Health Consultation

PUBLIC COMMENT VERSION

Assessment of Soil Exposures in Communities
Adjacent to the Walter Coke, Inc. Site
(a/k/a/ 35th Avenue Coke Site)
Birmingham, AL

EPA FACILITY ID: ALN000410750

FEBRUARY 12, 2013

COMMENT PERIOD ENDS: MARCH 29, 2013

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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HEALTH CONSULTATION

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Prepared By:

Agency for Toxic Substances and Disease Registry (ATSDR)
Division of Community Health Investigations
Central Branch, Headquarters

Forward

The Agency for Toxic Substances and Disease Registry, ATSDR, was established by Congress in 1980 under the Comprehensive Environmental Response, Compensation, and Liability Act, also known as the Superfund law. This law set up a fund to identify and clean up our country's hazardous waste sites. The Environmental Protection Agency, EPA, and the individual states regulate the investigation and clean-up of the sites.

Since 1986, ATSDR has been required by law to conduct a public health assessment at each of the sites on the EPA National Priorities List. The aim of these evaluations is to find out if people are being exposed to hazardous substances and, if so, whether that exposure is harmful and should be stopped or reduced. If appropriate, ATSDR also conducts public health assessments when petitioned by concerned individuals. Public health assessments are carried out by environmental and health scientists from ATSDR and from the states with which ATSDR has cooperative agreements. The public health assessment program allows the scientists flexibility in the format or structure of their response to the public health issues at hazardous waste sites. For example, a public health assessment could be one document or it could be a compilation of several health consultations - the structure may vary from site to site. Nevertheless, the public health assessment process is not considered complete until the public health issues at the site are addressed.

Exposure: As the first step in the evaluation, ATSDR scientists review environmental data to see how much contamination is at a site, where it is, and how people might come into contact with it. Generally, ATSDR does not collect its own environmental sampling data but reviews information provided by EPA, other government agencies, businesses, and the public. When there is not enough environmental information available, the report will indicate what further sampling data is needed.

Health Effects: If the review of the environmental data shows that people have or could come into contact with hazardous substances, ATSDR scientists evaluate whether or not these contacts may result in harmful effects. ATSDR recognizes that children, because of their play activities and their growing bodies, may be more vulnerable to these effects. As a policy, unless data are available to suggest otherwise, ATSDR considers children to be more sensitive and vulnerable to hazardous substances. Thus, the health impact to the children is considered first when evaluating the health threat to a community. The health impacts to other high risk groups within the community (such as the elderly, chronically ill, and people engaging in high risk practices) also receive special attention during the evaluation.

ATSDR uses existing scientific information, which can include the results of medical, toxicologic and epidemiologic studies and the data collected in disease registries, to determine the health effects that may result from exposures. The science of environmental health is still developing, and sometimes scientific information on the health effects of certain substances is not available. When this is so, the report will suggest what further public health actions are needed.

Conclusions: The report presents conclusions about the public health threat, if any, posed by a site. When health threats have been determined for high risk groups (such as children, elderly, chronically ill, and people engaging in high risk practices), they will be summarized in the conclusion section of the report. Ways to stop or reduce exposure will then be recommended in the public health action plan.

ATSDR is primarily an advisory agency, so usually these reports identify what actions are appropriate to be undertaken by EPA, other responsible parties, or the research or education divisions of ATSDR. However, if there is an urgent health threat, ATSDR can issue a public health advisory warning people of the danger. ATSDR can also authorize health education or pilot studies of health effects, full-scale epidemiology studies, disease registries, surveillance studies or research on specific hazardous substances.

Community: ATSDR also needs to learn what people in the area know about the site and what concerns they may have about its impact on their health. Consequently, throughout the evaluation process, ATSDR actively gathers information and comments from the people who live or work near a site, including residents of the area, civic leaders, health professionals and community groups. To ensure that the report responds to the community's health concerns, an early version is also distributed to the public for their comments. All the comments received from the public are responded to in the final version of the report.

Comments: If, after reading this report, you have questions or comments, we encourage you to send them to us.

Letters should be addressed as follows:

Agency for Toxic Substances and Disease Registry
ATTN: Records Center
1600 Clifton Road, NE (Mail Stop F-09)
Atlanta, GA 30333

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List of Abbreviations

ATSDR	Agency for Toxic Substances and Disease Registry
AVG	average
BaP	benzo(a)pyrene
BaP-TE	benzo(a)pyrene toxic equivalents
Bkgd	background
CREG	cancer risk evaluation guide
CV	comparison value
EMEG	environmental media evaluation guide
EPA	U.S. Environmental Protection Agency
mg/kg	milligram per kilogram
mg/kg/day	milligrams per kilogram per day
MRL	minimal risk level
PAH	polycyclic aromatic hydrocarbon
PHC	public health consultation
PHAP	Public Health Action Plan
ppm	parts per million
RfD	reference dose
RPF	relative potency factor
TEF	toxic equivalency factor
WCI	Walter Coke, Inc.

Summary

The Public Health Issues

The purpose of this public health consultation (PHC) is to determine if exposure to soils in Collegeville, Harriman Park, and Fairmont communities is a public health hazard for people who live or work in the area. The United States Environmental Protection Agency (EPA) Region IV requested that the Agency for Toxic Substances and Disease Registry (ATSDR) evaluate environmental data collected from three communities that surround the Walter Coke Inc. facility in North Birmingham, Jefferson County, Alabama. Residents in the three communities of Collegeville, Harriman Park, and Fairmont are concerned about contaminated soil in their neighborhood and the effect that exposure to contaminants in the soils may be having on their health.

Seventy-five properties within the nearby communities have been sampled for arsenic and polycyclic aromatic hydrocarbons. (A broad range of soil contaminants were measured and only arsenic and polycyclic aromatic hydrocarbons were detected above health screening values.) The polycyclic aromatic hydrocarbons (PAHs) were measured as benzo(a)pyrene toxic equivalents (BaP-TE). The BaP-TE concentration is the sum of 7 different PAHs with their concentrations adjusted for their toxicity relative to benzo(a)pyrene (BaP).

Walter Coke, Inc. has agreed to remediate properties with arsenic levels above 37 mg/kg and/or BaP-TE levels above 1.5 mg/kg. Sixteen residential properties and two schools have already been remediated. This public health consultation will evaluate whether those cleanup levels are protective of public health based on an evaluation of the soil contamination data from two sampling events (2005 and 2009) conducted for Walter Coke, Inc. and the pathways by which people may be exposed to those soils.

In addition to the soil data evaluated in this health consultation, ATSDR is currently evaluating air monitoring data from the surrounding communities. Residents living adjacent to the WCI site may have exposures to site-related contaminants from breathing the contaminants that are released to the air. The pending Public Health Consultation of air monitoring data will include an evaluation of those contaminants that may be present in both air and soil.

