ft or 0 to 2 ft).

Of the samples collected in April 2011 from areas near Buildings A-C, eleven samples that represent the shallowest soils are evaluated in this report. See Table 1 for a complete list of sample identifiers. Samples were submitted to a Contract Laboratory Program (CLP) for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), pesticides, polychlorinated biphenyls (PCBs), and total metals analysis; a CLP non-RAS Laboratory for dioxin analysis; and DAS Laboratories for hexavalent chromium and asbestos analysis (Weston Solutions Inc. 2011). Additionally, forty one

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[2] Photographs prior to fence construction are available from the Trip Report for Creese & Cook Co. (Former) 2 Combined Preliminary Assessment/Site Investigation, Danvers, Massachusetts (Weston Solutions Inc. 2011).

[3] One of the eleven samples from April 2011 was collected at a soil depth of 0 to 2 feet.

soil samples were collected in October 2011 near buildings A-C (see Table 1). These samples were submitted to the EPA Office of Environmental Measurement and Evaluation (OEME) Laboratory, located in North Chelmsford, MA, for limited analysis (X-Ray Fluorescence [XRF] analysis for arsenic and total chromium) (Weston Solutions, Inc. 2012). Total chromium samples that exceeded 120 mg/kg were submitted to a subcontracted DAS laboratory for hexavalent chromium analysis (Weston Solutions, Inc. 2012). Additionally, in April 2011 two soil samples (SS-31A and SS-32A) were collected northwest of the site at 71 Purchase Street in Danvers and analyzed for metals to evaluate background soil conditions (Weston Solutions Inc. 2011). The results of these background soil samples were not available at the time of this health consultation.

The combined samples (52 samples) from April and October 2011collected near Buildings A-C at the 33 Water Street property were the shallowest soil samples available at the time of this evaluation. During the course of preparing this health consultation, US EPA has generated supplemental soil data as part of the ongoing phase I site investigation (US EPA 2014c). A total of 16 soil borings were collected from the 33 Water Street property between June 12th and June 26th 2014 and screened for metals and PAHs in the field. Samples were also sent for laboratory analysis for dioxins/furans, metals, PAHs, PCBs, pesticides, SVOCs and VOCs. The supplemental data from June 2014 include eleven soil samples collected at a depth (0-6 inches) shallower than previous samples from April and October of 2011 and additional soil borings are planned for the spring of 2015. The supplemental data from June 2014, although not as numerous as deeper soil samples from 2011, provide support to the current evaluation of soil exposure at the 33 Water Street property. See Table 4 for a comparison of soil data from April/October 2011 and June 2014.

Methods for Evaluating Contaminants of Soil

Health assessors use a variety of health-based screening values, called comparison values, to help determine whether compounds detected in environmental samples require further evaluation. These comparison values include ATSDR cancer risk evaluation guides (CREGs), environmental media evaluation guides (EMEGs), and Reference Dose Media Evaluation Guides (RMEG). These comparison values have been scientifically peer-reviewed or derived using scientifically peer-reviewed values and published by Federal and State Agencies. If the concentration of a compound exceeds its comparison value, adverse health effects are not necessarily expected. Rather, these comparison values help in selecting compounds for further consideration. ATSDR CREG values provide information on the potential for carcinogenic effects and are derived assuming a lifetime of daily exposure in a residential setting. ATSDR EMEG and RMEG values are used to evaluate the potential for non-cancer health effects in a residential setting.

For chemicals that do not have ATSDR comparison values, US EPA Regional Screening Levels (RSLs) for Chemical Contaminants at Superfund Sites can be used. The RSLs are chemical-specific concentrations for individual contaminants in air, drinking water and soil that US EPA uses to determine whether further investigation or site cleanup is warranted. RSLs are based on default exposure parameters and factors that represent Reasonable Maximum Exposure (RME) conditions for long-term/chronic exposures that are protective of humans including sensitive populations (US EPA 2011b). Additionally, Massachusetts state standards (e.g. S-1 soil standards) were also used in the absence of ATSDR comparison values. The Massachusetts Contingency Plan (MCP) S-1 soil standards (310 CMR 40.0975(6)(a)) apply to soil associated with unrestricted use (e.g. parks, playgrounds and schoolyards) and consider incidental ingestion of the soil, dermal contact with the soil and ingestion of produce grown in the soil (MassDEP 2013).

This health consultation also makes use of “background” concentrations to aid in evaluating the chemical contamination at the 33 Water Street property. Many metals are present in the earth’s crust and hence have typical background concentrations. The United States Geological Survey (USGS) has identified levels of metals that are considered typical for soil in the eastern United States (Shacklette and Boerngen 1984). ATSDR has compiled data on levels of polycyclic aromatic hydrocarbons (PAHs) and some metals (e.g., lead) that are considered typical for soil of urban and suburban communities due to centuries of human activities (ATSDR 1995). In addition, MassDEP has published background values for PAHs and metals for "natural" soil, meaning levels that would exist in the environment in absence of a disposal site of concern (310 CMR 40.0006), and for soil associated with wood/coal ash fill, i.e., resulting from general human activities (MassDEP 2002). Thus, available typical background levels are used along with comparison values as screening methods for metals and PAHs in this analysis.

The comparison values described above are specific concentrations of a chemical used by health assessors to identify environmental contaminants that require further evaluation. These health-based comparison values assume exposure situations that represent conservative estimates of human exposure. Chemicals detected in soil at concentrations that exceed a comparison value do not necessarily represent a health threat. Rather, these chemicals are evaluated in more detail to determine whether exposure is occurring and, if so, whether health effects may occur as a result of that exposure.

RESULTS

Soil samples were collected at the 33 Water St. property in April and October 2011 and analyzed for a variety of contaminants including dioxins**,** pesticides, PCBs, VOCs, SVOCs, metals and asbestos. The data indicate ten chemicals detected that exceed health-based comparison values and/or typical background levels and therefore required further evaluation in this report. Screening values were exceeded in at least one soil sample for one metal (arsenic), eight PAHs (benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, chrysene, dibenz(a,h)anthracene, indeno(1,2,3,-cd)pyrene, and phenanthrene), and one PCB (aroclor-1248). No comparison values were available for carbazole, detected in 7/11 samples collected.

The following is a summary of the analytical results for the eleven soil samples collected in April of 2011 and the forty one soil samples collected in October of 2011 at the 33 Water street property, including the analytes detected above screening values, frequency of detects, range of detected concentrations for each of these analytes, as well as their relevant health-based comparison values and available background levels. This summary also includes other contaminants that do not exceed screening values but are of interest for this site (e.g. dioxins and hexavalent chromium). This information is also summarized in Table 1.

Polychlorinated Biphenyls (PCBs)

Aroclors are one of the most commonly known trade names for **PCB** mixtures produced in the U.S. from approximately 1930 to 1979 (US EPA 2013d). Soil samples were analyzed for nine **Aroclors**: Aroclor-1016, Aroclor-1221, Aroclor-1232, Aroclor-1242, Aroclor-1248, Aroclor-1254, Aroclor-1260, Aroclor-1262 and Aroclor-1268. Aroclor 1248 was the only Aroclor detected in 2/11 samples collected, with detections of 0.19 mg/kg and 0.39J mg/kg. Sample SS-20A slightly exceeded the health-based screening value of 0.35 mg/kg (ATSDR CREG). It is important to note that the detection in sample SS-20A was J qualified (or J flagged) by the laboratory conducting the analysis; meaning that the reported concentration was an estimated value. Because the estimated value was similar to the ATSDR CREG and not quantifiable, and because no other samples at the site had either detectable PCBs or any PCBs above a screening value, PCBs were not further evaluated in this consult.

Metals

Arsenic was detected in 23/51[4] samples collected, with detections ranging from 10 mg/kg to 42 mg/kg detected in sample SS-08. Eleven of these samples exceeded the health-based screening value (ATSDR chronic EMEG for a child of 15 mg/kg) and none of the samples exceeded the background levels for arsenic in soil (Shacklette and Boerngen 1984). Levels of arsenic detected in five samples from April 2011 were J qualified by the laboratory.

[4] Of the 52 soil samples collected for this area, one sample (SS-02A) was eliminated because the value detected was flagged by the laboratory as having detections of the analyte in the associated equipment blank (denoted as EB).

Total Chromium was detected in 48/52 samples collected, ranging from 18.9 mg/kg to 2040 mg/kg detected in sample SS-23; a subset of these samples were further analyzed for **hexavalent chromium. Hexavalent chromium** was detected in 10/26 samples collected with a maximum[5] of 6.6 mg/kg in sample SS-40. None of the detections of total chromium or hexavalent chromium exceeded health-based screening values.

Lead was detected in 11/11 samples collected, ranging from 9.6 mg/kg to 189J mg/kg detected in sample SS-02A. ATSDR does not have a health-based screening value for lead in soil; therefore the MassDEP S-1 soil standard of 200 mg/kg was used for comparison. None of the levels of lead detected exceeded the MassDEP S-1 soil standard or background levels for lead in soil (Shacklette and Boerngen 1984). Current state of the science indicates that there is no safe level of lead exposure (i.e. measured in blood). In humans, the main target for lead toxicity is the nervous system. Lead exposure is of greatest concern for young children because children exposed to lead, primarily due to the presence of lead paint in housing, may experience neurological damage (including learning disabilities) and behavioral changes. The U.S. Centers for Disease Control and Prevention (CDC) has updated its recommendations on children's blood lead levels and are focusing on primary prevention of lead exposure to reduce or eliminate dangerous lead sources in children's environments before they are exposed.[6] Therefore, as with all known sources of lead, steps should be taken to minimize exposure to lead in soil for children as much as possible.

Polycyclic Aromatic Hydrocarbons (PAHs) and other Semi-Volatile Organic Compounds (SVOCs)

[5] A maximum value of 10 mg/kg of hexavalent chromium detected in sample SS-06A, equal to ATSDRs Intermediate EMEG for PICA behavior in children, was eliminated because the value was flagged by the laboratory as having detections of the analyte in the associated equipment blank (denoted as EB) and also J qualified (flagged as an estimated value).

[6] Recently, CDC has established a new reference level of 5 μg/dL to identify children as having lead exposures; thereby lowering the blood lead level at which evaluation and intervention are recommended. This new reference level is based on the U.S. population of children ages 1 to 5 years who are in the highest 2.5% of children when tested for lead in their blood (CDC 2012).

