Health Consultation

Federal Way and Des Moines Beach Sediment Evaluation,
Pierce and King Counties, Washington

March 24, 2009

Prepared by

The Washington State Department of Health
Under a Cooperative Agreement with the
Agency for Toxic Substances and Disease Registry

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Foreword

The Washington State Department of Health (DOH) has prepared this health consultation in cooperation with the Agency for Toxic Substances and Disease Registry (ATSDR). ATSDR is part of the U.S. Department of Health and Human Services and is the principal federal public health agency responsible for health issues related to hazardous waste. This health consultation was prepared in accordance with methodologies and guidelines developed by ATSDR.

The purpose of this health consultation is to identify and prevent harmful human health effects resulting from exposure to hazardous substances in the environment. Health consultations focus on specific health issues so that DOH can respond to requests from concerned residents or agencies for health information on hazardous substances. DOH evaluates sampling data collected from a hazardous waste site, determines whether exposures have occurred or could occur, reports any potential harmful effects, and recommends actions to protect public health. The findings in this report are relevant to conditions at the site during the time of this health consultation, and should not necessarily be relied upon if site conditions or land use changes in the future.

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For more information about ATSDR, contact the ATSDR Information Center at 1-888-422-8737 or visit the agency's Web site: www.atsdr.cdc.gov/.

Glossary

Agency for Toxic Substances and Disease Registry (ATSDR)	The principal federal public health agency involved with hazardous waste issues, responsible for preventing or reducing the harmful effects of exposure to hazardous substances on human health and quality of life. ATSDR is part of the U.S. Department of Health and Human Services.
Bioavailability	The fraction of lead that is absorbed and enters the blood by whatever portal-of-entry compared with the total amount of lead acquired.
Cancer Risk Evaluation Guide (CREG)	The concentration of a chemical in air, soil or water that is expected to cause no more than one excess cancer in a million persons exposed over a lifetime. The CREG is a comparison value used to select contaminants of potential health concern and is based on the cancer slope factor (CSF).
Carcinogen	Any substance that causes cancer.
Comparison value	Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause harmful (adverse) health effects in exposed people. The CV is used as a screening level during the public health assessment process. Substances found in amounts greater than their CVs might be selected for further evaluation in the public health assessment process.
Contaminant	A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.
Dermal Contact	Contact with (touching) the skin (see route of exposure).
Dose **(for chemicals that are not radioactive)**	The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An "exposure dose" is how much of a substance is encountered in the environment. An "absorbed dose" is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.
Environmental Media Evaluation Guide (EMEG)	A concentration in air, soil, or water below which adverse non-cancer health effects are not expected to occur. The EMEG is a comparison value used to select contaminants of potential health concern and is based on ATSDR's minimal risk level (MRL).

Environmental Protection Agency (EPA)	United States Environmental Protection Agency.
Exposure	Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [acute exposure], of intermediate duration, or long-term [chronic exposure].
Hazardous substance	Any material that poses a threat to public health and/or the environment. Typical hazardous substances are materials that are toxic, corrosive, ignitable, explosive, or chemically reactive.
Ingestion	The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see route of exposure].
Ingestion rate	The amount of an environmental medium that could be ingested typically on a daily basis. Units for IR are usually liter/day for water, and mg/day for soil.
Inhalation	The act of breathing. A hazardous substance can enter the body this way [see route of exposure].
Inorganic	Compounds composed of mineral materials, including elemental salts and metals such as iron, aluminum, mercury, and zinc.
Media	Soil, water, air, plants, animals, or any other part of the environment that can contain contaminants.
Model Toxics Control Act (MTCA)	The hazardous waste cleanup law for Washington State.
Parts per billion (ppb)/Parts per million (ppm)	Units commonly used to express low concentrations of contaminants. For example, 1 ounce of trichloroethylene (TCE) in 1 million ounces of water is 1 ppm. 1 ounce of TCE in 1 billion ounces of water is 1 ppb. If one drop of TCE is mixed in a competition size swimming pool, the water will contain about 1 ppb of TCE.
Route of exposure	The way people come into contact with a hazardous substance. Three routes of exposure are breathing [inhalation], eating or drinking [ingestion], or contact with the skin [dermal contact].

Purpose

The Washington State Department of Health (DOH) conducted this health consultation to evaluate whether contaminants found at Federal Way and Des Moines beach sediment sites pose a health hazard to people who use the beach for wading, swimming, picnicking, and other recreational activities. This health consultation is directed to the community or local residents concerned about using the beach sites for recreation. DOH prepares health consultations under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR).