Conclusions

ATSDR has evaluated the past, present, and future exposures to residential soils in the communities adjacent to the WCI site. On the basis of the likely exposure pathways and the available environmental data, ATSDR concludes the following:

Arsenic Soil exposures to arsenic in sampled properties around the Walter Coke, Inc. site do not present a public health hazard with the possible exception of a child with pica behavior eating a large amount of soil from the property with the highest arsenic concentration. In this case, the pica child could develop short term health effects such as pain, nausea, vomiting, and diarrhea. Three of the sampled properties had average arsenic concentrations above the proposed cleanup value. Adverse health effects are not expected from arsenic soil exposures at properties with average arsenic concentrations below the proposed cleanup value.

BaP-TE Soil exposures to BaP-TE in sampled properties around the Walter Coke, Inc. site do not present a public health hazard. Fifteen properties have average BaP-TE values above the proposed cleanup value Adverse health effects are not expected from BaP-TE soil exposures at properties with average BaP-TE concentrations below the proposed cleanup value.

Recommendations

ATSDR makes the following recommendations:

1) Although the soil exposures do not present a public health hazard (with the possible exception of a pica child at the property with the highest arsenic concentration) it is prudent public health policy to remediate several of the sampled properties with the highest contaminant concentrations to decrease soil exposures (sixteen residential properties and two school yards have been or are proposed for remediation). Residents should follow practices such as washing hands and garden produce and wiping shoes to reduce exposures to soil.

2) ATSDR should complete the review of site-specific air data to assess community exposures to airborne contaminants released from the WCI site

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For More Information

If you have concerns about your health, you should contact your health care provider. For questions or comments related to this Public Health Consultation please call ATSDR at 1-800-CDC-INFO:

Statement of Issues

The United States Environmental Protection Agency (EPA) Region IV requested that the Agency for Toxic Substances and Disease Registry (ATSDR) evaluate environmental data collected from three communities that surround the Walter Coke Inc. facility in North Birmingham, Jefferson County, Alabama. Residents in the three communities of Collegeville, Harriman Park, and Fairmont are concerned about contaminated soil in their neighborhood and the effect that exposure to contaminants in the soils may be having on their health.

Walter Coke, Inc. collected soil samples from the three communities in 2005 and 2009 and analyzed those samples for arsenic and polycyclic aromatic hydrocarbons (PAHs; cited as CH2MHill, 2005 and 2011a). The 2005 soil samples were analyzed for a complete suite of contaminants (including volatile organic compounds, semi-volatile organic compounds, pesticides, dioxin/furans, metals, and others. Only arsenic and PAHs were detected in offsite soils at levels of potential health concern such that the 2009 soil sampling focused on those contaminants (CH2MHill, 2005). In this Health Consultation, ATSDR evaluates the potential for adverse health effects from exposures to arsenic and PAHs in the neighborhood soils. The polycyclic aromatic hydrocarbons were measured as benzo(a)pyrene toxic equivalents (BaP-TE). The BaP-TE concentration is the sum of 7 different PAH with their concentrations adjusted for their toxicity relative to BaP.[1] This consultation will also address whether proposed soil cleanup levels are protective of public health (CH2MHill, 2011b).

Community concerns about ingestion of soils and gardening are addressed in this consultation. Residents are also concerned about contaminants in the air in the neighborhoods. Residents living adjacent to the Walter Coke site may have exposures to site-related contaminants from breathing the contaminants that are released to the air from the site. Potential health effects from air exposures are being addressed in a separate Health Consultation.

Site Description and History

The Birmingham area has been heavily industrialized for decades. The area under investigation includes the Walter Coke facility (located at 3500 35th Avenue North in Birmingham, AL). The 400-acre Walter Coke facility has been in operation since 1919 and currently manufactures coke. Historic or ongoing activities at the facility include: manufacturing of coke, manufacturing of toluene sulfonyl acid, production of pig iron from iron ore, manufacturing of mineral fibers (mineral wool), and a biological treatment facility and sewers, designed to treat wastewater generated at the facility (CH2MHill, 2005). The facility has fencing around the perimeter and is located adjacent to the residential communities of Collegeville, Harriman Park, and Fairmont (Figure 1).

[1] Note that the referenced "toxic equivalents" or "toxic equivalency factors" are more specifically defined as "estimated order of potential potency" (EPA, 1993). The "toxic equivalent" terminology is retained in this consultation to retain consistency with other reports.

