Health Consultation

Evaluation of Contaminants in Sediment, Fish, Shellfish, and Plant Tissues from Port Gardner and the Lower Snohomish Estuary

Port Gardner, Snohomish County, Washington

June 16, 2011

Prepared by

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

Washington State Department of Health

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Foreword

The Washington State Department of Health (DOH) has prepared this health consultation in accordance with methodologies and guidelines developed by 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 sites and releases.

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.

This report was supported by funds from a cooperative agreement with ATSDR. However, it has not been reviewed and cleared by ATSDR.

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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

Acute	Occurring over a short time [compare with **chronic**].
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.
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).
Cancer Slope Factor	A number assigned to a cancer causing chemical that is used to estimate its ability to cause cancer in humans.
Carcinogen	Any substance that causes cancer.
Chronic	Occurring over a long time (more than 1 year) [compare with **acute**].
Comparison value (CV)	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.
Indeterminate public health hazard	The category used in ATSDR's public health assessment documents when a professional judgment about the level of health hazard cannot be made because information critical to such a decision is lacking.
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 (IR)	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.
Lowest Observed Adverse Effect Level (LOAEL)	The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.
Media	Soil, water, air, plants, animals, or any other part of the environment that can contain contaminants.

Minimal Risk Level (MRL)	An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified time period (acute, intermediate, or chronic). MRLs should not be used as predictors of harmful (adverse) health effects [see **oral reference dose**].
Model Toxics Control Act (MTCA)	The hazardous waste cleanup law for Washington State.
No Observed Adverse Effect Level (NOAEL)	The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.
Oral Reference Dose (RfD)	An amount of chemical ingested into the body (i.e., dose) below which health effects are not expected. RfDs are published by EPA.
Organic	Compounds composed of carbon, including materials such as solvents, oils, and pesticides that are not easily dissolved in water.
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.
Reference Dose Media Evaluation Guide (RMEG)	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 EPA's oral reference dose (RfD).
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].

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Executive Summary

Introduction	This health consultation was prepared at the request of the Washington State Department of Ecology (Ecology) and the Tulalip Tribe. The purpose of this health consultation is to evaluate contaminant data from the Port Gardner site in Everett, Washington and make recommendations for actions that ensure the public's health is protected. The Washington State Department of Health evaluated contaminants present in the surface sediment, fish/shellfish, and plant tissue. Contaminants in fish and shellfish were evaluated from the Port Gardner site. Total arsenic, mercury, and total dioxins (Tables 2 through 4) exceeded health comparison values; thus these contaminants were evaluated further. DOH used the general population and the Tulalip tribal consumption scenario to calculate risks from total seafood (i.e. bottom fish, crab, and clams). Generally, all contaminant concentrations detected in surface sediment at the Port Gardner site were low, except for total arsenic and total carcinogenic polycyclic aromatic hydrocarbons (cPAHs). Arsenic and cPAHs were evaluated further as contaminants of concern. This evaluation focused on potential health impacts for direct human contact with contaminated sediments through work related and recreational activities. The evaluation of plants is based on a review of the scientific literature specifically pertaining to the accumulation potential of contaminants in plants. Contaminants were present in plant tissues (Cattail and Tule plants) at very low levels.
Conclusions	Based on the information provided, DOH concludes the following:
Conclusion 1	Results based on consumption of seafood at tribal scenario rates, cancer health effects Eating seafood (bottom fish, crabs, and clams) at Tribal scenario rates (see Appendix D for Tulalip Tribe consumption rates) could harm the health of an adult. Subsistence fishers (tribes or nations) that eat seafood will most likely be at risk of developing cancer if arsenic and dioxin exposures are assumed from childhood into adulthood (average cancer risk over a 70 year lifetime exposure). Although the excess theoretical cancer risk is considered low, the sum of the cancer risks are above EPA's acceptable range of 1 excess cancer risk per 10,000 people exposed. If tribes or nations are harvesting from Port Gardner and consuming at Tribal consumption rates, this would represent a "*public health hazard.*" However, it is unlikely that 100 percent of subsistence consumers (tribes or nations) would be consuming and harvesting seafood from Port Gardner only.

Basis for Decision	Based on Tribal scenario consumption rates, exposures are above EPA's acceptable range of 1 excess cancer risk per 10,000 people exposed. Results based on consumption of seafood at tribal scenario rates, non-cancer health effects Non-cancer health effects are not likely if people eat seafood (bottom fish, crab, and clams) at Tribal scenario rates (see Appendix D for Tulalip Tribe consumption rates).
Basis for Decision	Based on exposure assumptions and calculations, contaminants present in bottom fish, crab, and clams are below levels known to result in harmful non-cancer health effects.