Background and Statement of Issues:

The DOH Office of Shellfish recently approved harvesting of geoducks on the east side of Puget Sound, near Federal Way and Des Moines. Figure 1 lists the current certified shellfish harvest area and potential contaminant sources within one mile of the Federal Way and Des Moines sites. DOH reviewed available geoduck tissue data and wrote a health consultation for the Dumas Bay site.[1] Local residents expressed that past studies have shown measurable quantities of arsenic, mercury, and lead in the top few feet of Pierce and King Counties sediments. Thus, residents are concerned that sediments (e.g., sediments to a depth of three feet) both in the subtidal and intertidal lands might be disturbed by current shellfish harvest operations and that people may be potentially exposed to toxic site-related contaminants. Exposed populations may include adults and/or children, residents and/or visitors, and others such as fishers, swimmers, and those who eat shellfish and/or play on the shoreline.

Bob Woolrich, the manager of the Growing Area Section within DOH's Office of Shellfish and Water Protection, asked the Office of Environmental Health Assessments (OEHA) if there were any studies showing contaminated sediments near, or at, the areas approved for geoduck harvesting. OEHA asked the Washington State Department of Ecology (Ecology) if sediment data had been collected in these areas. Ecology provided sediment data of contaminants, concentrations, and date/location of samples.

Previous studies of sediment quality data in Puget Sound have concluded that urban areas have low sediment quality (i.e., sediment quality is degraded by chemical pollution) compared to those from more rural areas. The East Passage area (i.e., along Federal Way through Des Moines) had the least degraded sediment quality compared with other Puget Sound sediment sites. Least degraded means that none of the sediment chemical concentrations exceeded critical values, the results of toxicity testing were not significant, and benthic indices indicated the infaunal assemblages were diverse and abundant and/or supported sensitive species.[2,3]

Results and discussion

DOH reviewed the available Federal Way and Des Moines sites sediment data. Following is a discussion about sampling and the level of contaminants found in the beach and shoreline sediments. It is difficult to determine whether sediment quality is or will be

impacted by harvesting operations at these sites. Thus, this evaluation will focus on potential health impacts for direct human contact with metal-contaminated sediments through recreational and other types of activities that exist at the shorelines of these sites.

Contaminants such as arsenic, lead and mercury were found in the beach and shoreline sediments located along Des Moines and Federal Way (Figures 2 and 3). Samples were collected within the top 2 to 5 inches of sediment in 1995, 1998, 1999, 2003, and 2006. The samples were analyzed for all metals, and only arsenic exceeded Ecology's Model Toxics Control Act (MTCA) Method A Soil Cleanup Level for Unrestricted Land Use. Arsenic also exceeded the Agency for Toxic Substances and Disease Registry (ATSDR) levels of 20 mg/kg for non-cancer and 0.5 mg/kg for cancer (Table 1).

Table 1. Summary of range of contaminant concentrations detected in sediment at Federal Way and Des Moines sites in Pierce and King Counties, Washington.

Chemical	Concentration range (mg/kg)	Comparison Value (mg/kg)	EPA Cancer Class	Comparison Value Reference	Contaminant of Concern (COC)
Arsenic	2.7 – 25.9	20 0.5	A	MTCA/EMEG CREG	Yes
Lead	2.7 – 89.6	250	B2	MTCA	No
Mercury	0.0057 – 0.31	2	D	MTCA	No

ATSDR (EMEG) Reference Dose Media Evaluation Guide (child)
ATSDR (CREG) Cancer Risk Evaluation Guide (child)

When a chemical exceeds a health-based screening value (SV) or comparison value, additional evaluation of that chemical is necessary. Of all contaminants analyzed, only arsenic exceeded Ecology's and ATSDR's comparison values. Therefore, arsenic will be evaluated further as a contaminant of concern (COC).

Arsenic

Arsenic is a naturally occurring element in the earth's soil. Natural soil background arsenic concentrations in the Puget Sound area have been reported to range from approximately 1.5 mg/kg to 17 mg/kg.[4] Higher arsenic values (greater than 50 mg/kg) were detected in the Tacoma vicinity (Point Defiance Park) probably due to fallout from the Asarco Smelter.