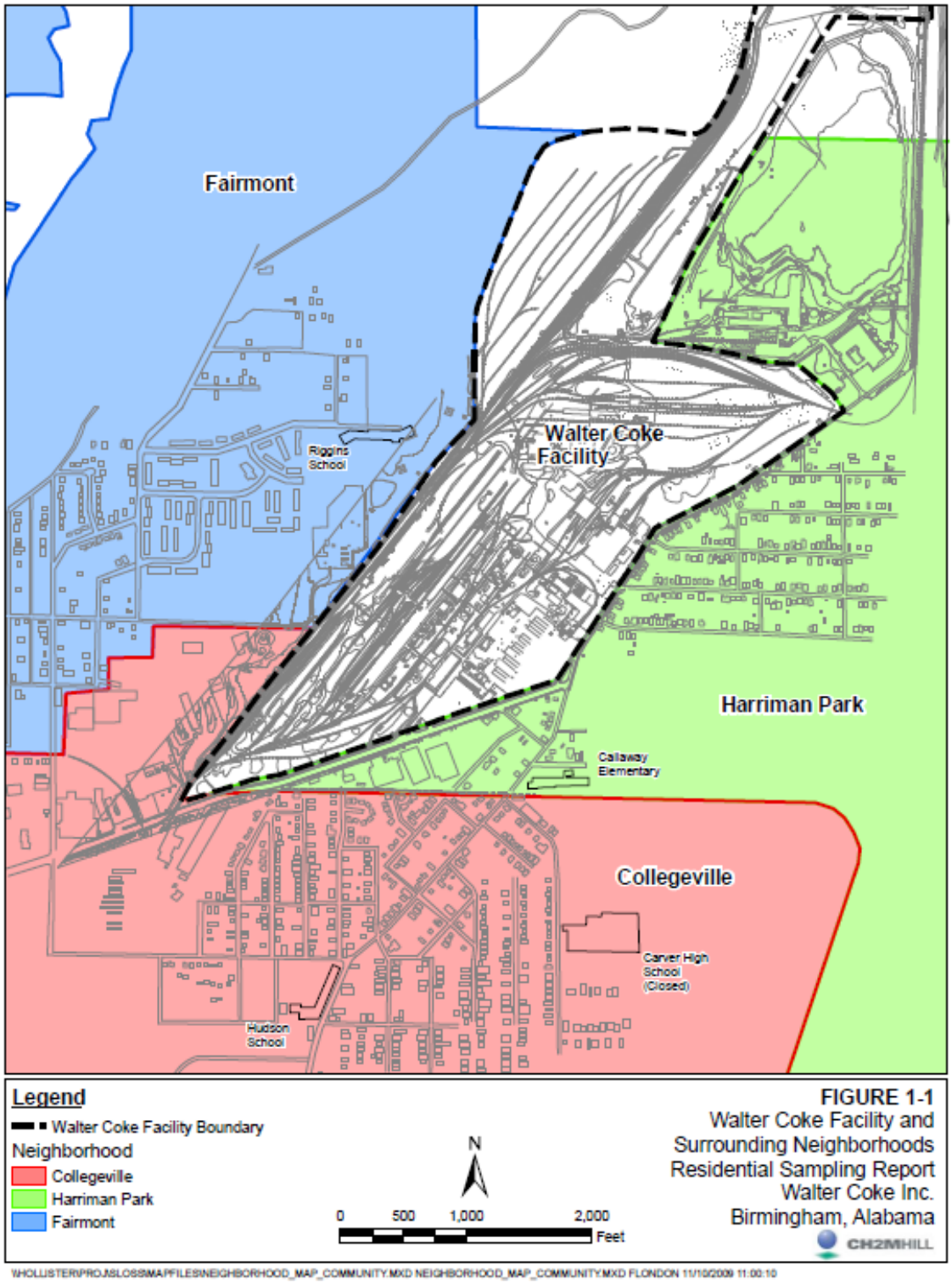

Figure 1. Neighborhood Locations (from CH2MHILL, 2011a)

Exposure Pathway Evaluation and Assessment Strategy

ATSDR assumes that there are completed exposure pathways to surface soil in residential yards and other properties. These exposures occur primarily as accidental ingestion of soil, but may also include ingestion of soil contaminants on or in home-grown produce, dermal contact with soil, and incidental ingestion of soil by children (pica behavior). Soil samples from two sampling activities (April 2005 and July 2009) were collected from residential yards, drip lines, gardens and playgrounds in the Collegeville, Harriman Park, and Fairmont communities.

Sampling Strategy – 2005. In April 2005, 35 soil samples were collected from 30 properties in the Collegeville, Harriman Park, and Fairmont communities (CH2MHill, 2005). All soil samples collected in 2005 were collected at a 0–2 inch depth.

Sampling Strategy – 2009. In 2009, EPA required Walter Coke, Inc. to collect soil samples from schools and residential areas in the neighborhoods. In addition, all properties from the 2005 sampling event were re-sampled in the July 2009 sampling study (CH2MHill, 2011a). Residences adjacent to the properties that exceeded the initial screening levels (EPA Risk Based Screening Levels) in 2005 were also sampled in 2009. One hundred and forty three soil samples were collected from 49 properties in the Collegeville community (Figure 1); 60 samples were collected from 23 properties in the Harriman Park community (Figure 1); and 32 samples were collected from six properties in the Fairmont community (Figure 1). Sample locations for additional properties were chosen by using a grid sampling approach. Sixteen additional properties were selected in grid squares that were not previously sampled at locations considered to be representative of potential exposure areas. In individual properties and roof drip lines, composite samples were collected at 0–6" (0—2" for the 2005 samples). In vegetable gardens and children's play areas, grab samples were collected at 0–12" depth.

The residential surface soil samples from both studies (CH2MHill, 2005; 2011a) were collected by removing the uppermost layer of sod or grass (if present) and scooping up the underlying soil or by direct scooping in bare soil areas. The available data do not indicate which samples were collected from bare soil or sodded areas. Although ATSDR assumes that there is some exposure to all of the residential soils, actual exposure to soil from sodded areas is likely to be much lower than bare soil areas. As the available data do not specify grass-covered from bare soil samples, ATSDR assumes that all samples represent bare soil.

Also, as most soil exposures are cumulative and most of the residential locations were subject to multiple sample events and locations, all of the sample results for evaluating chronic or long term doses are averaged for each property. However, exposures for pica children may occur as single events. Consequently, exposures for pica events are based on discrete or individual sample events and are not averaged across a property.

It should also be noted that this consultation does not identify the contaminant concentrations for specific properties. As this consultation evaluates potential health effects associated with specific contaminants, it is not appropriate for ATSDR to publicly identify properties (and property owners) by address or location. Further, as is standard procedure, property owners have previously been privately notified of the specific contaminant concentrations of their properties such that it is unnecessary for ATSDR to publicly repeat that information.

General Findings: Area-wide levels of Arsenic and PAHs

Arsenic

Arsenic is a naturally occurring element and was detected in 100% of the soil samples collected at average concentrations ranging from 13 – 41 mg/kg. Background concentrations of arsenic in the nearby Robbinwood area are typically less than 6.2 mg/kg (EPA/SESD, 2010). Twenty-five properties have average arsenic concentrations above the listed comparison value (20 mg/kg; Table 1). Walter Coke, Inc. has agreed to remediate properties with arsenic concentrations above 37 mg/kg (CH2MHill, 2011b). Three of the averaged property arsenic concentrations exceed the proposed cleanup value (Table 1).

Table 2 lists the child and adult doses associated with the measured minimum, maximum, and cleanup concentrations (property average). Note that the possible excess lifetime cancer risk[2] associated with the proposed cleanup value is 9E-05 (0.00009, which is within EPA's acceptable risk range for Superfund [1E-04 to 1E-06]).[3]

The above findings concerning average arsenic concentrations are not applicable for the evaluation of children with pica behavior. Pica behavior is a craving for and ingestion of non-food items such as soil, paint chips, and clay (ATSDR, 2005a). When a child exhibits pica behavior, they may eat a quantity of soil from a single location. In this case, the use of average property concentrations and long term ingestion rates are not appropriate. Several discrete or small area composite samples from gardens and play areas had higher arsenic concentrations than the average values listed in Table 1. The highest discrete arsenic concentration was 69 mg/kg and occurred in the Harriman Park community.

The public health implications of arsenic exposures are discussed in the Evaluation of Potential Health Effects Associated with Exposures to Arsenic and PAHs section.

Polycyclic Aromatic Hydrocarbons (PAHs)

The polycyclic aromatic hydrocarbons are evaluated as benzo(a)pyrene toxic equivalents (BaP-TE). The BaP-TE concentration is the sum of 7 different PAHs with their concentrations

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[2] **Cancer risk**: A theoretical risk for getting cancer if exposed to a substance every day for 70 years (a lifetime exposure). The true risk might be lower. The calculated cancer risk is expressed as a statistical probability or the likelihood of occurrence. The excess risk represents the additional risk due to exposure to contaminated soil and does not include the U.S average lifetime cancer risk of 0.4 (http://seer.cancer.gov/statfacts/html/all.html#risk).

[3] "EPA uses the general 10-4 (1 in 10,000) to 10-6 (1 in 1,000,000) risk range as a "target range" within which the Agency strives to manage risks as part of a Superfund cleanup.… A specific risk estimate around 10-4 may be considered acceptable if justified based on site-specific conditions, including any remaining uncertainties on the nature and extent of contamination and associated risks. Therefore, in certain cases EPA may consider risk estimates slightly greater than 1 x 10-4 to be protective" EPA. 1991. OSWER Directive 9355.0-30. Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions. http://www.epa.gov/oswer/riskassessment/baseline.htm

adjusted for their toxicity relative to BaP. In 2009, all PAH compounds that were detected in the North Birmingham communities were equated to BaP-TE. For this assessment, the 2005 sampling results were converted to BaP-TE and the results averaged with the 2009 results for each property.