Conclusion 2	Results based on consumption of seafood for the general (non-tribal) population, non-cancer and cancer health effects Eating bottom fish or shellfish from Port Gardner is not expected to harm the health of the general (non-tribal) population (children or adults). Overall, a lifetime increase of theoretical cancer risk associated with exposure to arsenic and dioxin in bottom fish and shellfish is very low (i.e., theoretical cancer risk estimates are 4 excess cancers in 100,000 people exposed). However, dioxins is insignificant (i.e., theoretical cancer risk estimates are 1 excess cancer in 1,000,000 people exposed).
Basis for Decision	Based on consumption rates for the general population, exposures are below levels known to result in harmful cancer and non-cancer health effects.

Conclusion 3	Results based on surface sediment contaminant exposure, non-cancer and cancer health effects Touching, breathing, or accidentally eating sediment containing arsenic and carcinogenic polycyclic aromatic hydrocarbons (cPAHs) approximately five-days-per-week or 250 days per year (adult) and/or 52 days per year (a child) from Port Gardner is not expected to harm people's health.
Basis for Decision	Based on exposure calculations, the maximum levels of arsenic and cPAHs in surface sediment are below levels known to result in harmful non-cancer and cancer health effects for an adult and children. Overall, a lifetime increase of theoretical cancer risk associated with exposure to arsenic in the surface sediment is low and cPAHs is insignificant.

Conclusion 4	Results based on plant tissue data Plant ingestion rates were not available to quantify human exposure to site-specific contaminants in Port Gardner. DOH acknowledges that workers (e.g., basket weavers and/or plant harvesters) who spend most of the day in an enclosed environment may inhale substantial amounts of dust and small soil particulates bound to plant materials. If the plant materials, dust, and/or soil particulates contain high concentrations of contaminants, workers may be exposed at levels that could be harmful. DOH is unable to determine levels of contaminants in these plants (i.e., Cattail and Tule plants) that may cause an adverse health effect in workers due to the lack of data.
Basis for Decision	Based on available information related to the contaminant levels of chemicals (i.e., metals) in plant tissue, DOH cannot currently conclude whether eating or inhaling plant tissue could harm people's health.

Next Steps

1. DOH recommends that the general population and the Tulalip Tribe follow the Puget Sound fish consumption advisory for Recreational Marine Area 8-2 (Port Susan and Port Gardner) and the Puget Sound crab consumption advisory for Port Gardner, which has meal restrictions for seafood harvested in urban areas. More information regarding these advisories is available on the DOH website (http://www.doh.wa.gov/fish) or by calling toll-free 1-877-485-7316.

2. As a prudent public health measure, DOH recommends following advice for cleaning and preparing fish and shellfish to reduce exposure to contaminants that accumulate in the fat of fish and shellfish. This method of preparation can be found in the General Advice section of this document along with other ways to minimize exposures.

3. DOH will develop a fact sheet that summarizes the findings of this health consultation.

4. DOH will coordinate with Ecology on the development of the fact sheet. DOH will plan to distribute the fact sheet within two months of the health consultation being finalized.

5. DOH will provide copies of this health consultation to Ecology and concerned parties when the report is approved.

6. DOH will be available any time to answer health related questions regarding Port Gardner site contaminants.

Purpose

The Washington State Department of Health (DOH) prepared this health consultation at the request of the Tulalip Tribe and the Department of Ecology, Toxics Cleanup Program (TCP). The purpose of this health consultation is to evaluate contaminant data from the Port Gardner site in Everett, Washington and to make recommendations for actions that ensure the public's health is protected. DOH prepares health consultations under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR).

Background and Statement of Issues

Port Gardner is an embayment of Puget Sound's Whidbey Basin, bordered to the east by the City of Everett (Figure 1). The Snohomish River system, the second largest river discharge into Puget Sound, empties into Port Gardner Bay at the City of Everett waterfront and provides approximately 30 percent of the freshwater discharge to the Whidbey Basin.

Port Gardner has a wide variety of commercial and industrial uses, multiple potential point sources of contamination, and an overall history of contamination. Since the early 1900s, the lower Snohomish River has been used for commercial and industrial purposes, often related to timber and maritime industries (saw mills, paper production, boat building, and waste disposal). In the last 25 years, several sediment investigations have detected chlorinated aromatics, polycyclic aromatic hydrocarbons (PAHs), metals, miscellaneous extractables (such as resin acids and guaiacols), pesticides, phenols, and phthalates at levels exceeding Ecology's current Sediment Management Standards (SMS) criteria at numerous locations throughout Port Gardner. The most extensive contamination has been identified within the East Waterway which has been dredged in the past.