Benzo(a)pyrene was detected in 11/11 samples collected, with detections ranging from 0.055J mg/kg to 18 mg/kg and ten samples exceeded the health-based screening value (ATSDR CREG of 0.096 mg/kg). One of these samples (0.160J mg/kg detected in sample SS-08A) was J qualified. Eight samples exceeded background levels of benzo(a)pyrene in soil typical for urban areas (ATSDR 1995).

Benzo(a)anthracene was detected in 11/11 samples collected, with detections ranging from 0.049J mg/kg to 30 mg/kg and ten samples exceeded the health-based screening value (EPA RSL of 0.15 mg/kg). One of these samples (0.270J mg/kg detected in sample SS-09A/SS-33A) was J qualified. None of these samples exceeded background levels of benzo(a)anthracene in soil typical for urban areas (ATSDR 1995).

Benzo(b)fluoranthene was detected in 11/11 samples collected, with detections ranging from 0.065J mg/kg to 37 mg/kg and ten samples exceeded the health-based screening value (EPA RSL of 0.15 mg/kg). Two of these samples (0.370J mg/kg detected in sample SS-08A and 0.300J mg/kg detected in sample SS-09A/SS-33A) were J qualified. None of these samples exceeded background levels of benzo(b)flouranthene in soil typical for urban areas (ATSDR 1995).

Benzo(k)fluoranthene was detected in 11/11 samples collected, with detections ranging from 0.046J mg/kg to 14 mg/kg and five samples exceeded the health-based screening value (EPA RSL of 1.5 mg/kg). None of these samples exceeded background levels of benzo(k)flouranthene in soil typical for urban areas (ATSDR 1995).

Chrysene was detected in 11/11 samples collected, with detections ranging from 0.076J mg/kg to 34 mg/kg and one sample exceeded the health-based screening value (EPA RSL of 15 mg/kg). Seven samples (SS-02A, SS-06A, SS-11A, SS-18A, SS-19, SS-20, SS-21) exceeded background levels (0.251-0.64 mg/kg) of chrysene in soil typical for urban areas (ATSDR 1995).

Dibenzo(a,h)anthracene was detected in 8/11 samples collected, with detections ranging from 0.045J mg/kg to 3.7 mg/kg and eight samples exceeded the health-based screening value (EPA RSL of 0.015 mg/kg). Two of these samples (0.45J mg/kg detected in sample SS-08A and 0.160J mg/kg detected in sample SS-19A) were J qualified. Three samples (SS-06A, SS-18A and SS-21A) exceeded background levels of dibenzo(a,h)anthracene in natural soils (MassDEP 2002).

Indeno(1,2,3-cd)pyrene was detected in 10/11 samples collected, with detections ranging from 0.11J mg/kg to 13 mg/kg and seven samples exceeded the health-based screening value (EPA RSL 0.15 mg/kg). None of the samples exceeded background levels of indeno(1,2,3-cd)pyrene in soil typical for urban areas (ATSDR 1995).

Phenanthrene was detected in 11/11 samples collected, with detections ranging from 0.04J mg/kg to 59 mg/kg and one sample exceeded the health-based screening value (MassDEP S-1 of 10 mg/kg). Three of the samples (SS-11A, SS-18A and SS- 21A) exceeded background levels of phenanthrene in natural soil (MassDEP 2002). Unlike other PAHs previously discussed, phenanthrene is not classifiable as to human carcinogenicity (ATSDR 1995). Additionally, there are no ATSDR health guidelines (or MRLs) for evaluation of the non-cancer health effects of phenanthrene. However, the detected levels of phenanthrene in soil are well below the lowest available ATSDR health-based screening value for other non-carcinogenic PAHs (i.e. child RMEG of 15,000 mg/kg for pyrene)[7] and thus exposure to phenanthrene in soil was not further evaluated in this report.

Carbazole was detected in 7/11 samples collected, with detections ranging from 0.036 mg/kg to 6.7 mg/kg. There are no health-based guidelines or background levels available for comparison of carbazole levels detected in soil. Additionally, carbazole is not

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[7] As demonstrated in other ATSDR certified public health documents, when toxicity data are limited for a specific contaminant it is often useful to compare detected levels with health-based screening values for other contaminants within a chemical class that represent the lowest toxicity values available within the class i.e. PAHs that are not considered carcinogenic.

classifiable as to human carcinogenicity (IARC Group 3), there is no toxicological profile available for carbazole, and a literature search did not provide any relevant toxicity data for further evaluation of potential non-carcinogenic health effects (NLM 2014). Therefore, exposure to carbazole in soil was not further evaluated in this report.

Dioxins

Dioxins are a group of compounds that share chemical structures and characteristics; 2, 3, 7, 8-tetrachlorodibenzo-para-dioxin (2, 3, 7, 8-TCDD) is considered the most toxic in this group. Soil samples were analyzed for seventeen dioxins and the reported concentrations were evaluated based on the toxicity of the dioxins relative to 2, 3, 7, 8-TCDD (US EPA 2013e). Toxicity equivalency factors (TEFs) for each dioxin compound were used to calculate 2, 3, 7, 8-TCDD toxicity equivalence (TEQ) and the sum of TEQs for each sample were then reported as the total TEQ. Dioxins were detected in 11/11 samples collected, with the maximum total TEQ of 4.51J x 10^{-5} mg/kg (or 45.1J picograms per gram, pg/g) detected in sample SS-20A. None of the total TEQs exceeded the health-based screening value for for 2, 3, 7, 8-TCDD in soil (ATSDR chronic EMEG for a child of 5.0 x 10^{-5} mg/kg). Approximately 60% of the results for sample SS-20A were J qualified.

EXPOSURE PATHWAY ANALYSIS

MDPH conducted an exposure pathways evaluation to determine if people could come into contact with contaminants detected in soil at 33 Water Street, including residents of the Crane River East Condominium Complex.

Exposure to a chemical must occur before any potential adverse health effects can result. Five conditions must be present for exposure to occur. First, there must be a source of that chemical. Second, an environmental medium must be contaminated by either the source or by contaminants transported away from the source. Third, there must be a location where a person can potentially contact the contaminated medium. Fourth, there must be a means by which the contaminated medium could enter a person’s body, such as ingestion, inhalation, and dermal absorption. Fifth, there must be a potentially exposed population.

When all five conditions are present, the exposure pathway is determined to be a completed exposure pathway. Even if all five elements of an exposure pathway are present, adverse health effects will not necessarily occur. The chemical must actually reach the target organ susceptible to the toxic effects caused by that particular substance at a sufficient dose and for a sufficient exposure time for an adverse health effect to occur (ATSDR 2005).

This evaluation of the former Creese & Cook Tannery is focused on current site conditions at the Crane River East Condominium Complex at 33 Water Street. Exposures to contaminants in soil are most likely to occur through contact with surface soils (e.g. 0-3 inches), but no soil samples were available at the time of this evaluation for the 33 Water Street property at depths more shallow than 0-1 foot. Thus, the exposure pathway analysis is based on the assumption that the concentrations found in 0-1 foot samples are similar to concentrations in the soil closer to the surface (e.g. top 0-3 inches). Additionally, supplemental soil data from June 2014 supports this assumption (see Table 4).

Contamination at the Water Street parcel is thought to be from the tanning operations of the former Creese & Cook Tannery located at the site from the early 1900's until the early 1980's when the facility went bankrupt (US EPA 2013b). Based on available data, children and adults residing at the Crane River East Condominium Complex could come in contact with soils located on the 33 Water Street property and, therefore, a completed exposure pathway currently exists for site related contaminants detected in soil samples. Residents and other individuals spending time at 33 Water Street could come in contact with soils by inadvertently ingesting soil and settled dust by hand-to-mouth activity. Young children (less than 5 years of age) may be particularly susceptible due to their hand-to-mouth activities (including soil-pica for some), and they typically incidentally ingest more soil/dust than adults. The grassy lawn areas of the Crane River East Condominiums are easily accessible for recreational use; a small garden was observed during the MDPH site visit and it is reasonable that young children may reside at the property. It is also important to note that the grass coverage existing over most of the 33 Water Street property will act as a buffer and minimize direct exposure to the soil contamination at the site; areas with exposed soil and no vegetation would increase the likelihood of exposure to contaminated soils.

As mentioned previously, a small garden surrounded by wire fencing was observed on the southern portion of the site. It is unknown as to the specific details of the type of garden or how it was used by the residents. Based on observations during the site visit in the spring of 2013, the garden appeared to be active with tomato seedlings, marker tags and a soaker hose visible in the soil. There is inadequate information about the use of the garden to accurately evaluate exposure from consumption of home-grown vegetables; however, this potential pathway for exposure will be further discussed for those contaminants that have exceeded screening values. Typically there are greater exposure concerns related to direct contact with or ingestion of potentially contaminated soils during gardening, rather than from the consumption of food grown in contaminated soils (US EPA 2011c).

HEALTH EFFECTS EVALUATION

To evaluate the potential for health effects, exposure dose estimates (Appendix A) were calculated for incidental ingestion of chemicals detected in soil samples at concentrations that exceeded initial screening values. These contaminants include, arsenic, and carcinogenic PAHs (benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3,-cd)pyrene). The 95% upper confidence limit (UCL) of the arithmetic mean (calculated using PRO-UCL Software) or the maximum detected value for each contaminant was used when calculating exposure dose estimates for incidental ingestion of chemicals detected in soil at the site.[8] Additionally, an estimated cancer risk for total carcinogenic PAHs was calculated based on the total BaP equivalent concentration (Appendix A).

Exposure dose estimates were calculated using conservative assumptions for children and adults that may have incidentally ingested soil and indoor/outdoor dust (e.g. soil that may have been tracked indoors) while residing at the Crane River East Condominiums. Exposure doses were calculated using both average (central tendency exposure or CTE) and high (reasonable maximum exposure or RME) intake rates of soil/dust during the exposure period of April through November (35 weeks or 245 days).[9] Soil/dust intake rates used to estimate exposure also incorporate exposure from indoor and outdoor dust particulates that may be suspended in air and then inhaled and swallowed (US EPA 2011a). It was assumed that a young child[10] (11.4 kg) ingested 100 mg/day (CTE) or 200 mg/day (RME) of soil and dust every day containing the 95% UCL of the mean or the maximum concentration of contaminant detected in any soil sample (US EPA 2008). For adults, it was assumed that an adult (80 kg) ingested 50 mg/day (CTE) or 100 mg/day (RME) of soil and dust every day containing the 95% UCL of the mean or maximum concentration of contaminant detected in any soil sample (US EPA 2011a). Additionally, exposure dose estimates were also calculated for special groups, such as children with soil-pica behavior (acute exposure), to account for behaviors that may result in different levels of exposure and when possible residential specific information was incorporated. It was assumed that a young child exhibiting soil-pica behaviors ingested 5000 mg/day of soil and indoor dust 3 days per week (for 2 weeks). Since individual behaviors of the residents are unknown and may vary, conservative exposure assumptions are used to calculate an estimated dose that likely over estimates exposure. Exposure doses for all

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[8] When possible the 95% UCL of the arithmetic mean was used for exposure dose calculations. If the data were insufficient for calculation of the UCL of the arithmetic mean then the maximum value detected was used.