The main route of exposure for arsenic at the Des Moines and Federal Way sites is expected to be through ingestion of contaminated sediments. Dermal contact with sediments is unlikely to result in harmful exposure because arsenic is poorly absorbed through the skin. Ingestion of inorganic arsenic has been shown to cause cancer and many other health problems in people, including cardiovascular disease, stroke, diabetes, liver damage, nerve damage, and changes in the skin (i.e., hyperkeratinization of the skin especially on the palms and soles).[5] Inhalation of sediments is unlikely. Therefore, the

following evaluation will focus on the potential health hazard to children and adults by ingestion of contaminated sediments. For recreational beach use, it was assumed that exposure occurred one day per week during the calendar year, for a total of 52 days of exposure per year.

Health evaluation for Arsenic - Non-cancer effects

In order to evaluate the potential for non-cancer adverse health affects that might result from exposure to arsenic-contaminated soil and sediment, an exposure dose was estimated for children who might come into contact with the contamination during seasonal beach recreation. The estimated arsenic dose for this scenario was then compared to ATSDR's minimal risk level (MRL) and EPA's oral reference dose (RfD) which, for arsenic, have the same values. MRLs and RfDs are doses below which non-cancer adverse health effects are not expected to occur and, for arsenic, are based on effects seen in people. A level of uncertainty exists when defining an MRL or RfD because of uncertainty about the quality of data on which it is based. To account for this uncertainty, "safety factors" are used to set RfDs and MRLs below toxic effect levels (e.g., Lowest Observed Adverse Effect Level [LOAEL]) that have been observed in relevant studies. This approach provides an added measure of protection against the potential for adverse health effects to occur. For chronic oral exposure to arsenic, the MRL and RfD is 0.0003 milligrams of arsenic per kilogram of body weight per day (mg/kg/day).[6]

Because of uncertainty in these data, the toxic effect level is divided by "safety factors" to produce the lower and more protective RfD. If a dose exceeds the RfD, this indicates only the potential for adverse health effects. The magnitude of this potential can be inferred from the degree to which this value is exceeded. If the estimated exposure dose is only slightly above the RfD, then that dose will fall well below the toxic effect level. The higher the estimated dose is above the RfD, the closer it will be to the actual toxic effect level. This comparison is known as a hazard quotient (HQ) and is given by the equation below:

Equation 1

$$HQ = \frac{\text{Estimated Dose (mg/kg-day)}}{\text{RfD (mg/kg-day)}}$$

The calculated maximum soil arsenic concentration is 26 mg/kg at Wooten Park (Table 1 and Figure 2). An exposure scenario of 52 days per year at these sites with exposure to 26 mg/kg was used in dose calculations in Appendix A, Table A2. An older child (age 3-6) would receive an exposure dose of 0.000062, which is lower than the chronic MRL of 0.0003 mg/kg/day. **Overall, estimated doses for children and adults are below the acute and chronic MRLs indicating that non-cancer health effects are unlikely to occur from exposures to arsenic at these sites.**

Cancer effects

The EPA classifies arsenic as a Group A (known human) carcinogen by the oral and inhalation routes.[6] Theoretical cancer risk is estimated by calculating an exposure dose (Appendix A) similar to that described above and multiplying it by a cancer potency factor, also known as the cancer slope factor. Some cancer potency factors are derived from human population data. Others are derived from laboratory animal studies involving doses much higher than are encountered in the environment.

Use of animal data requires extrapolation of the cancer potency obtained from these high dose studies down to real-world exposures. This process involves much uncertainty.

Current regulatory practice assumes that there is no "safe dose" of a carcinogen and that a very small dose of a carcinogen could give a very small cancer risk. Theoretical cancer risk estimates are, therefore, not yes/no answers but measures of chance (probability). Such measures, however uncertain, are useful in determining the magnitude of a theoretical cancer risk. The validity of the "no safe dose" assumption for all cancer-causing chemicals is not clear. Some evidence suggests that certain chemicals considered carcinogenic must exceed a threshold of tolerance before initiating cancer. For such chemicals, risk estimates are not appropriate. More recent guidelines on theoretical cancer risk from EPA reflect the potential that thresholds for some carcinogenesis exist. However, EPA still assumes no threshold unless sufficient data indicate otherwise.