The Everett waterfront is a treasure serving local and regional needs for business and industry, recreation, housing, and cultural activities (e.g. fishing and foraging in the bay). A more detailed history and description of this site can be found in the data report titled "Sediment Characterization Study in Port Gardner and Lower Snohomish Estuary, Port Gardner, Washington" [1].

The Tulalip Tribe is a federally recognized Indian tribe located on the Tulalip Reservation in the mid-Puget Sound area near the town of Marysville, Washington (Figure 1). The Tulalip Reservation exterior boundaries enclose a land base of 22,000 acres, more than 50 percent of which is in federal trust status. The Reservation is rich with natural resources including marine waters, tidelands, fresh water creeks and lakes, wetlands, forests, and developable land.

Native American Tribes and Nations in the Puget Sound have reserved the right to take fish and shellfish at their usual and accustomed grounds and stations. In addition to fishing, other reserved cultural activities include hunting, gathering traditional and medicinal plants, and other activities.

These usual and accustomed treaty fishing areas include the freshwater areas of the Snohomish-Snoqualmie-Skykomish river basin and certain marine waters of the Puget Sound.

The Tulalip Indian Tribal Community stated that Port Gardner is an important historic harvest site that has been impacted by contamination that currently limits the Tulalip tribal community from access and use of treaty protected natural resources within their treaty protected areas.

The Tulalip Tribe expressed concern about the safety of using plant and animal resources from Port Gardner and/or areas near Port Gardner where the Tribe may use these resources for subsistence and/or traditional practices. This evaluation has three data components: 1) surface sediment, 2) fish/shellfish, and 3) plant tissue. The evaluation of plants is based on a review of the scientific literature specifically pertaining to the accumulation potential of contaminants in plants. The objective of this study is to evaluate the contaminants of concern identified during this sampling investigation and assess potential human health risks. This report also provides perspective on whether these contaminants are likely to accumulate in the plant tissues traditionally used by the tribe.

Existing Fish Consumption Advisories

DOH has issued a Puget Sound Fish consumption advisory for Recreational Marine Area 8-2 (Port Susan and Port Gardner) and a Puget Sound crab consumption advisory for Port Gardner. This advisory recommends the following:

1. Eat no more than two meals per month for rockfish and flat fish (e.g., sole, sanddab, and flounder), and no more than two meals per month for Chinook salmon.

2. Eat Dungeness and Red Rock crab from non-urban areas and do not eat the "crab butter" (viscera). Data have shown that crabs from industrial urban areas may contain more contaminants than those from non-urban areas, and that crab butter (viscera) has more contaminants than crab muscle. More information regarding these advisories is available at http://www.doh.wa.gov/fish or by calling toll-free 1-877-485-7316.

Discussion and Results

A summary of the contaminants of concern are presented in Table 1 – Table 5. Appendix A, Table A1-A6 list all sampling results of contaminants detected in surface sediment, fish, shellfish, and plant tissues found at Port Gardner.

Sample collection and analysis

As part of the Puget Sound Initiative, Ecology identified Port Gardner and the Lower Snohomish River Estuary as a high priority area for cleanup and restoration because it is an important habitat and contains valuable natural resources. In 2008, Ecology conducted a bay wide sediment investigation of Port Gardner and the lower Snohomish River Estuary. Ecology collected surface (depth of 0 - 0.3 feet) and subsurface sediment [a] (depth of 0.3 - 11 feet), fish (bottom fish), shellfish, crab, and plant tissue samples from these areas. More information about detailed sample collection and analysis for Port Gardner can be found in the data report titled "Sediment Characterization Study in Port Gardner and Lower Snohomish Estuary, Port Gardner, Washington" [1].

Methods, results, quality assurance/quality control (QA/QC), and data validation are summarized in the final data report - Sediment Characterization Study in Port Gardner and Lower Snohomish Estuary, Port Gardner, Washington [1]. In general, all data validation reports followed the specified analytical methods. Accuracy was acceptable as demonstrated by the surrogate, laboratory control samples, and matrix spikes/matrix spike duplicates percent recovery values with the exceptions noted in the report.

Contaminant screening

Contaminants of concern (COC) in surface sediment, fish, and shellfish were determined by employing a screening process. DOH uses ATSDR comparison values as health based screening values (SVs), whenever available, to identify COCs. In the absence of ATSDR comparison values, DOH may also use other SVs including the Environmental Protection Agency's (EPA) health guideline values or other available values.