[9] The CTE and RME soil ingestion rates include assumptions about both outdoor soil and indoor dust ingestion for estimating exposure.

[10] Exposure doses were calculated for a child age 1 to <2 years, which is the most highly exposed group when considering soil ingestion. Additional age categories were considered if exposure dose estimates for a child age 1 to < 2 years exceeded health guidelines.

groups were then compared to health guidelines developed by ATSDR and US EPA to evaluate the potential for health effects (Tables 2 and 3).

ATSDR health guidelines are called minimal risk levels (MRLs) and are estimates of daily human exposure to a substance that is likely to be without an appreciable risk of adverse non-cancer health effects over a specified duration of exposure. MRLs are derived based on no-observed-adverse-effect levels (NOAELs) or lowest-observed-adverse-effect levels (LOAELs) from either human or animal studies. The LOAELs or NOAELs reflect the actual levels of exposure that are used in studies. To derive these levels, ATSDR also accounts for uncertainties about the toxicity of a compound by applying various margins of safety to the MRL, thereby establishing a level that is well below a level of health concern. When there are no available MRLs for a chemical, US EPA health guidelines called reference doses (RfDs) are used for comparison. An RfD is an estimate, with uncertainty or safety factors built in, of the daily lifetime dose of a substance that is unlikely to cause non-cancer health effects in humans (ATSDR 2005). Additionally, to evaluate potential cancer risks, exposure estimates for contaminants of concern were combined with USEPA cancer slope factors (CSF) to evaluate the potential cancer risk. The cancer risk is an estimated risk for getting cancer if exposed to a substance every day for a specified duration[11] of exposure; the true risk may be lower (ATSDR 2005).

Arsenic

For arsenic, exposure dose estimates were calculated for adults, young children, and young children exhibiting soil-pica behaviors. Two exposure scenarios were used for exposure doses for young children; a 95% UCL of the mean was calculated using arsenic concentrations from (1) all available soil samples at the site and (2) a subset of soil samples from areas where exposure for young children is more likely to occur. The

[11] The national upper bound percentile for length of time at one residence (95th percentile value) of 33 years was used for the duration of exposure when calculating exposure dose estimates (US EPA 2009). This length of residency was used instead of an estimated length of residency based on the year the complex was built (1986 from the Town of Danvers, MA 2013) as a more conservative estimate because this consultation includes potential future exposure to current site contaminants.

highest concentration of arsenic at the site was 42 mg/kg from sample SS-08, detected by the laboratory using XRF analysis. This sample is in an area that appears to be a combination of grass and mulch with some vegetation, located in the northern portion of the property adjacent to the condo access road/parking area and Water Street (Route 35) (See Figure 2). Other samples collected (SS-09 and SS-19A) from this area have concentrations of arsenic detected at 26 mg/kg and 12.9 mg/kg, respectively. Based on visual observations of the area from aerial maps and photographs, this seems an unlikely location for regular recreational use by very young children. The concentration of arsenic in sample SS-08 exceeds the MassDEP (Massachusetts Contingency Plan (MCP) imminent hazard level of 40 mg/kg but was not removed during remedial activities due to the location of the sample. According to US EPA, the soils near sample SS-08 have limited potential for exposure because it is an area used for dumpster storage for the condo complex (US EPA 2013f). Should current property landscape or storage uses change making this area more accessible for recreational use, additional sampling would be prudent to address this data gap. Also, given that this sample was taken from a depth of 0 to 1 ft. it is unclear whether the levels of arsenic measured are representative of soils near the surface (e.g. 0-3 inches) that would be more accessible for frequent contact in a residential scenario. If additional sampling data for this area are generated during the upcoming US EPA investigations, MDPH could re-evaluate the data upon request.

Exposure doses calculated for arsenic, using the 95% UCL of the arithmetic mean (14.8 mg/kg) for all available soil samples ranged from 0.0001 to 0.0002 milligrams per kilograms per day (mg/kg-day) for a child and 0.000006 to 0.00001 mg/kg-day for an adult, incidentally ingesting typical amounts of soil or more. The exposure doses calculated for a child and adult are below the chronic oral MRL of 0.0003 mg/kg-day for arsenic; meaning that it is unlikely that non-cancer health effects would result in children or adults from exposure to levels of arsenic that were detected in soil at the 33 Water Street property. Since it is possible that young children may reside at the Crane River East Condos, additional exposure dose calculations were done to evaluate acute exposure for children who may exhibit soil-pica behaviors. The exposure doses calculated for arsenic ranged from 0.002 mg/kg-day to 0.003 mg/kg-day for young children (ages 1 to less than 6 years) with acute soil-pica behaviors. The acute exposure doses calculated for young children incidentally ingesting above average amounts of soil as seen with soil-pica behaviors, are below the ATSDR acute oral MRL of 0.005 mg/kg-day meaning that harmful effects are not expected.

Additionally, exposure doses were calculated for arsenic using the 95% UCL of the arithmetic mean (13.8 mg/kg) for sample locations near and around the condo buildings, including the larger grassy areas in the rear of the complex, but excluding less accessible areas such as adjacent to the parking lot and Water Street (i.e. SS-08). Exposure doses for young children incidentally ingesting typical amounts of soil per day or more range from 0.0001 mg/kg-day to 0.0002 mg/kg-day. The exposure doses calculated for areas of the property where exposure for young children is more likely to occur are also below the chronic oral MRL for arsenic. The acute exposure doses calculated for young children incidentally ingesting above average amounts of soil as seen with soil-pica behaviors, are again below the ATSDR acute oral MRL of 0.005 mg/kg-day.

Estimated doses from both exposure scenarios using (1) all available soil samples at the site and (2) a subset of soil samples from areas where exposure for young children is more likely to occur were below ATSDR MRLs. Therefore, it is unlikely that non-cancer health effects would result in adults and children exposed to the mean levels of arsenic while residing at the 33 Water Street property, even those children that may eat soil occasionally.

Arsenic is classified as a human carcinogen with an oral cancer slope factor of 1.5 $(mg/kg\text{-}day)^{-1}$ based on the prevalence of skin cancer in Taiwanese populations (US EPA 1998). Cancer risks were calculated for all exposure scenarios previously discussed and summarized in Table 3. The highest estimated cancer risk calculated for adults exposed to arsenic in soil was 3.9 in 1,000,000 (3.9×10^{-6}) for average soil ingestion and 7.9 in 1,000,000 (7.9×10^{-6}) for above average soil ingestion; meaning for adults the risk estimate would result in approximately 4-8 excess cancers diagnoses in a population of one million people. The highest estimated cancer risk calculated for children exposed to arsenic in soil was 1.3 in 100,000 (1.3×10^{-5}) for average soil ingestion and 2.5 in 100,000 (2.5×10^{-5}) for above average soil ingestion; meaning for children the risk estimate would result in approximately 1-3 excess cancer diagnoses in a population of one hundred thousand people. Therefore, it is unlikely that children or adults who have been exposed to arsenic at mean levels detected in soils across the 33 Water Street property (Buildings A-C) would experience an unusual cancer risk.

It is possible for arsenic to accumulate in plants by root uptake from the soil or absorption of airborne arsenic deposited on the leaves; concentrations will depend on the species of arsenic in the soil as well as the plant species grown in the soil (ATSDR 2007). Studies have shown that the majority of arsenic accumulates in the root system of the plant by uptake from the soil and adherence to the roots (ATSDR 2007; Rahman et al. 2004, as cited in Heiger-Bernays et al. 2009). Therefore, greater concentrations of arsenic are likely to be found in root vegetables compared to above-ground crops grown in contaminated soils. This is further demonstrated by a study of tomato plants grown in arsenic contaminated soils showing that eighty five percent of arsenic accumulated in the root system while one percent accumulated in the fruit (Burlo et al. 1999, as cited in ATSDR 2007). Exposure to arsenic related to gardening can also occur from contaminated soils that adhere to or deposit on the surface of unwashed plants, especially for plants with large outer leaves (e.g. leafy greens).

There are no soil samples currently available for the garden area observed behind Building A and accessible to the 33 Water Street property; however, there are three soil samples (SS-22A, SS-32, SS-49) that were collected on the southern most portion of the site in close proximity to the tree line where the garden was observed. Of these three soil samples only one sample (SS-22A) had detectable levels of arsenic at a concentration of

12.1J mg/kg, which is below the health based screening level of 15 mg/kg[12]. There is limited information regarding specific gardening practices at the site, although observations of a small garden suggest tomato plants as a possible crop. Given the low concentrations of arsenic near the area of the garden and the nature of arsenic uptake in plants, such as tomatoes, it is unlikely that consuming fruits and vegetables from this garden would have contributed significantly to arsenic exposure. Growing above-ground fruiting crops (such as tomatoes, peppers, peas, bean and corn) that accumulate less contaminants in the edible portion of the plant (CT DPH 2013) and using good gardening practices will further reduce opportunities for exposure to arsenic from growing and consuming fruits and vegetables from this area or other potentially contaminated areas of the site. Good gardening practices include washing produce thoroughly before eating, wearing gloves during gardening, and washing hands.

Polycyclic Aromatic Hydrocarbons (PAHs)

Benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, and chrysene were detected in 11/11 samples collected. Dibenzo(a,h)anthracene and indeno(1,2,3-cd)pyrene were detected in 8/11 and 10/11 samples collected, respectively. Detections of PAHs in soil samples ranged from 0.04J mg/kg to 37 mg/kg, with the highest detections of all PAHs from sample SS-18A located north of and within 200 feet of Building C (front of building) (Weston Solutions Inc. 2011) (Figure 2). Twenty two percent of the data for PAHs were J qualified by the laboratory. Additionally, seventy seven percent of the samples collected had levels of carcinogenic PAHs within typical background (ATSDR 1995, MassDEP 2002), as PAHs are ubiquitous in soils due to centuries of human activity.