Theoretical Cancer Risk

Theoretical cancer risk estimates do not reach zero no matter how low the level of exposure to a carcinogen. Terms used to describe this risk are defined below as the number of excess cancers expected in a lifetime:

Term		# of Excess Cancers
low	is approximately equal to	1 in 10,000
very low	is approximately equal to	1 in 100,000
slight	is approximately equal to	1 in 1,000,000
insignificant	is less than	1 in 1,000,000

This document describes theoretical cancer risk that is attributable to site-related contaminants in qualitative terms like low, very low, slight and no significant increase in theoretical cancer risk. These terms can be better understood by considering the population size required for such an estimate to result in a single cancer case. For example, a low increase in cancer risk indicates an estimate in the range of one excess cancer case per ten thousand persons exposed over a lifetime. A very low estimate might result in one excess cancer case per several tens of thousands exposed over a lifetime and a slight estimate would require an exposed population of several hundreds of thousands to result in a single case. DOH considers theoretical cancer risk insignificant when the estimate results in less than one cancer per one million exposed over a lifetime. The reader should note that these estimates are for excess cancers that might result in addition to those normally expected in an unexposed population. Theoretical cancer risks quantified in this document are an upper-bound theoretical estimate. Actual risks are likely to be much lower.

EPA has derived a cancer potency factor based on these studies so that theoretical cancer risk to humans can be quantified. Theoretical cancer risk is the likelihood, or chance, of getting cancer. DOH used a cancer slope factor (CSF) of 5.7 mg/kg per day. The maximum arsenic concentration in the sediment exceeds the ATSDR CREG of 0.5 mg/kg. As mentioned above, exposure doses were calculated for an adult over a year exposure period with 52 days of exposure per year (specifically, one day per week). In a worst-case scenario, the current highest level of arsenic in the sediment (26 ppm) would increase a person's theoretical cancer risk by 5 in 100,000 (5 excess cancers in a population of 100,000 people exposed) (See Appendix A - Table A3). The reader should note that these estimates are for excess cancers that might result in addition to those normally expected in an unexposed population. These theoretical cancer risk estimates range from insignificant to very low.

The calculated theoretical lifetime cancer risk for adults exposed to arsenic-contaminated sediment along the shorelines of Des Moines and Federal Way is estimated at about seven additional cancers in a population of a million. **The risk from arsenic at these sites is very low (10^{-6} cancer risk).**

Uncertainty

Although there is some uncertainty surrounding the magnitude of the carcinogenic potential of arsenic, there is a strong scientific basis for choosing a slope factor that is different from the value (1.5 per mg/kg-day) currently listed in the EPA IRIS database.[6] Several recent reviews of the literature have evaluated bladder and lung cancer endpoints instead of skin cancer (which is the endpoint used for the current IRIS value):

- National Research Council (2001) [7]
- EPA Office of Drinking Water (2001) [8]
- Consumer Product Safety Commission (2003) [9]
- EPA Office of Pesticide Programs (2003) [10]
- California Office of Environmental Health Hazard Assessment (2004) [11]
- EPA IRIS Review Draft for the SAB (2005) [6]

Information provided in these reviews allows the calculation of slope factors for arsenic which range from 0.4 to 23 per mg/kg-day (but mostly greater than 3.7). The recent EPA IRIS review draft presented a slope factor for combined lung and bladder cancer of 5.7 per mg/kg-day. The slope factor calculated from the work by the National Research Council is about 21 per mg/kg-day. These slope factors could be higher if the combined risk for all arsenic-associated cancers (bladder, lung, skin, kidney, liver, etc.) were evaluated. For this Health Consultation, DOH used a slope factor of 5.7 per mg/kg-day, which reflects EPA's most recent assessment.

Child Health Considerations

Exposure scenarios for children's play activities that involve contact with Federal Way and Des Moines beach sediments, such as digging, were evaluated in this document to determine if children's exposures were of public health concern. ATSDR and DOH recognize infants and children are susceptible to chemical toxicity. Infants and children are also more vulnerable to exposures than adults. The following factors contribute to this vulnerability at this site:

- Children are more likely to play in ways that involve close contact with soil and sediment in contaminated outdoor areas.
- Children often bring food into contaminated areas, resulting in hand-to-mouth activities.
- Children are smaller and receive higher doses of metals exposure per body weight.
- Children are shorter than adults; therefore they are more likely to breathe in dust and soil.

These unique vulnerabilities of infants and children demand special attention in communities with water, food, soil, or air contamination. Children's health was considered in the writing of this health consultation and the exposure scenarios treated children as the most sensitive population being exposed.