Several types of health-based SVs were used during this process including ATSDR's cancer risk evaluation guides (CREG), environmental media evaluation guides (EMEGs), and reference dose media evaluation guides (RMEG) (see the glossary for descriptions of CREGS, EMEGs, and RMEGs). Comparison values such as the CREG and EMEG offer a high degree of protection and assurance that people are unlikely to be harmed by contaminants in the environment. For chemicals that cause cancer, the comparison values represent levels that are estimated to increase the risk of cancer for similarly exposed persons by about one in a million. That risk, however, could be as low as zero.

Surface sediment, fish, and shellfish were screened using values that DOH considers protective for the general population and for tribal exposure scenarios. There are no available comparison values for plant tissue data.

In this health evaluation, maximum surface sediment levels were screened against ATSDR soil comparison values, the Washington State Model Toxics Control Act (MTCA) soil cleanup levels, and EPA's Preliminary Remediation Goals (PRGs) regional screening levels for soils (see Table 1 and Appendix A - Table A1). SVs for fish and shellfish were developed according to EPA guidance (Appendix A) and are used to narrow the focus of evaluation to contaminants that are present at potential levels of public health concern. Maximum fish and shellfish contamination levels for each contaminant were screened against SVs for non-cancer health effects (see Table 2 through Table 4 and Appendix A - Table A2). Contaminant concentrations

[a] This evaluation will not consider subsurface samples. People are unlikely to be exposed to contaminants in the deeper sediment. Digging at this depth (i.e., > 0.3 - 11 feet) in these sediments is unlikely at the Port Gardner site.

exceeding these comparison values do not necessarily pose health threats but are evaluated further to determine whether they are at levels of human health concern.

Surface sediment

Surface sediment samples were collected from numerous locations from Port Gardner and the Lower Snohomish River Estuary. Some locations included intertidal areas (i.e., clam sampling locations). Levels of contaminants were highest in the East Waterway, Snohomish River and in Steamboat Slough locations at Port Gardner Bay. Levels of contaminants at other locations were low and/or below comparison values. Appendix A, Table A1 shows levels of all surface sediment contaminants sampled at Port Gardner. Table 1 shows maximum levels of contaminants that exceeded comparison values. Since some levels of contaminants were found in the surface sediment in recreational and industrial areas, people are likely to come in contact with the contaminants. Thus, this evaluation will focus on potential health impacts for direct human contact with contaminated surface sediments through work-related activities (i.e., marine worker), and/or outdoor activities (i.e., recreational activities)[b]. Arsenic and total cPAHs TEQs exceeded comparison values; thus, these contaminants will be evaluated further as contaminants of concern.

Table 1. Maximum contaminant concentrations detected in surface sediment at Port Gardner site, Everett, Snohomish County, Washington.

Chemical	Maximum Concentration (mg/kg)	Comparison Value (mg/kg)	EPA Cancer Class	Comparison Value Reference	Contaminant of Concern (COC)
Arsenic	50	20 [a]	A	EMEG	**Yes**
Total cPAH TEQ	0.61	0.1[b]	B2	CREG	**Yes**

Bold values exceed comparison value
EMEG - ATSDR's Environmental Media Evaluation Guide (child)
CREG – ATSDR's Cancer Risk Evaluation Guide
A – EPA: Human carcinogen
B2 – EPA: Probable human carcinogen (inadequate human, sufficient animal studies)
[a] – Comparison value for soil
[b] – Comparison value corresponds to benzo (a) pyrene.
Total cPAH TEQ – sum of all carcinogenic polycyclic aromatic hydrocarbons (cPAHs) toxic equivalent (TEQ), all cPAHs in COC are added using the TEQ approach to obtain Total cPAH TEQ.
mg/kg – milligrams per kilograms

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[b] DOH used 52 days/year of exposure for a child playing and/or digging in the sediment in recreational areas. In general, EPA recommends the central tendency of 350 days/year for residential exposures to soil and Reasonable Maximum Exposure (RME) of 250 days/year for industrial scenarios for workers. EPA suggests that exposure duration may be adjusted to reflect site-specific conditions [2,3]. Thus, current exposure assumptions used in this health evaluation were very conservative and represented actual occurrences as accurately as possible.

Contaminants of concern in seafood

A number of contaminants were detected in seafood (i.e., English sole, clams and crabs) (see Appendix A, Table A2 and A3 for a list of all detected contaminants).The maximum concentration of each contaminant was compared to SVs to identify COCs. Only total arsenic, mercury and total dioxins exceeded the SVs (Tables 2, 3, and 4). Thus, only these contaminants were further evaluated. In general, if a contaminant level is greater than its screening value, it does not mean that people will get sick but that the contaminant needs to be evaluated further.