Seventy-one (of 75 sampled) properties had average BaP-TE concentrations that exceeded the comparison value (CV; 0.1 mg/kg; Table 1). Table 2 lists the average yard concentrations for the minimum, the maximum, and the proposed clean up values and the resulting contaminant doses from daily exposures (using the procedures and assumptions from Appendix A). These doses are calculated assuming that soil contaminants are taken into peoples bodies by both incidental soil ingestion and direct intake through their skin (see Appendix A). Note that BaP-TE does not have an applicable non-cancer minimal risk level (MRL; see appendix A). Also note that the listed CREG is for BaP, rather than BaP-TE.

Table 1. Summary of Soil Data of Properties Near the Walter Coke, Inc. site.

Contaminant	**Range (mg/kg) Property Average**	**Properties Sampled**	**CV (mg/kg)**	**# Properties that Exceed CV**
Arsenic	13--41	75	20 EMEGcc 0.5 CREG [1]	24
BaP-TE	0.063—10.2 [2]	75	0.1 CREG [3]	71

CV—Comparison value (see Appendix A for descriptions and derivations).
BaP-TE—benzo(a)prene toxic equivalents; All individual PAHs were converted to BaP equivalents using the Toxic Equivalency Factors described in following sections.
CREG – ATSDR's Cancer Risk Evaluation Guide
EMEGcc – ATSDR's Environmental Media Evaluation Guide for chronic exposure for a child
[1]The arsenic CREG is lower than normal background values so the listed EMEG is the recommended CV.
[2] The highest maximum BaP-TE value excludes 4 samples from the roof drip line of a school that contained visible tar (roof tar is not soil and should not be evaluated as a soil).
[3] The listed CREG is for benzo(a)pyrene; non-cancer CVs are not available for BaP or BaP-TE.

Table 2. Soil Arsenic and BaP-TE concentrations and calculated doses and cancer risks.

Soil Contaminant		Avg. Concentration mg/kg	Child Doses mg/kg/day	Adult Doses mg/kg/day	Excess Cancer Risk (70 year)
Arsenic	minimum	9.2	6.4E-05	6.7E-06	2E-05
	maximum	40.6	2.8E-04	3.0E-05	1E-04
	cleanup value	37	2.6E-04	2.7E-05	9E-05
For a pica child--maximum arsenic concentration is 69 mg/kg with event dose of 0.006 mg/kg/day					
BaP-TE	minimum	0.063	6.0E-07	7.1E-08	1E-06
	maximum	10.2	9.8E-05	1.2E-05	1E-04
	cleanup value	1.5	1.4E-05	1.7E-06	3E-05

--Doses are calculated using procedures and assumptions described in Appendix A and in units of milligrams [contaminant] per kilogram body weight per day **(mg/kg/day**).
--BaP-TE**:** benzo(a)pyrene toxic equivalents
--Procedures for calculating TEqs are described in in the following section.
--mg/kg: milligrams per kilogram (or parts per million)

Evaluation of Health Effects Associated with Exposures to Arsenic and PAHs

Table 2 lists the maximum and minimum average property concentrations and contaminant doses from daily exposures (using the procedures and assumptions from Appendix A). These doses are calculated assuming that soil contaminants are taken into peoples bodies by both incidental soil ingestion and direct intake through their skin (see Appendix A). The calculated doses are compared with MRLs or other appropriate health comparison value (see Appendix A) to determine the potential for adverse health effects.

An MRL is an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse non-cancer health effects over a specified duration of exposure. The MRL is derived from exposure levels observed to produce adverse effects, with uncertainties (or safety factors) incorporated into the value. Thus, MRLs are intended only to serve as a screening tool to help public health professionals decide which exposure situations require more extensive evaluation. Estimated exposure dose levels below an MRL are not likely to produce non-cancer adverse effects. Exposure estimates above an MRL do not mean that adverse effects will occur, but rather that further evaluation of the exposure is warranted.

ATSDR then evaluates the potential for adverse health effects in an exposed community by comparing levels known to produce adverse effects to the estimated site-related doses. This margin of exposure (MOE) approach, along with an evaluation of available epidemiologic, toxicologic, and medical data, is used by health assessors as part of the public health determination to reach qualitative (rather than quantitative) decisions about hazards posed by site-specific conditions of exposure.

It is important to note that the above listed doses and cancer risks do not necessarily indicate that any residents will suffer health effects from their exposures to contaminated soil. The calculated doses are based on health protective assumptions regarding intake and exposure and may overestimate actual exposures. Similarly, the listed health comparison values are based on measured contaminant doses to laboratory animals that typically include significant safety factors in order to apply those results to actual human exposures. The following sections describe the potential health effects specifically related to arsenic and BaP and how the respective health comparison values are derived.

Arsenic Health Effects

ATSDR calculated that the potential dose to a non-pica child at the highest average arsenic soil concentration is 0.00028 mg/kg/day (2.8E-04; Table 2). This dose is below the chronic MRL (3.0E-04 mg/kg/day) and not likely to cause adverse non-cancer health effects. Ingestion of soil by a pica child from the location with highest discrete arsenic concentration results in a dose of 0.006 mg/kg/day assuming an oral bioavailability of 100% and a dose of 0.003 mg/kg/day assuming a more likely oral bioavailability of 50% (see Appendix A) . The calculated pica child dose of 0.003 mg/kg/day is below the acute MRL of 0.005 mg/kg/day and unlikely to cause any adverse health effects.

The theoretical excess cancer risk from 70 year exposures to soils for the highest property average concentration of arsenic is 1E-04 (Table 2). Cancer risks less than 1E-04 are within EPA's acceptable risk range for Superfund and represent a low increased cancer risk. No

adverse health effects (cancer and non-cancer) are expected for exposures at the proposed cleanup level (37mg/kg). It should be noted that the doses and cancer risks are calculated assuming that arsenic has a 100% bioavailability via ingestion and 2% bioavailability for dermal absorption (Appendix A).

Arsenic occurs naturally in soil and minerals. People normally take in small amounts of arsenic in air, water, soil, and food. Of these, food is usually the most common source of arsenic for people (ATSDR 2005b). In order to determine whether the potential exposures to arsenic-contaminated soil presents a public health hazard at this site, ATSDR compared the estimated doses with benchmarks or screening doses that are derived from dose levels known to produce adverse health effects. For arsenic, ATSDR has developed minimal risk levels (MRLs) that cover brief exposures (acute, or less than 14 days) and longer term exposures (chronic, or more than a year).

At low-level exposures, arsenic compounds are detoxified—that is, changed into less harmful forms—and excreted in the urine (ATSDR, 2005b) . At higher-level exposures, however, the body may not have the ability to detoxify the increased amount of arsenic. When this overload happens, blood levels of arsenic increase and adverse health effects may occur. Arsenic, like some other chemicals, does not seem to cause adverse health effects until a certain amount, or threshold, of the chemical has entered the body. Once the threshold, also known as the minimal effective dose, is reached adverse health effects may result (ATSDR 2005b).