There are no MRLs for these seven PAHs (i.e., benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene and indeno(1,2,3-cd)pyrene) for evaluation of non-cancer health effects; however, these

[12] The lowest ATSDR health comparison value for arsenic is the CREG value of 0.47 mg/kg, this level is below background levels for arsenic in soil and therefore ATSDR recommends using the chronic EMEG for a child of 15 mg/kg for data screening purposes (ATSDR 2013).

PAHs are classified as probable human carcinogens and exceeded screening values and some background values in at least one soil sample collected. Benzo(a)pyrene has an oral cancer slope factor of 7.3 $(mg/kg\text{-}day)^{-1}$ based on the increased incidence of total tumors and tumors at the site of exposure in rodents and primates (US EPA 1991a, as cited in US EPA 1994)[13]. The other six PAHs (i.e., benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene and indeno(1,2,3-cd)pyrene) are considered less potent than benzo(a)pyrene and when calculating cancer risks US EPA provides potency factors that are applied to the cancer slope factor for benzo(a)pyrene to adjust for the lower potency (US EPA 1993). The individual estimated cancer risks for benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene and indeno(1,2,3-cd)pyrene were calculated using the 95% UCL of the arithmetic mean. For dibenz(a,h)anthracene the max value detected was used to calculate estimated cancer risks because of too few detections reported to calculate the 95% UCL of the arithmetic mean. Estimated cancer risks for these seven PAHs are summarized here as a total estimated cancer risk (using the total BaP equivalent concentration) for these carcinogenic PAHs that were detected in soil samples at the site (See Appendix A, sample calculation 3).

The highest levels of PAHs were detected in sample SS-18A, based on available data it does not appear that concentrations of PAHs detected in this sample are representative of other areas of the 33 Water Street property that were sampled; PAH results for sample SS-18A were also flagged as outliers using PRO-UCL software. Therefore, two exposure scenarios were used for calculating exposure doses (1) all available soil samples at the site and (2) soil samples excluding sample SS-18A to compare the effect of this outlier. Using all available soil data, the estimated cancer risk calculated for adults incidentally ingesting typical amounts of PAH contaminated soil is 1.9 in 100,000 (1.9×10^{-5}) and 3.8 in 100,000 (3.8×10^{-5}) for above average ingestion; meaning for adults the risk estimate would result in approximately 2-4 excess cancer diagnoses in a population of one

[13] Benzo(a)pyrene has been identified by US EPA as having a mutagenic mode of action. Therefore cancer risk calculations have been modified using age-dependent adjustment factors (ADAFs) (US EPA 2005, 2012c).

hundred thousand people. The estimated cancer risk calculated for children incidentally ingesting typical amounts of PAH contaminated soil is 2.5 in 10,000 (2.5×10^{-4}) and 4.9 in 10,000 (4.9×10^{-4}) for above average ingestion; meaning for children the risk estimate would result in approximately 3-5 excess cancer diagnoses in a population of ten thousand people. When excluding sample SS-18A the estimated cancer risks for typical to above average incidental ingestion are approximately 1 excess cancer diagnosis in an adult population of one hundred thousand (5.1×10^{-6} to 1.0×10^{-5}), and approximately 1 excess cancer diagnosis in a population of ten thousand (6.7×10^{-5} to 1.3×10^{-4}) for children. Therefore, regardless of outliers detected for PAHs, children who incidentally ingest soil contaminated with mean concentrations of carcinogenic PAHs detected at the site may have an increased risk of cancer, while it would be unlikely for adults to have an increased risk of cancer. It is likely that this increased cancer risk for children is an overestimation of the actual cancer risk when considering the specific site conditions at the 33 Water Street property. As described earlier, the grounds surrounding the condo complex appear to be grassy and well maintained with very few areas of exposed soil. It is expected that the grass coverage will reduce exposure to contaminated soil that occurs during typical outdoor activities as well as minimizing tracked in soil/dust to the homes. In comparison, the estimated cancer risks for children living at the 33 Water Street property are similar to what would be expected from exposure to soil in typical urban environments. Estimated cancer risks calculated for children exposed to the maximum concentrations of PAHs that are reported as typical concentrations for urban areas (ATSDR 1995) show similar increased cancer risks.

Sample SS-18A, with the outlier concentrations of PAHs, is located in a grassy area in the front of building C (Figure 2). Although this sample may be located in a high traffic area for those entering the building near that location, it seems unlikely that extensive disturbance of soil would occur given grassy conditions. To further minimize potential exposure to soils in this particular location, it may be prudent to wipe shoes on a mat when entering the home.

There are additional uncertainties in the evaluation of PAHs in soil at the 33 Water Street property because of limitations in the data, e.g. there were only eleven available sample points for the site and one sample was identified as an outlier having much higher concentrations of PAHs, and soil depths were greater than typically used in public health evaluations (i.e. 0 to 1 or 2 feet rather than the top 3 inches). Therefore, a more thorough evaluation of PAH contamination in surface soil across the site was not possible. MDPH recommends that US EPA, as part of future investigations, further characterize the concentrations of PAHs in surface soils at the 33 Water Street property.

It is possible for PAHs to accumulate in plants depending on the type of PAHs in soil and the species of plants. However, the uptake of PAHs from soil to plants is considered to be low (ATSDR 1995; Kipopoulou et al. 1999, Samsoe-Peterson et al. 2002, Schnoor et al. 1995, as cited in Heiger-Bernays 2009). Ratios of PAH concentrations in vegetation to those in soil have been reported to range from 0.001 to 0.18 for total PAHs and from 0.002 to 0.33 for benzo[a]pyrene (Edwards 1983, as cited in ATSDR 1995). Because of this low uptake of PAHs by plants, incidental ingestion (from hand to mouth or from unwashed produce) and dermal contact during gardening are considered more likely pathways of exposure.

There are no soil samples currently available for the garden area observed behind Building A and accessible to the 33 Water Street property; however, there is one soil sample (SS-22A) that was collected on the southern most portion of the site in close proximity to the tree line where the garden was observed that was analyzed for PAHs. This sample had levels of PAHs below screening values and well below average concentrations of PAHs across the site. Given the low PAH uptake in plants it is unlikely that consuming fruits and vegetables from this garden would have contributed significantly to PAH exposure. Washing fruits and vegetable thoroughly and using other good gardening practices will further reduce opportunities for exposure to PAHs that may occur while gardening or from consuming produce grown at this site. Good gardening practices include washing produce thoroughly before eating, wearing gloves during gardening, and washing hands.

CONCLUSIONS

US EPA site investigations for the 33 Water Street property and other areas of the Site are ongoing and therefore future sampling efforts may provide additional data points that should be evaluated for public health implications. Results of soil sampling from April and October of 2011 at the 33 Water Street property, also known as the Crane River East Condominium Complex, indicate that the maximum concentrations of some contaminants (e.g. arsenic and PAHs) detected in some soil samples exceeded health-based screening values. Concentrations of these contaminants were further evaluated to determine the potential for health effects for children and adults that may ingest soil at the site.

MDPH does not have adequate data representing surface soil (e.g. 0-3 inches) to conclude if eating soil containing chemicals (e.g. arsenic and PAHs) near Buildings A, B, and C of the Crane River East Condominium Complex at 33 Water Street is expected to harm people's health. Exposures to contaminants in soil are most likely to occur through contact with surface soils (e.g. 0-3 inches), but no soil samples were available for the 33 Water Street property at depths more shallow than 0-1 foot. Therefore, the following conclusions are based on currently available soil data assuming that the concentrations found in 0-1 foot samples are similar to concentrations in the soil closer to the surface (e.g. top 0-3 inches). This assumption is further supported by additional sampling data that were generated by US EPA during the course of preparing this health consultation (US EPA 2014c). As part of the ongoing US EPA Phase I site investigation for the Creese and Cook Superfund site, environmental sampling was conducted in June 2014 and additional soil borings are planned for the spring of 2015. The sampling conducted at the 33 Water Street property in June 2014 included eleven additional soil samples at more shallow depths (0-6 inches) than previously available (0-1 foot). The average and maximum concentrations of arsenic and carcinogenic PAHs detected in the 0-6 inch soil samples were similar to or less than detected in deeper soil samples (0-1 foot) used in this health consultation (Table 4). For example, the average concentration of arsenic in 0-1 foot samples was 17.5 ppm vs. 14.8 ppm in 0-6 inch samples. For B(a)P, the average in 0-1 foot samples was 2.89 ppm vs 0.74 ppm in 0-6 inch samples. Thus, newly available data from more shallow soil samples, though not as numerous as deeper soil samples, suggest that arsenic and PAH concentrations in residential surface soil are either consistent with or even less than those detected in deeper soil samples. US EPA remedial investigations for the Creese and Cook Superfund site are ongoing and MDPH will evaluate additional data as investigations are completed. Based on evaluation of currently available data, current site conditions, and analysis of exposure pathways, MDPH concludes the following:

- The grassy lawn areas of the Crane River East Condominiums are easily accessible for recreational use for children and adults. It is however important to note that the grass coverage existing over most of the 33 Water Street property will act as a buffer and minimize direct exposure to soil contamination at the site or generation of fugitive dust; areas with exposed soil and no vegetation would increase the potential for exposure to contaminated soils.
- Ingesting average concentrations of chemicals detected in soils near Buildings A, B and C at 33 Water Street is not expected to harm the health of adult residents or other adults that may visit the site. MDPH does not consider the levels of chemicals detected in soil at the site to present an unusually elevated cancer risk for adults.
- Exposure to arsenic in soils at the site is not expected to harm the health of children including those children who exhibit soil-pica behaviors for acute durations. MDPH does not consider the levels of arsenic detected in soil at the site to present an unusually elevated cancer risk for children.
- Children who incidentally ingest soil contaminated with average concentrations of total carcinogenic PAHs detected at the site are estimated to have a small increased risk of cancer (1 excess cancer diagnosis in a population of ten thousand). This risk level is similar to what would be expected from exposure to the concentrations of PAHs typically found in soils in U.S. urban environments due to the widespread presence of PAHs from centuries of human activity (e.g. burning of fuel such as

wood, coal and oil). However, MDPH does not believe children at the site are at increased risk for cancer because of the similarity in estimated risks to a general urban environment and the fact that exposures were likely overestimated (e.g. it is likely that grassy lawns will minimize direct contact).