Table 2. Maximum concentration of contaminants detected in Dungeness crab tissue (meat) sampled at Port Gardner site, Everett, Snohomish County, Washington.

Chemicals	Contaminant maximum concentration (ppm)	Screening Values [a] (ppm)		EPA Cancer Class	RfD (mg/kg/day)	Contaminant of concern
		General Population	Subsistence population			
Arsenic total	**5.0**	1.2	0.147	A	0.0003	**Yes**
Mercury	**0.07**	0.4	0.049	D	0.0001*	**Yes**
Total Dioxin TEQ	**1.6×10^{-7}**	4.0×10^{-6}	4.9×10^{-7}	B2	1.0×10^{-9}***	**Yes**

BOLD values exceeded comparison values
[a] – Source of screening values are listed in Appendix A
A - EPA: Human carcinogen
B2 - EPA: Probable human carcinogen (inadequate human, sufficient animal studies)
D - EPA: Not classifiable as to health carcinogenicity
* Minimal Risk Level (MRL) for methylmercury
*** ATSDR Minimal Risk Level (MRL) for Dioxin total equivalent (TEQ)
RfD – Reference dose
mg/kg/day – milligrams per kilograms per day
ppm – parts per million

Table 3. Maximum concentration of arsenic detected in English sole and clam tissues sampled at Port Gardner site, Everett, Snohomish County, Washington.

Chemicals	Contaminant maximum concentration (ppm)			Screening Values [a] (ppm)		EPA Cancer Class	RfD (mg/kg/day)	Contaminant of concern
	English sole	Varnish clam†	Eastern soft shells	General Population	Subsistence population			
Arsenic total	**3.0**	**1.0**	**2.0**	1.2	0.147	A	0.0003	**Yes**

A - EPA: Human carcinogen
[a] – Source of screening values are listed in Appendix A
† Varnish clams were sampled for Ecological purposes. Consumption of these clams is very insignificant, thus DOH is not evaluating these clams.
BOLD - values exceed screening levels
ppm – parts per million
RfD – Reference dose
mg/kg/day – milligrams per kilograms per day

Table 4. Dioxin concentrations detected in Dungeness crab, fish, and shellfish from Port Gardner site, Everett, Snohomish County, Washington.

Species	Contaminant	Maximum Concentration (ppt)	Range of Concentration (ppt)	Screening Value [a] (ppt)	
				U.S. EPA (subsistence fishers) (cancer)	Subsistence population (non cancer)
Dungeness crab (hepato pancreas)*	Total Dioxin TEQ	**4.38**	3.6 – 4.38	0.0315	0.49
Dungeness crab (meat)		**0.16**	0.09 – 0.155		
English Sole		**0.306**	0.128 – 0.306		
Varnish clam †		**0.104**	0.0258 – 0.104		
Eastern softshell clam		**0.034**	0.0156 – 0.034		

BOLD – values exceed screening value
Total Dioxin TEQ – sum of dioxin/furans toxic equivalent (TEQ) using half detection limit
[a] – Source of screening values are listed in Appendix A
† Varnish clams were sampled for Ecological purposes. Consumption of these clams is very insignificant, thus DOH is not evaluating these clams.
***** Only crab meat data is used for this evaluation. Hepatopancreas won't be considered in the analysis because as mentioned above there is an existing fish consumption advisory placed in this area that warns the consumption of Dungeness crab from industrial or urban areas. The advisory warns against eating hepatopancreas from all areas across Puget Sound. http://www.doh.wa.gov/fish
ppt – parts per trillion
U.S. EPA – United States Environmental Protection Agency

Exposure Pathways

In order for any contaminant to be a health concern, the contaminant must be present at a high enough concentration to cause potential harm, and there must be a completed route of exposure [c] to people. In general, people can be exposed to contaminants through incidental ingestion of soils or sediments that are contaminated, eating contaminated foods and drinking water, inhaling airborne contaminants, and skin contact with contaminated media. Human use patterns and site-specific conditions were considered in the evaluation of exposure to the contaminants of concern identified in Tables 1 to 4. Exposure to contaminants in sediments occurs through inadvertent sediment ingestion, dust particle inhalation, and dermal absorption of contaminants in sediment during beach play. Exposure to contaminants in bottom fish, crab, and clams at the Port Gardner site for the general population and a subsistence fish/shellfish consumer occurs mainly through ingestion.