Arsenic (inorganic) is considered to be a human carcinogen by the Department of Health and Human Services, by the US Environmental Protection Agency, and by the International Agency for Research on Cancer (as referenced in ATSDR, 2005b). The EPA's quantitative estimate of cancer risk for arsenic, expressed as a cancer slope factor (CSF), is 1.5 (per mg/kg/day). The calculated lifetime excess cancer risk for the property with the highest arsenic concentration (40.6 mg/kg) is 1E-04 (0.00001; Table 2). This estimate of lifetime cancer risk is within the EPA acceptable risk range, which is calculated assuming that 100% of the ingested arsenic is absorbed, probably overestimates the arsenic dose and resulting cancer risk (see Appendix A).

ATSDR reviewed the scientific literature regarding arsenic toxicity to evaluate whether non-cancer adverse health effects would be expected to occur at the estimated exposure doses. The acute oral MRL for arsenic (0.005 mg/kg/day) is based on several temporary effects that could occur from acute exposures (≤14 days). Acute exposure to arsenic can be toxic to the stomach and intestines, with symptoms such as pain, nausea, vomiting, and diarrhea. When an estimated acute exposure dose for pica behavior is below 0.005 mg arsenic/kg/day, non-cancerous effects are unlikely. It should be noted that the acute MRL is 10 times below the levels reported to cause these effects in humans (acute Lowest Observed Adverse Effect Level (LOAEL) = 0.05 mg/kg/day).

The arsenic dose for a child (11 kg body weight) with pica behavior at the highest discrete arsenic concentration (69 mg/kg) at a rate of 1000 mg/day (recommended pica ingestion rate; EPA, 2011) is 0.006 mg/kg/day. This dose is slightly greater than the acute oral MRL (0.005 mg/kg/day) but less than the LOAEL on which it is based (0.05 mg/kg/day; ATSDR 2005b). The maximum pica dose (0.006 mg/kg/day; Table 2) is calculated assuming 100% bioavailability. Using a more likely bioavailability of 50% (see Appendix A), the highest pica dose is 0.003 mg/kg/day and below the acute oral MRL (0.005 mg/kg/day). Pica intake of soil at the proposed arsenic cleanup level results in a short term dose of 0.003 mg/kg/day (100% bioavailability) or

0.0015 mg/kg/day (50% bioavailability). Both doses are less than the acute MRL (0.005 mg/kg/day).

In addition to the uncertainty associated with arsenic bioavailability, estimates of soil ingestion rates for children with pica behavior range from 1,000 mg/day used in Table 2 and Appendix A up to 5,000 mg/day (ATSDR, 2005a). Although unlikely, a child with pica behavior could eat a large amount of soil from the property with the highest soil arsenic concentration. In this case, the pica child could develop short term health effects such as pain, nausea, vomiting, and diarrhea.

In addition to the acute MRL, ATSDR developed a chronic oral MRL for arsenic of 0.0003 mg/kg/day. The highest estimated exposure doses for children (non-pica) and adults are below the chronic oral MRL (see Table 2). The ATSDR chronic oral MRL is based on common and characteristic effects of arsenic ingestion that produce a pattern of skin changes known as hyperpigmentation and hyperkeratosis. These dermal effects have been noted in some human studies that involved daily, long-term ingestion (more than 45 years) of elevated arsenic levels in drinking water. Collectively, these studies indicate that the lowest dose producing the hyperpigmentation and hyperkeratosis is 0.014 mg As/kg/day (Lowest Observed Adverse Effect Level, LOAEL; ATSDR 2005b). These skin effects have not been observed at arsenic doses of 0.0008 mg/kg/day (No adverse observed health effect; NOAEL).

The estimated chronic (long term) dose for a 16 kg (35 pound) child is below the arsenic NOAEL dose of 0.0008 mg/kg/day (assuming ingestion of 100 mg of soil for 365 days/year). Consequently, no long term adverse health effects are expected from exposure to arsenic in soil.

BaP-TE Health Effects

ATSDR calculated that the excess cancer risk from 70 year exposures to soil for the highest property average concentration of BaP-TE is 1E-04 (Table 2). Cancer risks less than 1E-04 are within EPA's acceptable risk range for Superfund and represent a low increased possible cancer risk (for skin or stomach cancers). The possible excess cancer risks are calculated using the cancer slope factor (CSF) for BaP, which may not be directly applicable to risk estimation for the wider range of PAHs included in derivation of the BaP-TE (Fitzgerald et.al., 2004). It should be noted that the doses and cancer risks are calculated assuming that the PAHs comprising the BaP-TE have a 100% bioavailability via ingestion and 10% bioavailability for dermal absorption (Appendix A).

The following summary of BaP health effects is primarily from the ATSDR Toxicological Profile for Polycyclic Aromatic Hydrocarbons (ATSDR, 1995) with other references as cited. Benzo(a)pyrene (BaP) is one compound in a class of more than 100 chemicals called polycyclic aromatic hydrocarbons (or PAHs). PAHs are formed during the incomplete combustion of coal, oil, gas, wood, garbage, and other organic substances. PAHs, including BaP, occur naturally in air, water, and soil but are also found in creosote products such as those used at wood treating facilities.

The BaP toxic equivalent (TE) is a derived concentration of the 7 most common PAHs with their specific concentrations adjusted for their toxicity relative to BaP. Those specific PAHs and relative toxicities (expressed as toxic equivalency factors; TEFs) are as follow (from EPA, 1993):

PAH compound	TEF
Benzo(a)pyrene	1
Benz(a)anthracene	0.1
Benzo(b)fluoranthene	0.1
Benzo(k)fluoranthene	0.01
Chrysene	0.001
Dibenz(ah)anthracene	1
Indeno(123-cd)pyrene	0.1

BaP-TE equals the sum of the individual concentrations multiplied by their respective TEF.

PAHs, including BaP, can be harmful to your health. Several PAHs, as listed above, have caused tumors in laboratory animals when they breathed, ate, or had long periods of skin exposure to these substances. Human data specifically linking benzo[a]pyrene (BaP) to a carcinogenic effect are lacking. There are, however, multiple animal studies demonstrating BAP to be carcinogenic following administration by numerous routes ((http://www.epa.gov/iris/subst/0136.htm#quaoral). Workers who had long-term skin contact with creosote, especially during wood treatment or manufacturing processes, reported increases in skin cancer and cancer of the scrotum. Cancer of the scrotum has been associated with long-term exposure to soot and coal tar creosotes of chimney sweeps. Animal studies have also shown an association between creosote exposure and skin cancer (ATSDR, 2002).