It is expected that children will be playing and digging in contaminated sediment at these common use areas, especially from June through September. Children's activities on the beach may result in frequent, significant exposure to soil contaminants. The health risk from this exposure may be of concern over long periods of time**. The likelihood that children's exposure to arsenic will lead to illness depends on the frequency with which they come in contact with the soil and the amount of soil they might ingest. For most children, the long-term risks are low.**

Conclusion

Available environmental sampling data indicates there is some variation in contaminated sediment levels at the Federal Way and Des Moines beach sites. Areas with lower contaminant levels will generally be associated with lower degrees of hazard when people's exposures are the same. However, the true risk to the public is difficult to assess accurately and depends on the number of people who use each site, each person's exposure-related behaviors, and other site-related factors. Site-specific information about soil ingestion rates, frequency of visitation, and bioavailability of contaminants could improve the accuracy of this health evaluation but these data are not available. Further, sedimentation trends and how the levels change over time are difficult to predict.

Overall, the estimated non-cancer and theoretical cancer risk is low. Considering the exposure scenarios described above, this means that chronic and/or acute diseases are unlikely to occur from exposures to arsenic at these sites.

Recommendation

- Although sediments at the Federal Way and Des Moines beach sites do not appear to be degraded (i.e., impacted by chemical contamination above levels of health concern), DOH supports Ecology's initiative to conduct future sediment surveys in Puget Sound areas with sediment quality to ensure that areas impacted with chemical pollution are cleaned up.

- DOH also supports efforts by Ecology to evaluate deeper sediments disturbed by the Geoduck harvesting process (i.e., down to three feet).

Public health action plan

- DOH is available to review sediment and/or tissue data from certified shellfish area sites in the future if data become available.

Figure 1. Shellfish certified harvest area and potential contaminant sources within a mile of Federal Way and Des Moines, Pierce and King County, Washington.

Figure 2. Sediment sampling sites, Federal Way and Des Moines, Pierce and King County, Washington.

Figure 2. Soil arsenic levels at Federal Way and Des Moines sites, Pierce and King County, Washington.

Appendix A

Exposure Calculations

This section provides calculated exposure doses and assumptions used for exposure to arsenic in sediments near Federal Way and Des Moines, Pierce and King Counties, Washington. The following exposure parameters and dose equations were used to estimate exposure doses from ingestion, direct contact, and inhalation of arsenic in sediments. The reader should be aware that maximum concentrations were used to calculate these doses in order to represent a worst-case scenario. This assumption may overestimate actual exposure, but it is intended to be protective of public health.

Three different receptor populations were considered when calculating non-cancer doses: children (0-2 years old), older children (3-15 years old), and adults. Cancer dose calculations assumed a 30-year exposure of a child growing to adulthood.

Exposure to arsenic in sediments via ingestion, inhalation, and dermal absorption.

Total dose $_{\text{(non-cancer)}}$ = Ingested dose + inhaled dose + dermally absorbed dose

Ingestion Route

$$\text{Dose}_{\text{(non-cancer (mg/kg-day))}} = \frac{Cw \times CF \times IR \times EF \times ED}{BW \times AT_{\text{non-cancer}}}$$

$$\text{Cancer Risk} = \frac{Cw \times CF \times IR \times EF \times CSF \times ED}{BW \times AT_{\text{cancer}}}$$

Dermal Route - (Shower)

$$\text{Dermal Absorbed } (DA_{event}) = \frac{2 \times Kp \times Cw \times \text{SqR of } 6 \times tau \times t/pi}{ORAF}$$

$$\text{Dermal Absorbed Dose (DAD)}_{\text{(non-cancer (mg/kg-day))}} = \frac{DA_{event} \times EV \times SA \times EF \times ED}{BW \times AT_{\text{non-cancer}}}$$

$$\text{Dermal Absorbed Dose (DAD)}_{\text{(cancer (mg/kg-day))}} = \frac{DA_{event} \times EV \times SA \times EF \times ED \times CSF}{BW \times AT_{\text{cancer}}}$$

Inhalation Route – (Shower)

$$\text{Concentration in air (Ca)} = S/R \times (1 - (EXP\ (-R \times t)))$$

$$\text{Dose}_{\text{non-cancer (mg/kg-day)}} = \frac{Ca \times IHR \times EF \times ED}{BW \times AT_{\text{non-cancer}}}$$

$$\text{Cancer Risk} = \frac{\text{Ca x IHR x EF x ED x CSF}}{\text{BW x AT}_{\text{cancer}}}$$

Table A1. Exposure Assumptions for exposure to arsenic at Federal Way and Des Moines sediment sites, King and Pierce Counties, WA.