Ingestion exposure (swallowing)

Most people inadvertently swallow small amounts of sediment, soil, and dust (and any contaminants they might contain). Young children often put hands, toys, pacifiers, and other things in their mouths, and these items may have dirt or dust on them that may be swallowed. Adults may ingest sediments, soil, and dust through activities such as gardening, mowing, construction work, dusting, and recreational activities. For chemicals (like dioxins) that are persistent and build up over time, contaminants in food are the primary source of exposure. Meat, dairy products, and fish contribute more than 90% of the dioxin intake for the public. Therefore, everyone has some dioxin in their body. Yet for most, it is not a health threat; the health threat depends on how much meat or seafood a person eats, over what period of time and the level of contamination found.

Inhalation exposure (breathing)

Although people can inhale suspended sediment, soil, or dust, airborne sediment usually consists of relatively large particles that are trapped in the nose, mouth, and throat and are then swallowed, rather than breathed into the lungs.

Skin exposure (dermal)

Dirt particles that can adhere to the skin may cause additional exposure to contaminants through dermal absorption. Although human skin is an effective barrier for many environmental contaminants, some chemicals can move easily through the skin.

Exposure to contaminants in bottom fish, crab, and clams at the Port Gardner site for the general population and a subsistence fish/shellfish consumer occurs mainly through ingestion.

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[c] Route of exposure means the way people come into contact with a hazardous substance. There are three routes of exposure, breathing (inhalation), eating or drinking (ingestion), or contact with the skin (dermal contact). A completed exposure pathway exists when there is direct evidence of a strong likelihood that people have in the past or are presently coming in contact with site-related contaminants.

The following discussion addresses human use patterns and site-specific conditions that are considered in the evaluation of exposure to contaminants in bottom fish, crab, and clams, and contaminants in surface sediment at the Port Gardner site. Exposure to contaminants in surface sediments can occur through the following pathways and routes:

- Inadvertent sediment ingestion, dust particle inhalation, and dermal absorption of contaminants in sediment during beach play.

As mentioned earlier, exposures to contaminants in bottom fish, crab, and clams occurs mainly through ingestion.

Chemical Specific Toxicity

Below are general summaries of arsenic, polycyclic aromatic hydrocarbons, dioxins, and mercury health effects. The non-cancer and cancer health effects are described in the next section.

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) have been detected at other Puget Sound sites in the Tacoma vicinity (Point Defiance Park), which is probably due to fallout from the Everett Asarco Smelter. The Everett Asarco smelter operated in the early 1900s. The smelter and its smokestack polluted most of the soil in Northeast Everett [5].

The main route of exposure for arsenic at Port Gardner site is expected to be through ingestion of contaminated surface 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 [d] of the skin especially on the palms and soles) [6]. Therefore, the following health evaluation will focus on the potential health hazard to an adult (i.e., a marina worker) and children by ingestion of contaminated surface sediments. For marina workers, it was assumed that exposure occurred 250 days per year with exposure duration of 30 years, for children, exposures were assumed to occur during 52 days per year.

[d] Hyperkeratinization is an excessive development or retention of keratin tissue in the epidermis. It is an abnormally horny thickening of the epithelium of the palms and soles.

Polycyclic Aromatic Hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons (PAHs) are generated by the incomplete combustion of organic matter including oil, wood, and coal. They are found in materials such as creosote, coal, coal tar, and used motor oil. Based on structural similarities, metabolism, and toxicity, PAHs are often grouped together when one is evaluating their potential for adverse health effects. EPA has classified some PAHs as probable human carcinogens – called cPAHs – (B2) as a result of *sufficient* evidence of carcinogenicity in animals and *inadequate* evidence in humans.

Benzo(a)pyrene is the only cPAH for which EPA has derived a cancer slope factor. The benzo(a)pyrene cancer slope factor was used as a surrogate to estimate the total cancer risk of cPAHs in surface sediment. It should be noted, benzo(a)pyrene is considered the most carcinogenic of the cPAHs. The use of its cancer slope factor as a surrogate for total cPAH carcinogenicity may overestimate risk. To address this issue, DOH made an adjustment for each cPAH based on the relative potency to benzo(a)pyrene or TEQ.

Dietary sources make up a large percentage of PAH exposure in the U.S. population. Smoked or barbecued meats and fish contain relatively high levels of PAHs. The majority of dietary exposure to PAHs for the average person comes from ingestion of vegetables and grains (cereals) [7].

Dioxins – General Occurrence and Toxicity

Dioxins and furans

Dioxins and furans consist of about 210 structural variations of dioxin congeners, which differ by the number and location of chlorine atoms on the chemical structure. The primary sources of dioxin releases to the environment are: the combustion of fossil fuels and wood; the incineration of municipal, medical, and hazardous waste; and certain pulp and paper processes. Dioxins also occur at very low levels from naturally occurring sources and can be found in food, water, air, and cigarette smoke.