The cancer slope factor (CSF) for BaP (7.3 mg/kg/day^{-1}) is based on the geometric mean of four different dose response models using multiple species and both sexes. The EPA considers the available human cancer data to be inadequate but the animal carcinogenic data on which the CSF is based to be sufficient (http://www.epa.gov/iris/subst/0136.htm#quaoral). The above listed PAHs are considered by the Department of Health and Human Services (National Toxicology Program; http://ntp.niehs.nih.gov/) and the EPA to be known animal carcinogens and probable human carcinogens (respectively). It should be noted that the above CSF is specifically applicable to evaluation of BaP cancer risk and inferred for evaluation of BaP-TE cancer risks.

The lifetime (70 year) excess cancer risk for the property with the highest BaP-TE concentration (10.2 mg/kg) is 1E-04; 0.0001; Table 2). This risk estimate is within the EPA acceptable risk range of 1.0E-04 to 1.0E-6 and represents a low increased risk of cancer. It should be noted that this risk calculation assumes that 100% of the BaP-TE ingested is absorbed and probably overestimates the actual dose and resulting cancer risk.

It is important to understand that the cancer risks calculated above are based on the most conservative assessment model available (NCRP 2001). The dose-response models used to estimate the CSF assume that there is no threshold below which there is no dose-response and actually ignore data which suggest that such a threshold exists (NCRP 2001; Fitzgerald, et.al. 2004). Using BaP and creosote exposures to mice and a benchmark dose-response model for the resulting tumor development, Fitzgerald, et.al. (2004) propose a soil guideline value of 5.0 mg/kg BaP is safe for human exposure. Although none of the sampled properties have average **BaP** concentrations above 5.0 mg/kg, six of the properties have average **BaP-TE** concentrations above 5.0 mg/kg.

At concentrations much higher than measured in these communities, non-cancer dermatological effects have been associated with exposure to PAH-contaminated soil. Creosote workers report skin rash symptoms as their most frequent complaint, as well as a high rate of photosensitivity (ATSDR, 2002). The dermatological system is particularly vulnerable to the effects of creosotes (ATSDR, 2002). In an industrial health survey (cited earlier) involving 251 employees at 4 wood preservative plants where coal tar creosote and coal tar is used, there were 82 reported instances of dermal effects, ranging from mild skin irritation, eczema, and folliculitis to benign skin growths such as warts (ATSDR, 2002). Skin irritation was described as a redness like a sunburn, lasting 2 to 3 days, along with photosensitivity that has been reported by workers who handle coal tar pitch products outdoors (ATSDR, 2002). Dermal effects were also noted as part of a site surveillance program conducted by the Texas Department of Health involving residents living in a housing development that was built on part of an abandoned creosote wood treatment plant (Koppers Company, Texarkana, Texas; Texas DOH, 1994).

Mice fed high concentrations of BaP during pregnancy (and/or their offspring) had difficulty reproducing, birth defects, and decreased birth weights. Studies of other animals have shown that BaP causes harmful effects on skin, intestinal mucosa (enzyme alterations), and immune system deficiencies. Similar effects could occur in people but have not been documented. No acute or chronic Minimal Risk Levels (MRLs) have been derived for BaP because no adequate human or animal dose-response data are available that identify threshold levels for appropriate non-cancer health effects. However, the doses at which these non-cancer health effects occurred in mice were more than a million times higher than BaP or BaP-TE doses from soil in the North Birmingham communities (ATSDR, 1995). Therefore, it is unlikely that any non-cancerous adverse health effects from PAH (BaP or BaP-TE) exposure would occur in children or adults.

The average BaP-TE soil concentration that results in a cancer risk greater than 1.0E-04 is about 8.0 mg/kg and only 2 of the 75 properties sampled have an average concentration above that level. Exposures at the proposed cleanup level of 1.5 mg/kg (CH2MHill, 2011b) result in an estimated excess lifetime cancer risk of 2.8E-05 which is within the EPA acceptable risk range (1E-04 to 1.0E-06; based on a 70 year exposure).

Gardening and Eating Homegrown Produce

ATSDR has learned through discussions with community members, that some residents living adjacent to the site grow fruits and vegetables in their home gardens. Actual measured concentrations of chemicals in fruits and vegetables grown in soil adjacent to the WCI are not available at this time. However, ATSDR does have information about the chemicals found in soil at levels that exceeded the health-based comparison values for residential soil. While actual exposures via homegrown produce cannot be determined based on available data, ATSDR conducted a literature search on arsenic and BaP uptake by garden plants and ways that exposure to these chemicals can be reduced.

In general, plants may take up chemical contaminants either by absorbing them through their root system or through their leaves and stems. Chemicals in air may also settle on the above ground parts of plants (Simonich and Hites, 1995). Based on a review of the available scientific literature, chemicals such as PAHs (as BaP-TE) are not thought to be taken into most plants by

the root system (Wild, et.al., 1992; Simonich & Hites, 1995; and Samsoe-Petersen, et.al., 2002). Studies also suggest that these chemicals may get into crops such as carrots and potatoes, but are located primarily in the peel of potatoes and carrots (Wild, et.al, 1992; Samsoe-Peterson, et.al., 2002).

Garden plants grown in arsenic-contaminated soils do take up small amounts of arsenic in their roots (Thorton, 1994; Samsoe-Petersen, 2002; and reviews by ATSDR, 2005b; and, Stilwell, 2002). In these studies the arsenic concentrations in the plant roots were a small fraction of arsenic concentrations in the soils and the arsenic concentrations in the plants did not exceed regulatory standards for food items (Thorton, 1994; Stilwell, 2002). Several studies also indicated that the plants took in more arsenic from air (and atmospheric deposition) than from uptake through their roots (from soil; Larsen, et.al. 1992; Thorton, 1994; Stilwell, 2002).

Based on the ATSDR's review of the literature, most plants do not readily take up the chemicals found in residential soil samples collected near the WCI site. Those plants that do take up small amounts of arsenic or PAHs into their roots do not move a significant amount of those contaminants into the edible portion of the plants that are typically eaten (Samsoe-Petersen, et.al. 2002; Stilwell, 2002). However, people may reduce their exposure to chemicals in their home-grown produce by peeling root crop vegetables, such as carrots and potatoes, which have been found to accumulate low levels of chemicals. Another way to minimize soil exposures is to remove dirt from garden produce before bringing it into the home. Washing home-grown produce thoroughly will also remove soil particles that may contain chemicals. Appendix B contains an ATSDR fact sheet describing everyday practices that will reduce exposures to soil.

Although the studies referenced above indicate that most plants do not take up significant amounts of arsenic or PAHs from soil, people with gardens are likely to have more exposure relative to non-gardeners. Consequently, soil ingestion and dermal uptake rates could be higher for gardeners. Appendix B presents common practices for reducing exposures to soil.

Child Health Considerations

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

This consultation uses child-specific exposure factors, such as body weights, intake rates, and skin exposure areas, as the basis for calculating exposures to contaminants in soil (Appendix A). The resulting exposure doses for children are higher than adult doses and represent the basis for

the following public health conclusions and recommendations. Additionally, soil data evaluated in this consultation includes sample locations from schoolyards and residential play areas and gardens. Two of the affected schools have been cleaned up and remediation has been proposed for other residential properties.