- Soil data used for the evaluation of PAHs in soil at the 33 Water Street property were limited by the small number of sample points representing the site area, an outlier sample not consistent with other sample points, and soil depths greater than typically used in public health evaluations to characterize exposure to surface soil where frequent contact is more likely rather than deeper less accessible soils. A more thorough characterization of PAH concentrations in surface soil is warranted to further evaluate whether the concentrations of PAHs in site soil are similar to the concentrations typically found in urban environments.
- Sample SS-18A has been identified as an outlier sample with higher concentrations of PAHs. While it does not seem likely that this sample is representative of other areas of the site, the sample SS-18A is located in a grassy area in the front of building C where foot traffic is possible by those entering the building near that location. Although the grass would reduce the potential for soil/dust to be carried in on shoes, it may be prudent to wipe shoes on a floor mat as a precautionary measure.
- Dioxins and hexavalent chromium were indicated as potential site contaminants of concern; however, levels of these contaminants detected in soil samples collected in April and October of 2011 near Buildings A, B, and C were below health-based screening values and did not warrant further health evaluation.
- Lead was detected in soil samples at the site below the MassDEP S-1 soil standard of 200 mg/kg and below background levels for lead in soil. Current state of the science indicates that there is no safe level of lead exposure for young children. As with all known sources of lead, steps should be taken to minimize exposure to lead for children as much as possible as outlined in the following recommendations to reduce exposure to contaminated soils.

RECOMMENDATIONS

- MDPH recommends that US EPA conduct additional soil sampling at shallower depths (0-3 inches) and in more representative locations (including the garden area located along the tree line behind building A and in front of Building C in the vicinity of sample SS-18A), during future investigations, to better characterize the levels of PAHs and arsenic in surface soils across the 33 Water Street property. The resulting data will allow MDPH to more thoroughly evaluate potential health risks from exposure to contaminants in the property's surface soils.
- MDPH recommends that residents, particularly children, of the Crane River East Condominium Complex, take steps to reduce their potential exposure to contaminants in soils at the complex until further sampling is conducted. These steps include:
    - Avoiding direct contact with bare soil, especially in front of Building C (where higher levels of PAHs were found);
    - Minimizing tracking soil into the house (e.g. wiping shoes on a door mat before entering the house);
    - Washing hands before eating and after playing outside; and
    - Avoiding digging or playing in areas with bare soil.
- MDPH recommends periodic inspection of the restricted, potentially-contaminated areas between the 33 Water Street property and the Crane River, including the Massachusetts Bay Transportation Authority Right of Way (MBTA ROW), to ensure that warning signs are posted and clearly visible.

PUBLIC HEALTH ACTION PLAN

This Health Consultation evaluates available soil data for a residential area of the Site where direct contact with contaminated soil is possible for residents of the Crane River East Condominium Complex. Investigations to establish the full nature and extent of contamination at the Creese and Cook Tannery site are underway, i.e. US EPA Remedial Investigation/Feasibility Study (RI/FS) (US EPA 2014b). The upcoming US EPA investigation (RI/FS) includes additional soil sample locations for the Creese and Cook Tannery Site east of the Crane River at 33 Water Street, 20 Cheever Street and along the

MBTA ROW (US EPA 2014a). Additionally, the sampling plan also includes other properties in the area of the site east of the Crane River, i.e. an MBTA property between 33 Water Street and 45 Water Street, 45 Water Street (Glen Condos), 15 Pleasant Street and 12 Cheever Street (the Polish Club or PRLACC) (US EPA 2014a). It is anticipated that soil sampling will also be planned for the 55 Clinton Avenue property, the area of the site to the west of the Crane River, in a later phase of the US EPA site investigation. MDPH will work with federal, state and local health agencies to determine how public health concerns can be most effectively addressed, as new data are generated during the upcoming US EPA site investigations.

REPORT PREPARATION

This health consultation for the 33 Water Street at the former Creese and Cook Tannery site was prepared by the Massachusetts Department of Public Health, Bureau of Environmental Health (MDPH/BEH), under a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with the approved agency methods, policies, and procedures existing at the date of publication. Editorial review was completed by the cooperative agreement partner. ATSDR has reviewed this document and concurs with its findings based on the information presented. ATSDR's approval of this document has been captured in an electronic database, and the approving agency reviewers are listed below.

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TABLES

Table 1: Data Screening Table for Soil Samples at 33 Water Street

CONSTITUENT	FREQUENCY OF DETECTION	MAXIMUM DETECTED CONCENTRATION	SAMPLE WITH MAXIMUM CONCENTRATION	NUMBER OF SAMPLES ABOVE COMPARISON VALUES	APPROPRIATE COMPARISON VALUES	
					VALUE	SOURCE
PAHs (ppm)						
Benzo(a)anthracene	11 / 11	30	SS-18A	10	0.15	EPA RSL (Carcinogenic SL)
				0	0.169-59	Background for Urban Areas (ATSDR 1995)
				4	2	Background for Natural Soil (MassDEP 2002)
Benzo(b)fluoranthene	11 / 11	37	SS-18A	10	0.15	EPA RSL (Carcinogenic SL)
				0	15-62	Background for Urban Areas (ATSDR 1995)
				5	2	Background for Natural Soil (MassDEP 2002)
Benzo(k)fluoranthene	11 / 11	14	SS-18A	5	1.5	EPA RSL (Carcinogenic SL)
				0	0.3-26	Background for Urban Areas (ATSDR 1995)
				6	1	Background for Natural Soil (MassDEP 2002)
Benzo(a)pyrene	11 / 11	18	SS-18A	10	0.096	ATSDR CREG
				8	0.165-0.22	Background for Urban Areas (ATSDR 1995)
				5	2	Background for Natural Soil (MassDEP 2002)
Chrysene	11 / 11	34	SS-18A	1	15	EPA RSL (Carcinogenic SL)
				7	0.251-0.64	Background for Urban Areas (ATSDR 1995)
				5	2	Background for Natural Soil (MassDEP 2002)
Dibenzo(a,h)anthracene	8 / 11	3.7	SS-18A	8	0.015	EPA RSL (Carcinogenic SL)
				3	0.5	Background for Natural Soil (MassDEP 2002)
Indeno(1,2,3-cd)pyrene	10 / 11	13	SS-18A	7	0.15	EPA RSL (Carcinogenic SL)
				0	8-61	Background for Urban Areas (ATSDR 1995)
				1	3	Background for Natural Soil (MassDEP 2002)
Phenanthrene	11 / 11	59	SS-18A	1	10	MassDEP S-1/GW-1
				3	3	Background for Natural Soil (MassDEP 2002)

Table 1 (CONT): Data Screening Table for Soil Samples at 33 Water Street

CONSTITUENT	FREQUENCY OF DETECTION	MAXIMUM DETECTED CONCENTRATION	SAMPLE WITH MAXIMUM CONCENTRATION	NUMBER OF SAMPLES ABOVE COMPARISON VALUES	APPROPRIATE COMPARISON VALUES	
					VALUE	SOURCE
PCBs (ppm)						
Aroclor-1248	2 / 11	0.39 J	SS-20A	1	0.35	ATSDR CREG[6]
Metals (ppm)[1]						
Arsenic[4]	23 / 51	42	SS-08	11	15	ATSDR Chronic EMEG (child)[3]
				0	0.1-73	USGS Background (Shacklette and Boerngen 1984)
				4	20	Background for Natural Soil (MassDEP 2002)
Chromium (Total)	48 / 52	2040	SS-23	0	75,000	ATSDR RMEG (child)[5]
Hexavalent Chromium[4]	10 / 26	6.6	SS-40	0	45	ATSDR Chronic EMEG (child)
Lead	11 / 11	189J	SS-02A	0	200	MassDEP S-1
				0	<10-300	USGS Background (Shacklette and Boerngen 1984)
Dioxin (ppt)						
Total of TEQ [2]	11 / 11	45.1 J	SS-20A	0	50	ATSDR Chronic EMEG (Child)

Data from soil samples collected in April and October of 2011 for the 33 Water Street Property, Danvers MA (areas near Buildings A, B and C). Eleven soil samples (0 to </= 2ft bgs) collected in April of 2011: SS-02A, SS-04A, SS-06A, SS-08A, SS-09A/SS-33A, SS-11A, SS-18A, SS-19A, SS-20A, SS-21A, and SS-22A; and forty one soil samples (0 to 1ft bgs analyzed using XRF) collected in October of 2011: SS-01 through SS-04, SS-05/SS-60, SS-06 through SS-09, SS-16, SS-17, SS-18/SS-63, SS-19 through SS-24, SS-25/SS-61, SS-26 through SS-42 and SS-45 through SS-49. (Weston Solutions, Inc. 2011 and 2012)

1) Calcium, iron, magensium, potassium and sodim were detected however these metals were not included in the table as they are considered nutrients.

2) The Chronic EMEG for a child is presented for 2,3,7,8- Tetrachlorodibenzo-p-dioxin.

3) ATSDR considers the CREG value of 0.47 mg/kg below background levels for arsenic in soil and therefore the ATSDR chronic EMEG for a child of 15 mg/kg is used for data screening purposes.

4) Of the total soil samples for this analyte, one sample was eliminated due to analyte also detected in the associated equipment blank.

5) The ATSDR RMEG (child) for Trivalent Chromium was used for screening of total chromium, additional analysis for hexavalent chromium was done in a subset of samples.

6) ATSDR CREG value for PCBs is based on toxicity of Aroclors 1260, 1254, 1242, and 1016.

J= Value is estimated

TABLE 2: Non-Cancer Exposure Dose Summary - Soil Ingestion

Contaminant	Exposure Scenario/ Description of Data	Mean[1] Soil Concentration (mg/kg)	Exposure Category	Child Exposure Dose (mg/kg/d)	Adult Exposure Dose (mg/kg/d)	Health Guideline (mg/kg/d)
ARSENIC	Residential/Recreational Use of All Site Areas - All Soil Data	14.8	High Exposures (RME)	0.0002	0.00001	ATSDR Chr Oral MRL 0.0003
			Average Exposures (CTE)	0.00009	0.000006	
			Pica Exposure (acute)	0.002 - 0.003		ATSDR Acute Oral MRL 0.005
ARSENIC	Residential Use of Areas Likely Used for Recreational Purposes - Subset of Soil Data	13.8	High Exposures (RME)	0.0002	0.00001	ATSDR Chr Oral MRL 0.0003
			Average Exposures (CTE)	0.00008	0.000006	
			Pica Exposure (acute)	0.002 - 0.003		ATSDR Acute Oral MRL 0.005

Exposure Assumptions[2,3]

Adult:

For adults, it was assumed that an adult (80 kg) ingested 100 milligrams (RME) or 50 milligrams (CTE) of soil per day for 245 days per year (April through November).