The most toxic of the dioxin congeners, 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) can cause chloracne (a condition of acne like lesions on the face and neck). Exposure to high levels of dioxins can cause liver damage, developmental effects, and impaired immune function. Long-term exposure to dioxins could increase the likelihood of developing cancer. Studies in rats and mice exposed to TCDD resulted in thyroid and liver cancer [8]. EPA considers TCDD to be a probable human carcinogen and developed a cancer slope factor of 1.5 x10^5 mg/kg/day [9,10].

Dioxins and Furans, and TEQ concentrations

Dioxins are a class of chemicals, and the most toxic of these compounds is 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (commonly referred to as TCDD or dioxin). There are many forms of dioxins and “dioxin-like compounds” (DLCs) that share most, if not all, of the toxic potential of TCDD, although nearly all are considerably less potent. Included in the list of DLCs are chlorinated forms of dibenzofurans and certain polychlorinated biphenyls (PCBs). Although several dioxin and furan congeners were analyzed in the surface sediment, only a single value, called a dioxin toxic equivalent (TEQ), was used to determine non-cancer health threat and cancer risks.

Each dioxin/furan is multiplied by a Toxic Equivalency Factor (TEF) [e] to produce the dioxin TEQ. The TEQs for each chemical are then summed to give the overall 2,3,7,8-tetrachlorodibenzo-p-dioxin TEQ. The TEQ approach is based on the premise that many dioxins/furans and in general dioxin-like PCB congeners are structurally and toxicologically similar to 2,3,7,8-tetrachlorodibenzo-p-dioxin. TEFs are used to account for the different potencies of dioxins and furans relative to 2,3,7,8-tetrachlorodibenzo-p-dioxin, and are available for ten chlorinated dibenzofurans and seven chlorinated dibenzodioxins using the World Health Organization (WHO) methodology [11].

Mercury

Mercury exists in the environment in three forms: elemental, inorganic, and organic. Methylmercury is the form of organic mercury related to exposure in seafood and usually only represents a portion of the mercury detected in shellfish. However, because analytical laboratories only analyze for total mercury, we conservatively assume that all the mercury detected in seafood at this site (i.e. Dungeness crab) is methylmercury.

Methylmercury is formed from inorganic mercury in the environment by microorganisms in aquatic systems. Through the process of biomagnification, larger fish at the top of the food chain may contain higher concentrations of methylmercury than the smaller fish they consume. This represents a potential health concern for consumers of fish.

Ingested methylmercury is readily absorbed by the body and, in pregnant women, can be distributed to the developing fetus. In Minamata Bay, Japan, mothers who were exposed to high amounts of mercury but were asymptomatic gave birth to severely affected infants. Other epidemiologic studies have shown developmental effects in both animal and human studies are the primary concern about methylmercury exposure. The EPA established RfD for mercury of 0.0001 mg/kg/day.

Health Evaluation:

Evaluating non-cancer hazards

In order to evaluate the potential for non-cancer adverse health effects that might result from exposure to arsenic-contaminated soil and surface sediment, and contaminants found in bottom fish, crab, and clams, an exposure dose was estimated for children and/or adults who might come into contact with the contamination during seasonal beach recreation, and who may eat bottom

[e] The TEFs are used to weight the measured levels of the congeners present in a sample in relation to the most toxic dioxin congener, TCDD, which is defined has having a TEF of 1. The measured concentration of each congener is multiplied by the TEF weighting factor. The total dioxin-like toxic equivalency, or TEQ, is the sum of these products.

fish, crab, and clam samples taken from Port Gardner site. These doses are calculated for situations (scenarios) in which a person might be exposed to the contaminated media. The estimated dose for each contaminant under each scenario is then compared to ATSDR Minimal Risk Levels (MRLs). MRLs are an estimate of the daily human exposure to a substance that is likely to be without appreciable risk of non-cancerous adverse health effects during a specified duration of exposure. In the absence of MRLs, DOH uses the EPA's oral reference dose (RfD). RfDs are doses below which non-cancer adverse health effects are not expected to occur (considered "safe" doses). MRLs and/or RfDs are derived from toxic effect levels obtained from human population and laboratory animal studies.

Because of study data uncertainty, the toxic effect level is divided by "safety factors" to produce the lower and more protective MRL. If a dose exceeds the MRL, 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 MRL, then that dose will fall well below the observed toxic effect level. The higher the estimated dose is above the MRL, the closer it will be to the actual observed toxic effect level. This comparison is called a hazard quotient (HQ). See Appendix B for the hazard quotient equation.