Adequacy of Available Data

The soil data (CH2MHill, 2005; 2011a) underlying this consultation appear to be an adequate basis for the following public health determinations with several notable exceptions. Sample location, collection, and quality assurance procedures that were established (and apparently implemented) resulted in a consistent, well-documented data set. As previously noted, soil samples collected from below an extant sod layer probably overestimate actual exposure to surface soil. It should also be noted that ATSDR considers the upper three inches of surface soil to be most representative for exposure (ATSDR, 1994). Gardens and play areas were sampled from a 0 to 12 inch depth (which is appropriate considering that a person is likely to be digging in the soil in these areas).

Inhalation of air contaminants may be a pathway of exposure for this community. Air exposures will be evaluated in a pending ATSDR health consultation.

Conclusions, Recommendations, and Public Health Action Plan

Conclusions

ATSDR has evaluated the past, present, and future exposures to residential soils in the communities adjacent to the WCI site. On the basis of the likely exposure pathways and the available environmental data, ATSDR concludes the following:

Arsenic Soil exposures to arsenic in sampled properties around the Walter Coke, Inc. site do not present a public health hazard with the possible exception of a child with pica behavior eating a large amount of soil from the property with the highest arsenic concentration. In this case, the pica child could develop short term health effects such as pain, nausea, vomiting, and diarrhea. Three of the sampled properties had average arsenic concentrations above the proposed cleanup value. Adverse health effects are not expected from arsenic soil exposures at properties with average arsenic concentrations below the proposed cleanup value.

BaP-TE Soil exposures to BaP-TE in sampled properties around the Walter Coke, Inc. site do not present a public health hazard. Fifteen properties have average BaP-TE values above the proposed cleanup value. Adverse health effects are not expected from BaP-TE soil exposures at properties with average BaP-TE concentrations below the proposed cleanup value.

Recommendations

ATSDR makes the following recommendations:

1) Although the soil exposures do not present a public health hazard (with the possible exception of a pica child at the property with the highest arsenic concentration) it is prudent public health policy to remediate several of the sampled properties with the highest contaminant concentrations to decrease soil exposures (sixteen residential properties and two school yards have been or are proposed for remediation). Residents should follow practices such as washing hands and garden produce and wiping shoes to reduce exposures to soil.

2) ATSDR should complete the review of site-specific air data to assess community exposures to airborne contaminants released from the WCI site.

Public Health Action Plan

ATSDR will distribute this health consultation to members of the Collegeville, Harriman Park, and Fairmont communities and ensure that the public health conclusions and recommendations are effectively communicated by presentation at a public meeting or other appropriate means.

ATSDR will continue to work with EPA to evaluate community exposures from the WCI site.

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Appendix A: Health Comparison Values and Dose Calculation Procedures

When a hazardous substance is released to the environment, people are not always exposed to it. Exposure happens when people breathe, eat, drink, or make skin contact with a contaminant. Several factors determine the type and severity of health effects associated with exposure to contaminants. Such factors include exposure concentration, frequency and duration of exposure, route of exposure, and cumulative exposures (i.e., the combination of contaminants and routes). Once exposure takes place, individual characteristics—such as age, sex, nutritional status, genetics, lifestyle, and health status—influence how that person absorbs, distributes, metabolizes, and excretes the contaminant. These characteristics, together with the exposure factors discussed above and the specific toxicological effects of the substance, determine the health effects that may result. The following summary of ATSDR's procedure for developing health comparison values and calculating exposure doses is derived from the ATSDR Public Health Assessment Guidance Manual (ATSDR, 2005a).

ATSDR considers these physical and biological characteristics when developing health guidelines. Health guidelines provide a basis for evaluating exposures estimated from concentrations of contaminants in different environmental media (soil, air, water, and food) depending on the characteristics of the people who may be exposed and the length of exposure. Health guideline values are in units of dose such as milligrams (of contaminant) per kilogram of body weight per day (mg/kg/day).

ATSDR reviews health and chemical information in documents called toxicological profiles. Each toxicological profile covers a particular substance; it summarizes toxicological and adverse health effects information about that substance and includes health guidelines such as ATSDR's minimal risk level (MRL), EPA's reference dose (RfD) and reference concentration (RfC), and EPA's cancer slope factor (CSF). ATSDR uses these guidelines to determine a person's potential for developing adverse non-cancer health effects and/or cancer from exposure to a hazardous substance.

An MRL is an estimate of daily human exposure to a contaminant that is likely to be without an appreciable risk of adverse non-cancer health effects over a specified duration of exposure (acute, less than 15 days; intermediate, 15 to 364 days; chronic, 365 days or more). Oral MRLs are expressed in units of milligrams per kilogram per day (mg/kg/day); inhalation MRLs are expressed in micrograms per cubic meter ($\mu g/m^3$). MRLs are not derived for dermal exposure.

RfDs and RfCs are estimates of daily human exposure, including exposure to sensitive subpopulations that are likely to be without appreciable risk of adverse non-cancer health effects during a lifetime (70 years). These guidelines are derived from experimental data and lowest-observed-adverse-effect levels (or no-observed-adverse-effect levels), adjusted downward using uncertainty factors. The uncertainty factors are used to make the guidelines adequately protective for all people, including susceptible individuals. RfDs and RfCs should not be viewed as strict scientific boundaries between what is toxic and what is nontoxic.

For cancer-causing substances, EPA established the cancer slope factor (CSF; http://www.epa.gov/iris/help_ques.htm#cancersf). A CSF is used to estimate the theoretical excess cancer risks expected from maximal exposure for a lifetime. Cancer risk evaluation guides (CREGs) are estimated contaminant concentrations that would be expected to cause an estimated excess theoretical cancer risk less than 1.0E-06 (or 0.000001). The CREGs and CSFs represent statistical estimates of risk and are not indicative of actual health effects. Specifically, a one in a million risk does not mean that one person (out of a million exposed) will get cancer, but rather that each person exposed has a theoretical cancer risk of 1.0E-06.

Health comparison values (CVs) are estimated contaminant concentrations that are unlikely to cause detectable adverse health outcomes when these concentrations occur in specific media. CVs are used to select site contaminants for further evaluation. CVs are calculated from health guidelines and are presented in media specific units of concentration, such as micrograms/liter (µg/l) or ppm. CVs are calculated using conservative assumptions about daily intake rates by an individual of standard body weight. Because of the conservatism of the assumptions and safety factors, contaminant concentrations that exceed comparison values for an environmental medium do not necessarily indicate a health hazard.

For nonradioactive chemicals, ATSDR uses comparison values like environmental media evaluation guides (EMEGs), cancer risk evaluation guides (CREGs), reference dose (or concentration) media evaluation guides (RMEGs), and others. EMEGs, since they are derived from MRLs, apply only to specific durations of exposure. Also, they depend on the amount of a contaminant ingested or inhaled. Thus, EMEGs are determined separately for children and adults, and also separately for various durations of exposure. A CREG is an estimated concentration of a contaminant that would likely cause, at most, one excess cancer in a million people exposed over a lifetime. CREGs are calculated from CSFs. Reference dose (or concentration) media evaluation guides (RMEGs) are media guides based on EPA's RfDs and RfCs.