Child (most sensitive child receptor):

It was assumed that a young child, 1 to < 2 years, (11.4 kg) ingested 200 milligrams (RME) or 100 milligrams (CTE) of soil per day for 245 days per year (April through November).

Child-Pica:

It was assumed that young children, 1 to < 2 and 2 to < 6 years (11.4 and 17.4 kg) exhibiting pica behaviors ingested 5000 milligrams of soil per day for 3 days per week for 2 weeks (acute)

CTE - Central Tendency Exposure

RME - Reasonable Maximum Exposure

1. 95% UCL of the arithmetic mean was calculated using PRO-UCL software
2. U.S. Environmental Protection Agency (US EPA). 2008. Child-Specific Exposure Factors Handbook (Final Report). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-06/096F.
3. U.S. Environmental Protection Agency (US EPA). 2011. Exposure factors handbook: 2011 edition. National Center for Environmental Assessment, Washington, DC; EPA/600/R-09/052F.

TABLE 3: Cancer Risk Summary - Soil Ingestion

Contaminant	Exposure Scenario/ Description of Data	Mean[1] Soil Concentration (mg/kg)	US EPA Oral Cancer Slope Factor $(mg/kg/d)^{-1}$	Exposure Category	Child Cancer Risk	Adult Cancer Risk
ARSENIC	Residential/Recreational Use of All Site Areas - All Data	14.8	1.5	High Exposures (RME)	2.5E-05	7.9E-06
				Average Exposures (CTE)	1.3E-05	3.9E-06
ARSENIC	Residential Use of Areas Likely Used for Recreational Purposes - Subset of Soil Data	13.8	1.5	High Exposures (RME)	2.3E-05	7.3E-06
				Average Exposures (CTE)	1.2E-05	3.7E-06
Total PAHs[2,3]	Residential/Recreational Use of All Site Areas - All Soil Data	14.6606	7.3	High Exposures (RME)	4.9E-04	3.8E-05
				Average Exposures (CTE)	2.5E-04	1.9E-05
Total PAHs[2,3]	Subset of sample area - excludes sample outlier SS-18A	3.9267	7.3	High Exposures (RME)	1.3E-04	1.0E-05
				Average Exposures (CTE)	6.7E-05	5.1E-06

CTE - Central Tendancy Exposure

RME - Reasonable Maximum Exposure

* Due to so few detections of this analyte, the maximum value detected was used instead of calculating the 95% UCL of the mean.

1. 95% UCL of the arithmetic mean was calculated using PRO-UCL software

2. This is considered to be a contaminant with a mutagenic mode of action, therefore cancer risk was calculated using an age dependent adjustment factor (ADAF)

3. The concentration for total PAHs is expressed as the benzo(a)pyrene equivalent dose. This concentration was calculated from the detected concentrations of benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene* and indeno(1,2,3-cd)pyrene.

TABLE 4: Comparison of Supplemental Soil Data for 33 Water Street

Analyte	Arsenic[1]		Benzo(a)anthracene		Benzo(a)pyrene		Benzo(b)fluoranthene	
Sample Date	April/Oct 2011	June 2014	April 2011	June 2014	April 2011	June 2014	April 2011	June 2014
Sample Depths (feet)	0-1	0-0.5	0-1	0-0.5	0-1	0-0.5	0-1	0-0.5
No. of Samples	51	11	11	11	11	11	11	11
No. of Detects	23	11	11	11	11	11	11	11
Minimum Concentration (ppm)	ND	9.4	0.049	0.37	0.055	0.27	0.065	0.42
Maximum Concentration (ppm)	42.0	29.1	30	1.7	18	1.5	37	2.5
2^{nd} Maximum[2] Concentration (ppm)	26.0	17.8	5.8		3.4		5	
Mean[3] (ppm)	17.5	14.8	4.24	0.806	2.89	0.738	5.03	1.195

TABLE 4 (continued): Comparison of Supplemental Soil Data for 33 Water Street

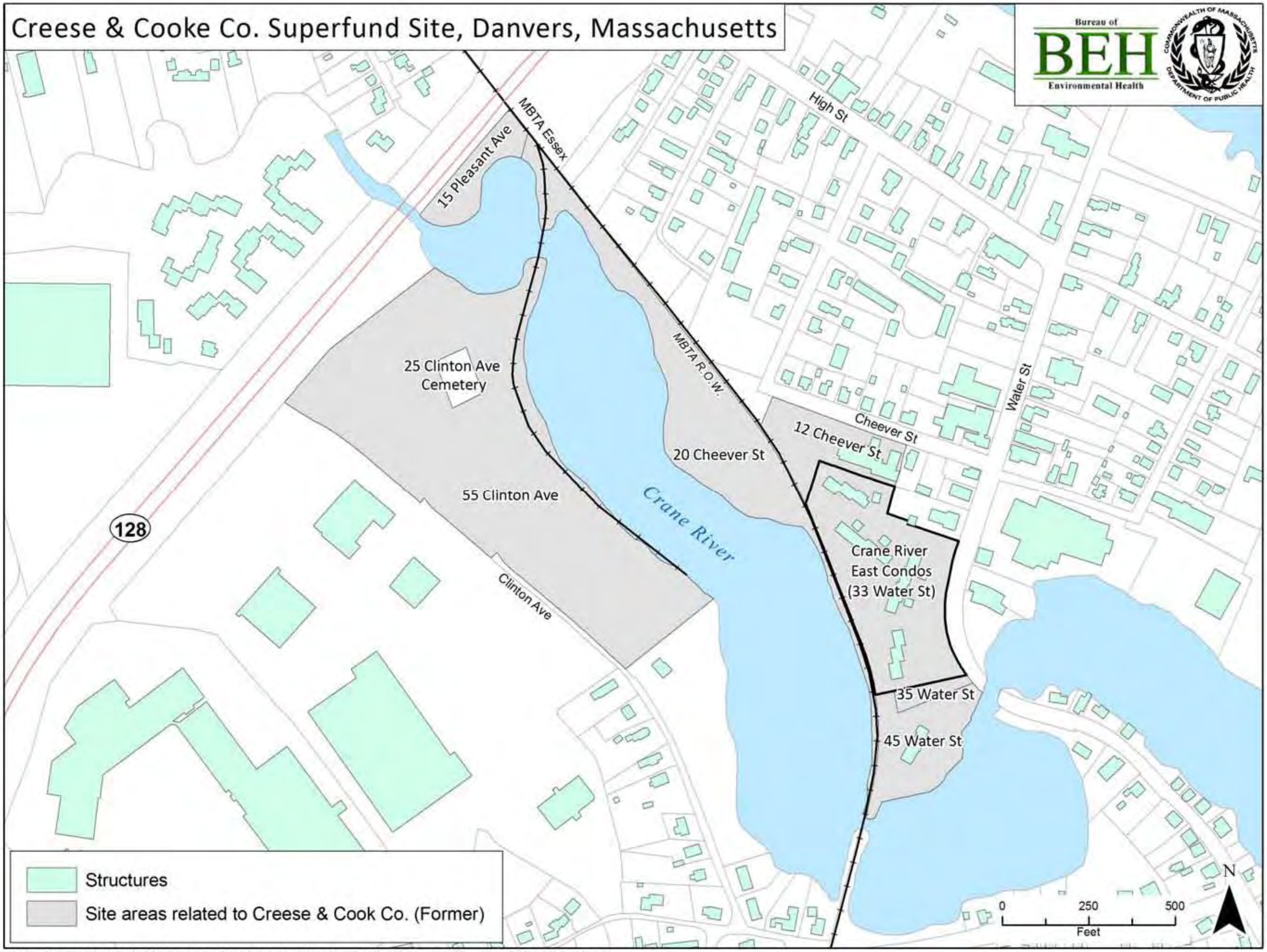
Analyte	Benzo(k)fluoroanthene		Chrysene		Dibenzo(a,h)anthracene		Indeno(1,2,3-cd)pyrene	
Sample Date	April 2011	June 2014	April 2011	June 2014	April 2011	June 2014	April 2011	June 2014
Sample Depths (feet)	0-1	0-0.5	0-1	0-0.5	0-1	0-0.5	0-1	0-0.5
No. of Samples	11	11	11	11	11	11	11	11
No. of Detects	11	11	11	11	8	11	10	11
Minimum Concentration (ppm)	0.046	0.26	0.076	0.39	0.45	0.055	0.11	0.14
Maximum Concentration (ppm)	14	1.3	34	2.2	3.7	0.27	13	0.88
2nd Maximum[2] Concentration (ppm)	5.1		5		1.0		2.6	
Mean[3] (ppm)	2.64	0.445	4.68	0.92	0.83	0.127	2.24	0.453

Data from soil samples collected in April/October of 2011 and June 2014 for the 33 Water Street Property, Danvers MA (Weston Solutions, Inc. 2011 and 2012; US EPA 2014c).
ppm =parts per million

1. Results for June 2014 samples are from lab analysis and not field screening; XRF data is also available. Results from 2011 are a mixture of lab analysis and field XRF.
2. Second maximum values are provided for data collected in 2011 because of outlier sample results.
3. Mean values for PAHs collected in April 2011 are calculated using an outlier sample.

FIGURES

Figure 1: Site Areas for the former Creese and Cook Tannery Site in Danvers, MA



Map created by BEH-GIS, MDPH. Geographic Data Courtesy of Office of Geographic Information (MassGIS), MA, ITD

Figure 2: **Soil Sample Locations for 33 Water Street at the former Creese and Cook Tannery Site in Danvers, MA**

APPENDIX A

Sample Exposure Calculations

SAMPLE EXPOSURE CALCULATIONS

(1) Residential Non-Cancer Exposure Estimate Equation for Soil Ingestion =

$$D = \frac{(C)(IR)(EF^*)(CF)}{(BW)}$$

Where:
D = Exposure Dose, mg/kg-day
C = Contaminant Concentration, mg/kg
IR = Intake Rate of Contaminated Soil, mg/day
CF = Conversion Factor, 10^{-6} kg/mg
BW = Body Weight, kg
EF = Exposure Factor* (unit less)

*Non-cancer Health Effects Exposure Factor (EF) = (F x ED) / AT where, F = Frequency of Exposure (days/year); ED = Exposure Duration (years); AT = Averaging Time (ED x 365 days/year)

Sample calculation for Arsenic (Adult 21 <65 yrs CTE): $\frac{(14.8\ mg/kg)(50\ mg/d)(.67^*)(10^{-6}\ kg/mg)}{(80\ kg)} =$ **6.2×10^{-6} mg/kg-d**

$^*EF = \frac{(245\ d/y)(33\ y)}{12045\ d} = .67$

Sample calculation for Arsenic (Adult 21 <65 yrs RME): $\frac{(14.8\ mg/kg)(100\ mg/d)(.67^*)(10^{-6}\ kg/mg)}{(80\ kg)} =$ **1.2×10^{-5} mg/kg-d**

$^*EF = \frac{(245\ d/y)(33\ y)}{12045\ d} = .67$

Children ages 1-<2 years are the most highly exposed group with CTE or RME rates of soil ingestion. Calculations were first done for children ages 1-2 years, and then calculations were done for other age groups only if this highly exposed group exceeded the health guideline. Calculations were also done for children ages 1 to <6 years with acute soil-pica behaviors.