Parameter	Value	Unit	Comments
Concentration (C)	variable	mg/kg	Maximum concentration
Conversion Factor (CF)	0.000001	kg/mg	Converts contaminant concentration from milligrams (mg) to kilograms (kg)
Ingestion Rate (IR) – adult	100*	mg/day	Estimated Soil ingestion rate by children for As and Cd.[12]
Ingestion Rate (IR) – older child	300*		
Ingestion Rate (IR) - child	300*		
Exposure Frequency (EF)	52	days/year	Average days exposed to beach sediment
Exposure Duration (Ed)	(4, 9, 15)	years	Number of years at one residence (child, older child, adult years)
Body Weight (BW) - adult	70	kg	Adult mean body weight
Body Weight (BW) – older child	41		Older child mean body weight
Body Weight (BW) - child	19		3-6 year-old child average body weight
Surface area (SA) - adult	5700	cm^2	Risk Assessment Guidance (EPA) [13]
Surface area (SA) – older child	2900		
Surface area (SA) - child	2900		
Averaging $Time_{non\text{-}cancer}$ (AT)	3285	days	Child 7-15 years
Averaging $Time_{cancer}$ (AT)	27375	days	75 years
Cancer Potency Factor (CPF)	As: 5.7E+00	mg/kg-day^{-1}	Source: EPA: CPF are presented in Table A3
24 hr. absorption factor (ABS)	0.03	unitless	Source: EPA Chemical Specific Arsenic – 0.03 Inorganic – 0.001 Organic – 0.01
Oral route adjustment factor (ORAF)	1	unitless	Non-cancer (nc) / cancer (c) - default
Adherence duration (AD)	1	days	Source: EPA
Adherence factor (AF)	0.2	mg/cm^2	Child, older child
	0.07		Adult
Inhalation rate (IHR) - adult	15.2	m^3/day	Exposure Factors Handbook [14]
Inhalation rate (IHR) – older child	14		
Inhalation rate (IHR) - child	8.3		
Soil matrix factor (SMF)	1	unitless	Non-cancer (nc) / cancer (c) - default
Particulate emission factor (PEF)	1.45E+7	m^3/kg	Model Parameters

As: Arsenic

* For Exposures at the beach, children are assumed to potentially ingest greater amounts of soil/sediment than they would at home; consequently, the soil/sediment ingestion rate selected for the maximum concentration and EPA's risk-based screening concentration (RBC) is 300 mg/day, rather than 200 mg/day.[12]

Table A2. Non-cancer hazard calculations resulting from exposure to arsenic at Federal Way and Des Moines sediment sites, Pierce and King Counties, WA.

Contami_ nant	Max concentration (mg/kg)	Scenarios	Estimated Dose (mg/kg/day)			Total Dose	RfD (mg/kg/day)	Hazard quotient
			Incidental Ingestion of Soil	Dermal Contact with Soil	Inhalation of Particulates			
Arsenic	26	Child 0-2	9.3E-05	5.4E-06	8.0E-09	9.8E-05	3E-4	0.3
		Older child 3-6	5.9E-05	3.4E-06	4.1E-08	6.2E-05		0.2
		7-15	2.7E-05	1.6E-06	8.2E-08	2.9E-05		0.096
		Adult	5.3E-06	6.3E-07	6.0E-08	6.0E-06		0.020

Soil Ingestion Route of Exposure – Theoretical Cancer

Table A3. Theoretical cancer risk resulting from exposure to arsenic at Federal Way and Des Moines sediment sites, Pierce and King Counties, WA.

Contaminant	Maximum Concentration (mg/kg)	EPA cancer Group	Cancer Potency Factor ($mg/kg\text{-}day^{-1}$)	Scenarios	Increased Cancer Risk			Total Cancer Risk
					Incidental Ingestion of Soil	Dermal Contact with Soil	Inhalation of Particulates	
Arsenic	26	A	5.7	Child 0-2	1.8E-05	1.0E-06	2.0E-08	1.9E-05
			5.7	Child 7-15	1.9E-05	1.1E-06	7.0E-08	2.0E-05
			5.7	Adult	6.0E-06	7.2E-07	6.3E-08	6.8E-06

Lifetime theoretical cancer risk: 1.9E-5 + 2.0E-5 + 6.8E-6 = 4.6E-5

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