EPA's maximum contaminant levels (MCLs) are maximum contaminant concentrations of chemicals allowed in public drinking water systems. MCLs are regulatory standards set as close to health goals as feasible and are based on treatment technologies, costs, and other factors.

Health comparison values, such as EMEGs and MCLs, are derived using standard intake rates for inhalation of air and ingestion of water, soil, and biota. These intake rates are derived from the ATSDR Public Health Assessment Guidance Manual (ATSDR 2005a) or from the EPA Exposure Factors Handbook (EPA 2011). Doses calculated using health protective exposure factors and environmental concentrations are considered "health protective doses" because it is unlikely that any real community exposures are greater than the calculated doses and are most likely to be less than the health protective doses.

After estimating the potential exposure at a site, ATSDR identifies the site's "contaminants of concern" by comparing the exposures of interest with health guidelines, or contaminant concentrations with comparison values. As a general rule, if the guideline or value is exceeded, ATSDR evaluates exposure to determine whether it is of potential health concern. Sometimes additional medical and toxicological information may indicate that these exposures are not of

health concern. In other instances, exposures below the guidelines or values could be of health concern because of interactive effects with other chemicals or because of the increased sensitivity of certain individuals. Thus additional analysis is necessary to determine whether health effects are likely to occur.

Exposure doses via ingestion are calculated on the basis of the following equation:

Dose (Ingestion) = (Chemical Conc. x IR x EF x ED x ABS) / (BW x AT)

Where:

Chemical Conc.	= concentration of each contaminant (in mg/g, µg/g, mg/L, or µg/L; with appropriate unit conversion factors)
IR	= ingestion rate (in grams/day or liters/day)
EF	= exposure frequency in days per year
ED	= exposure duration in years
ABS	= a chemical-specific absorption or bioavailability factor (unitless)
BW	= body weight in kilograms
AT	= averaging time in days

For soil and sediment doses, we take an additional step to determine exposure via dermal absorption, with the total dose being the sum of the ingestion dose and the dermal dose.[4]

Dose (Dermal) = (Chemical Conc. x ABS x TSA x EF x ED) / (BW x AT)

Where all factors are as above except:

TSA	= total soil adhered in milligrams (skin surface area x soil adherence value)

The total soil exposure dose = ingestion dose + dermal dose

The specific exposure factors used to calculate doses for community soil exposures are listed in Table A-1. Doses to residents from soil exposures include exposures to both average property contaminants for both incidental ingestion and direct absorption through the skin. The calculation of the 70 year theoretical excess cancer risk from BaP-TEq exposure includes 12 years of exposure as a child and 58 years of exposure as an adult.

[4] Soil particle may also be inhaled as airborne dust. However, the majority of dust particles greater than ~one micron diameter are trapped in the upper respiratory system and ultimately swallowed (or ingested). As most airborne soil particles are greater than one micron diameter, the exposure is included in the ingestion dose.

The above dose equations include terms for the relative absorption factors (listed as ABS in above equations). These absorption factors account for the difference in contaminant bioavailablity for the doses administered to laboratory animals in their feed or corn oil vs. absorption from soil. Note that the ABS values are different (Table A-1) for uptake via ingestion and dermal exposure. Dermal absorption of strongly particle-bound contaminants such as PAHs and arsenic is limited (ATSDR, 1995; ATSDR, 1998).

Numerous studies have determined that the relative oral bioavailabilities of arsenic and BaP (and associated PAHs) from soil are less than 100% (as reviewed in: ATSDR, 1995; ATSDR, 1998; Chen, et.al., 2001; Casteel, 2003). Reported PAH ABS values range from 17% to 66% (in mice, rats, and swine) and had a cumulative average of 40% (Stroo, et.al., 2005; Ounnas, et.al., 2009). It should also be noted that BaP-TE values represent the toxicity adjusted concentrations of numerous PAH species and that the relative bioavailabilities of the specific PAH compounds may vary (Ounnas, et.al., 2009). Similarly, reported values of arsenic ABS in 26 test soils range from 8% to 61% (http://www.epa.gov/region8/r8risk/hh_rba.html) and Roberts, et.al. (2006) measured arsenic bioavailability from 14 contaminated soils that ranged from 19% to 31%.

The ingestion ABS values listed in Table A-1 assume 100% bioavailability and probably overestimate the total absorption from ingestion of soils contaminated with arsenic and BaP-TE. The dermal ABS values listed in Table A-1 are 2% for arsenic ABS (Wester, et.al., 1993; Chen, et.al., 2001) and 10% for BaP-TE dermal ABS (Turkall, et.al., 2010) . Dermal absorption is insignificant for pica behavior.

Table A-1. Exposure Parameters Used to Calculate Soil Exposure Doses

Exposure Parameters (units)	Child	Adult
Soil Ingestion (IR; grams/day)	100	50
Exposure Factor (EF; unitless) = [freq. days/yr x duration yrs]/AT [days]	Soil--1	Soil--1
Exposure Duration (ED; years)	12	58
Arsenic Absorption-Ingestion (ABS)	100%	100%
Arsenic Absorption-Dermal (ABS)	2%	2%
BaP Absorption-Ingestion (ABS)	100%	100%
BaP Absorption-Dermal (ABS)	10%	10%
Body Weight (BW; kilograms)	16	80
Averaging Time (AT; days)	365	365
Total Soil Adhered; (TSA; mg/day) Area skin surf.[cm^2] x adherence factor [mg/cm^2/day]	2,670 cm^2 x 0.2 mg/cm^2/day =	5,800 cm^2 x 0.07 mg/cm^2/day =
TSA (milligrams/day; see above)	534	406
F (frequency; day/yr)	Soil--365	Soil--365
Pica child: soil ingestion—1,000 mg/day; body weight—11 kg		
The child/adult soil ingestion rates are the "General Population Central Tendency" recommended values and for a pica child are the recommended "high end" values (EPA Exposure Factors Handbook (Table 5-1; EPA, 2011).		

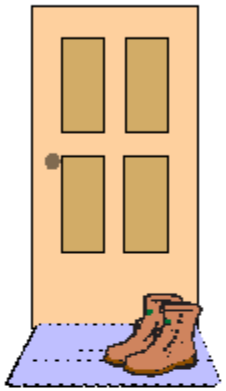
Appendix B: Ways to Protect Your Health

By Keeping Dirt from Getting Into Your Home and Body

Ways to protect your health

By keeping dirt from getting into your house and into your body

Wash and peel all fruits, vegetables, and root crops



Wipe shoes on doormat or remove shoes

Don't eat food, chew gum, or smoke when working in the yard

Damp mop floors and damp dust counters and furniture regularly

Wash dogs regularly

Wash children's toys regularly

Wash children's hands and feet after they have been playing outside

ATSDR