Sample calculation for Arsenic (Child, 1 to < 2 yrs CTE): $\frac{(14.8\ mg/kg)(100\ mg/d)(.67^*)(10^{-6}\ kg/mg)}{(11.4\ kg)} =$ **8.7×10^{-5} mg/kg-d**

$^*EF = \frac{(245\ d/y)(1y)}{365\ d} = .67$

Sample calculation for Arsenic (Child, 1 to <2 yrs RME): $\frac{(14.8\ mg/L)(200\ mg/d)(.67^*)(10^{-6}\ kg/mg)}{(11.4\ kg)} =$ **1.7×10^{-4} mg/kg-d**

$^*EF = \frac{(245\ d/y)(1\ y)}{365\ d} = .67$

Sample calculation for Arsenic (soil-pica child, 1 to< 2yrs): $\frac{(14.8\ mg/kg)(5000\ mg/d)(.43^*)(10^{-6}kg/mg)}{(11.4\ kg)} =$ **2.8×10^{-3} mg/kg-d**

$^*EF = \frac{(3\ d/w)(2w)}{14\ d} = .43$

Sample calculation for Arsenic (soil-pica child, 2 to< 6 yrs): $\frac{(14.8\ mg/kg)(5000mg/d)(.43^*)(10^{-6}kg/mg)}{(17.4\ kg)} =$ **1.8×10^{-3} mg/kg-d**

$^*EF = \frac{(3\ d/w)(2w)}{14\ d} = .43$

(2) Residential Cancer Exposure Estimate Equation for Soil Ingestion =

$$D = \frac{(C)(IR)(EF^{**})(CF)}{(BW)}$$

Where:
D = Exposure Dose, mg/kg-day
C = Contaminant Concentration, mg/kg
IR = Intake Rate of Contaminated Soil, mg/day
CF = Conversion Factor, 10^{-6} kg/mg
BW = Body Weight, kg
EF = Exposure Factor** (unit less)

**Cancer Health Effects Exposure Factor (EF) = (F x ED) / AT where, F = Frequency of Exposure (days/year); ED = Exposure Duration (years); AT = Averaging Time (78 x 365 days/year)

Exposure estimates for cancer effects were multiplied by U.S. EPA cancer slope factors to evaluate the potential (or theoretical) cancer risk (cancer slope factor for arsenic is 1.5 $(mg/kg\text{-}d)^{-1}$).

Sample calculation for Arsenic (Adult 21 <65 yrs CTE): $\frac{(14.8\ mg/kg)(50\ mg/d)(0.28^{**})(10^{-6}\ kg/mg)}{(80\ kg)} = 2.6 \times 10^{-6}$ mg/kg-d

$^{**}EF = \frac{(245\ d/y)(33\ y)}{28470\ d} = 0.28$

Estimated Cancer Risk (Adult 21 years and older) = (2.6×10^{-6} mg/kg-d)(1.5 $(mg/kg\text{-}d)^{-1}$) = **3.9×10^{-6}**

Sample calculation for Arsenic (Adult 21 <65 yrs RME): $\frac{(14.8\ mg/L)(100\ mg/d)(0.28^{**})(10^{-6}\ kg/mg)}{(80\ kg)} = 5.3 \times 10^{-6}$ mg/kg-d

$^{**}EF = \frac{(245\ d/y)(33\ y)}{28470\ d} = 0.28$

Estimated Cancer Risk (Adult 21 years and older) = (5.3×10^{-6} mg/kg-d)(1.5 $(mg/kg\text{-}d)^{-1}$) = **7.9×10^{-6}**

Sample calculation for Arsenic (child CTE):

0.5 to <1yr: $\frac{(14.8\ mg/kg)(60\ mg/d)(0.0043^{**})(10^{-6}\ kg/mg)}{(9.2\ kg)} = 4.2 \times 10^{-7}$ mg/kg-d

$^{**}EF = \frac{(245\ d/y)(0.5\ y)}{28470\ d} = 0.0043$

Estimated Cancer Risk (0.5 to <1yr) = (4.2×10^{-7} mg/kg-d)(1.5 $(mg/kg\text{-}d)^{-1}$) = 6.2×10^{-7}

1 to < 2 yr: $\frac{(14.8\ mg/kg)(100\ mg/d)(0.0086^{**})(10^{-6}\ kg/mg)}{(11.4\ kg)} = 1.1 \times 10^{-6}$ mg/kg-d

$^{**}EF = \frac{(245\ d/y)(1\ y)}{28470\ d} = 0.0086$

Estimated Cancer Risk (1 to <2 yrs) = (1.1×10^{-6} mg/kg-d)(1.5 $(mg/kg\text{-}d)^{-1}$) = 1.7×10^{-6}

2 to <6 yr: $\frac{(14.8\ mg/L)(100\ mg/d)(0.034^{**})(10^{-6}\ kg/mg)}{(17.4\ kg)} = 2.9 \times 10^{-6}$ mg/kg-d

$^{**}EF = \frac{(245\ d/y)(4\ y)}{28470\ d} = 0.034$

Estimated Cancer Risk (2 to <6 yrs) = $(2.9 \times 10^{-6}$ mg/kg-d$)(1.5\ (mg/kg\text{-}d)^{-1}) = 4.4 \times 10^{-6}$

6 to <11yr: $\frac{(14.8\ mg/kg)(100\ mg/d)(0.043^{**})(10^{-6}\ kg/mg)}{(31.8\ kg)} = 2.0 \times 10^{-6}$ mg/kg-d

$^{**}EF = \frac{(245\ d/y)(5\ y)}{28470\ d} = 0.043$

Estimated Cancer Risk (6 to < 11 yrs) = $(2.0 \times 10^{-6}$ mg/kg-d$)(1.5\ (mg/kg\text{-}d)^{-1}) = 3.0 \times 10^{-6}$

11 to <21yr: $\frac{(14.8\ mg/kg)(100\ mg/d)(0.086^{**})(10^{-6}\ kg/mg)}{(64.2\ kg)} = 2.0 \times 10^{-6}$ mg/kg-d

$^{**}EF = \frac{(245\ d/y)(10\ y)}{28470\ d} = 0.086$

Estimated Cancer Risk (11 to < 21 yrs) = $(2.0 \times 10^{-6}$ mg/kg-d $)(1.5\ (mg/kg\text{-}d)^{-1}) = 3.0 \times 10^{-6}$

Total Estimated Cancer Risk for a child (0.5 to <21 years, CTE) = 1.3 x10^{-5}

Sample calculation for Arsenic (child RME):

0.5 to <1yr: $\frac{(14.8\ mg/kg)(100\ mg/d)(0.0043^{**})(10^{-6}\ kg/mg)}{(9.2\ kg)} = 6.9 \times 10^{-7}$ mg/kg-d

$^{**}EF = \frac{(245\ d/y)(.5\ y)}{28470\ d} = 0.0043$

Estimated Cancer Risk (0.5 to <1yr) = $(6.9 \times 10^{-7}$ mg/kg-d$)(1.5\ (mg/kg\text{-}d)^{-1}) = 1.0 \times 10^{-6}$

1 to < 2 yr: $\frac{(14.8\ mg/kg)(200\ mg/d)(0.0086^{**})(10^{-6}\ kg/mg)}{(11.4\ kg)} = 2.2 \times 10^{-6}$ mg/kg-d

$^{**}EF = \frac{(245\ d/y)(1\ y)}{28470\ d} = 0.0086$

Estimated Cancer Risk (1 to <2 yrs) = $(2.2 \times 10^{-6}$ mg/kg-d$)(1.5\ (mg/kg\text{-}d)^{-1}) = 3.4 \times 10^{-6}$

2 to <6 yr: $\frac{(14.8\ mg/kg)(200\ mg/d)(0.034^{**})(10^{-6}\ kg/mg)}{(17.4\ kg)} = 5.9 \times 10^{-6}$ mg/kg-d

$^{**}EF = \frac{(245\ d/y)(4\ y)}{28470\ d} = 0.034$

Estimated Cancer Risk (2 to <6 yrs) = $(5.9 \times 10^{-6}$ mg/kg-d$)(1.5\ (mg/kg\text{-}d)^{-1}) = 8.8 \times 10^{-6}$

6 to <11yr: $\frac{(14.8\ mg/kg)(200\ mg/d)(0.043^{**})(10^{-6}\ kg/mg)}{(31.8\ kg)} = 4.0 \times 10^{-6}$ mg/kg-d

$$**EF = \frac{(245\ d/y)(5\ y)}{28470\ d} = 0.043$$

Estimated Cancer Risk (6 to < 11 yrs) = $(4.0 \times 10^{-6}$ mg/kg-d$)(1.5\ (mg/kg\text{-}d)^{-1}) = 6.0 \times 10^{-6}$

11 to <21yr: $\frac{(14.8\ mg/kg)(200\ mg/d)(0.086^{**})(10^{-6}\ kg/mg)}{(64.2\ kg)} = 4.0 \times 10^{-6}$ mg/kg-d

$$**EF = \frac{(245\ d/y)(10\ y)}{28470\ d} = 0.086$$

Estimated Cancer Risk (11 to < 21 yrs) = $(4.0 \times 10^{-6}$ mg/kg-d $)(1.5\ (mg/kg\text{-}d)^{-1}) = 6.0 \times 10^{-6}$

Total Estimated Cancer Risk for a child (0.5 to <21 years, RME) = 2.5 x10^{-5}

(3) Residential Cancer Exposure Estimate Equation for Ingestion of PAHs in Soil =

$$\frac{\text{(Total BaP Equivalent Concentration, mg/kg)(Ingestion Rate, mg/d)(EF**)(Conversion Factor, } 10^{-6}\text{ kg/mg)}}{\text{(Body Weight, kg)}}$$

BaP equivalent concentrations were calculated for each PAH detected in soil by multiplying the concentration of the PAH detected by a potency factor based on the individual PAH's potency when compared to BaP. These BaP equivalent concentrations were then added together for a total BaP Equivalent Concentration used for dose calculations, as shown in the following table.

PAH Detected	Mean[1] Soil Concentration (mg/kg)	EPA Potency Factor[3]	B(a)P Equivalent Concentration
Benzo(a)anthracene	13.6	0.1	1.36
Benzo(b)fluoranthene	16.2	0.1	1.62
Benzo(k)fluoranthene	6.6	0.01	0.066
Benzo(a)pyrene	7.2	1.0	7.2
Chrysene	14.8	0.001	0.0148
Dibenzo(a,h)anthracene[2]	3.7	1.0	3.7
Indeno(1,2,3-cd)pyrene	7	0.1	0.7
		Total B(a)P Equivalent Concentration:	14.6608

1. Calculated using the 95% UCL of the arithmatic mean (using PRO-UCL software), inlcuding all soil samples.
2. Too few detections (n=8) so max value was used instead of calculation PRO-UCL mean (SS-18A).
3. U.S. Environmental Protection Agency (US EPA). 1993. Provisional Guidance for Quantitative Risk Assessment of Polycyclic Aromatic Hydrocarbons. EAP/600/R-93/089

**Cancer Health Effects Exposure Factor (EF) = (F x ED) / AT where, F = Frequency of Exposure (days/year); ED = Exposure Duration (years); AT = Averaging Time (78 x 365 days/year)

Exposure estimates for cancer effects were multiplied by U.S. EPA cancer slope factors to evaluate the potential (or theoretical) cancer risk (cancer slope factor for B(a)P is 7.3 $(mg/kg\text{-}d)^{-1}$). For carcinogens with a mutagenic mode of action (MOA), such as B(a)P, the cancer risk was multiplied by a age-dependent adjustment factor (ADAF) to account for differences in susceptibility between children and adults (i.e. multiply by 10 for ages 0 to <2 yrs., multiply by 3 for ages 2 to <16 yrs., and multiply by 1 for ages ≥ 16 yrs.).

Sample calculation for Total PAHs (Adult 21<65 yrs CTE):

$$\frac{(14.6608\text{mg/kg})(50\text{mg/d})(0.2840^{**})(10^{-6}\text{kg/mg})}{(80\text{ kg})} = 2.6 \times 10^{-6}\text{ mg/kg-d}$$

$$^{**}EF = \frac{(245\text{ d/y})(33\text{ y})}{28470\text{ d}} = 0.2840$$

Estimated Cancer Risk (Adult 21 years and older) = $(2.6 \times 10^{-6}$ mg/kg-d$)(7.3\ (mg/kg\text{-}d)^{-1})(1)$ = **1.9×10^{-5}**

Sample calculation for Total PAHs (Adult 21 <65 yrs RME):

$$\frac{(14.6608\text{ mg/L})(100\text{ mg/d})(0.2840^{**})(10^{-6}\text{ kg/mg})}{(80\text{ kg})} = 5.2 \times 10^{-6}\text{ mg/kg-d}$$

$$^{**}EF = \frac{(245\text{ d/y})(33\text{ y})}{28470\text{ d}} = 0.2840$$

Estimated Cancer Risk (Adult 21 years and older) = $(5.2 \times 10^{-6}$ mg/kg-d$)(7.3\ (mg/kg\text{-}d)^{-1})(1)$ = **3.8×10^{-5}**

Sample calculation for Total PAHs (child CTE):

0.5 to <1yr: $\frac{(14.6608\ mg/kg)(60\ mg/d)(0.0043^{**})(10^{-6}\ kg/mg)}{(9.2\ kg)} = 4.1 \times 10^{-7}$ mg/kg-d

$^{**}EF = \frac{(245\ d/y)(0.5\ y)}{28470\ d} = 0.0043$

Estimated Cancer Risk (0.5 to <1yr) = (4.1×10^{-7} mg/kg-d)(7.3 (mg/kg-d)$^{-1}$)(10) = 3.0×10^{-5}

1 to < 2 yr: $\frac{(14.6608\ mg/kg)(100\ mg/d)(0.0086^{**})(10^{-6}\ kg/mg)}{(11.4\ kg)} = 1.1 \times 10^{-6}$ mg/kg-d

$^{**}EF = \frac{(245\ d/y)(1\ y)}{28470\ d} = 0.0086$

Estimated Cancer Risk (1 to <2 yrs) = (1.1×10^{-6} mg/kg-d)(7.3 (mg/kg-d)$^{-1}$)(10) = 8.1×10^{-5}

2 to <6 yr: $\frac{(14.6608\ mg/L)(100\ mg/d)(0.0344^{**})(10^{-6}\ kg/mg)}{(17.4\ kg)} = 2.9 \times 10^{-6}$ mg/kg-d

$^{**}EF = \frac{(245\ d/y)(4\ y)}{28470\ d} = 0.0344$

Estimated Cancer Risk (2 to <6 yrs) = (2.9×10^{-6} mg/kg-d)(7.3 (mg/kg-d)$^{-1}$) (3) = 6.4×10^{-5}

6 to <11yr: $\frac{(14.6608\ mg/kg)(100\ mg/d)(0.0430^{**})(10^{-6}\ kg/mg)}{(31.8\ kg)} = 2.0 \times 10^{-6}$ mg/kg-d

$^{**}EF = \frac{(245\ d/y)(5\ y)}{28470\ d} = 0.0430$

Estimated Cancer Risk (6 to < 11 yrs) = (2.0×10^{-6} mg/kg-d)(7.3 (mg/kg-d)$^{-1}$)(3) = 4.3×10^{-5}

11 to <16 yr: $\frac{(14.6608\ mg/kg)(100\ mg/d)(0.0430^{**})(10^{-6}\ kg/mg)}{(56.8\ kg)} = 1.1 \times 10^{-6}$ mg/kg-d

$^{**}EF = \frac{(245\ d/y)(5\ y)}{28470\ d} = 0.0430$

Estimated Cancer Risk (11 to < 16 yrs) = (1.1×10^{-6} mg/kg-d)(7.3 (mg/kg-d)$^{-1}$))(3) = 2.4×10^{-5}

16 to <21 yr: $\frac{(14.6608\ mg/kg)(100\ mg/d)(0.0430^{**})(10^{-6}\ kg/mg)}{(71.6\ kg)} = 8.8 \times 10^{-7}$ mg/kg-d

$^{**}EF = \frac{(245\ d/y)(5\ y)}{28470\ d} = 0.0430$

Estimated Cancer Risk (16 to < 21 yrs) = (8.8×10^{-7} mg/kg-d)(7.3 (mg/kg-d)$^{-1}$)(1) = 6.4×10^{-6}

Total Estimated Cancer Risk for a child (0.5 to <21 years, CTE) = 2.5 x10^{-4}

Sample calculation for Total PAHs (child RME):

0.5 to <1yr: $\frac{(14.6608\ mg/kg)(100\ mg/d)(0.0043^{**})(10^{-6}\ kg/mg)}{(9.2\ kg)} = 6.9 \times 10^{-7}$ mg/kg-d

$^{**}EF = \frac{(245\ d/y)(.5\ y)}{28470\ d} = 0.0043$

Estimated Cancer Risk (0.5 to <1yr) = (6.9×10^{-7} mg/kg-d)(7.3 $(mg/kg\text{-}d)^{-1}$)(10) = 5.0 $x10^{-5}$

1 to < 2 yr: $\frac{(14.6608\ mg/kg)(200\ mg/d)(0.0086^{**})(10^{-6}\ kg/mg)}{(11.4\ kg)} = 2.2 \times 10^{-6}$ mg/kg-d

$^{**}EF = \frac{(245\ d/y)(1\ y)}{28470\ d} = 0.0086$

Estimated Cancer Risk (1 to <2 yrs) = (2.2×10^{-6} mg/kg-d)(7.3 $(mg/kg\text{-}d)^{-1}$)(10) = 1.6 $x10^{-4}$

2 to <6 yr: $\frac{(14.6608\ mg/kg)(200\ mg/d)(0.0344^{**})(10^{-6}\ kg/mg)}{(17.4\ kg)} = 5.8 \times 10^{-6}$ mg/kg-d

$^{**}EF = \frac{(245\ d/y)(4\ y)}{28470\ d} = 0.0344$

Estimated Cancer Risk (2 to <6 yrs) = (5.8×10^{-6} mg/kg-d)(7.3 $(mg/kg\text{-}d)^{-1}$)(3) = 1.3 $x10^{-4}$

6 to <11yr: $\frac{(14.6608\ mg/kg)(200\ mg/d)(0.0430^{**})(10^{-6}\ kg/mg)}{(31.8\ kg)} = 4.0 \times 10^{-6}$ mg/kg-d

$^{**}EF = \frac{(245\ d/y)(5\ y)}{28470\ d} = 0.0430$

Estimated Cancer Risk (6 to < 11 yrs) = (4.0×10^{-6} mg/kg-d)(7.3 $(mg/kg\text{-}d)^{-1}$)(3) = 8.7 $x10^{-5}$

11 to <16yr: $\frac{(14.6608\ mg/kg)(200\ mg/d)(0.0430^{**})(10^{-6}\ kg/mg)}{(56.8\ kg)} = 2.2 \times 10^{-6}$ mg/kg-d

$^{**}EF = \frac{(245\ d/y)(5\ y)}{28470\ d} = 0.0430$

Estimated Cancer Risk (11 to < 16 yrs) = (2.2×10^{-6} mg/kg-d)(7.3 $(mg/kg\text{-}d)^{-1}$) (3) = 4.9 $x10^{-5}$

16 to <21yr: $\frac{(14.6608\ mg/kg)(200\ mg/d)(0.0430^{**})(10^{-6}\ kg/mg)}{(71.6\ kg)} = 1.8 \times 10^{-6}$ mg/kg-d

$^{**}EF = \frac{(245\ d/y)(5\ y)}{28470\ d} = 0.0430$

Estimated Cancer Risk (16 to < 21 yrs) = (1.8×10^{-6} mg/kg-d)(7.3 $(mg/kg\text{-}d)^{-1}$)(1) = 1.3 $x10^{-5}$

Total Estimated Cancer Risk for a child (0.5 to <21 years, RME) = 4.9 $x10^{-4}$