These toxic effect levels can be either the lowest-observed adverse effect level (LOAEL) or a no-observed adverse effect level (NOAEL). In human or animal studies, the LOAEL is the lowest dose at which an adverse health effect is seen, while the NOAEL is the highest dose that does not result in any adverse health effects. If the hazard quotient is above one, DOH evaluates the contaminant further and compares the estimated dose to the LOAEL and/or NOAEL.

Evaluation of contaminants in surface sediment

The calculated maximum soil arsenic concentration is 50 mg/kg at the Port Gardner site (Table 1). An exposure scenario of 250 days per year (adult) and 52 days per year (child) at these sites with exposure to 50 mg/kg was used in dose calculations in Appendix B, Table B2. An adult would receive an exposure dose of 0.0000537 mg/kg/day, which is lower than the chronic MRL of 0.0003 mg/kg/day (Appendix B, Table B2). Similarly, levels for PAHs fall below the chronic RfD. Estimated exposure doses for a child also fall below the chronic RfD (Appendix B, Table B2). Overall, estimated doses for adults are below the acute and chronic MRLs indicating that non-cancer health effects are unlikely to occur from exposures to arsenic and PAHs at these sites.

Evaluation of contaminants in bottom fish, crab, and clams

Estimated exposure doses, exposure assumptions, and hazard quotients are presented in Appendices C and D for contaminants found in tissue. Based on exposure estimates, neither the general population nor the tribes are likely to experience adverse non-cancer health effects from exposure to chemical contaminants in Port Gardner.

Evaluating cancer hazards

EPA classifies arsenic as a Group A (known human) carcinogen by the oral and inhalation routes [12]. 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.

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. Theoretical cancer risks quantified in this document are an upper-bound theoretical estimate. Actual risks are likely to be much lower.

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

EPA derives cancer potency factor based on various 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 for arsenic and 1.5×10^5 for dioxin.

Evaluation of contaminants in surface sediment

The maximum arsenic concentration in the surface 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 250 days of exposure per year and for a child 52 days per year. In a worst-case scenario, the current highest level of arsenic in the surface sediment (50 ppm) would increase a person's (adult) theoretical cancer risk by 1 in 10,000 (1 excess cancer risk estimates in a population of 10,000 people exposed) (see Appendix B - Table B3). Theoretical cancer risk estimates for exposure to cPAHs in the surface sediment are considered insignificant (i.e., three excess cancer risk estimates per million people exposed). 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 very low to low.

Similarly, theoretical cancer risks for children associated with exposure to arsenic in the surface sediment is very low (i.e., theoretical cancer risk estimates are 5 excess cancer risk estimates in 100,000 people exposed) and cPAHs is insignificant (i.e., theoretical cancer risk estimates are 1 excess cancer risk estimates in a 1,000.000 people exposed) (Appendix B, Table B3). These levels are within the EPA's acceptable range. The U.S. EPA generally considers an acceptable range for excess upper-bound lifetime cancer risk to an individual to be between 10^{-4} and 10^{-6}, meaning that regular exposure to a substance would lead to 1 additional case of cancer per 10,000 to 1 additional case of cancer per 1,000,000 people exposed.

Fish and shellfish ingestion tribal scenario

DOH obtained comparison values for contaminants in fish from EPA's guidance for Assessing Chemical Contaminant Data (subsistence fishers) [13]. As mentioned before, in order for a contaminant to be a health concern, it must be present at a high enough concentration to cause potential harm, and there must be a completed route of exposure to people.

People may at times disregard seafood consumption advisories, and consume more fish and crab from Port Gardner than recommended. In this scenario, DOH evaluated bottom fish (i.e., English sole), clams (i.e., Eastern softshell clams), and crab (only crab meat) contaminant exposure for the general population and for the Tulalip Tribe. Aspects of EPA's Tribal fish and shellfish consumption framework were used to set intake rates (see Appendix D) [14]. Eastern softshell clams are targeted shellfish species for human consumption. Varnish clams are not usually targeted shellfish species for human consumption.

Appendix C details the methodology and assumptions used by DOH to estimate exposure from eating bottom fish, crabs, and clams from Port Gardner. For the general adult population, average fish ingestion rates of 17.5 g/day represent the 90th percentile per capita ingestion rates for people of age 18 or older in the United States, including people that do and do not consume fish [15]. Since there was only data for bottom fish, it was assumed that bottom fish was consumed similar to the tribal rate of about 4 percent of the total intake of seafood. For the general adult population, an average shellfish consumption rate of 1.7 g/day was used to calculate exposure doses. For the general child population, an average fish consumption rate of 0.28 g/day based on bottom fish data only was used. The average shellfish consumption rate of 0.57 g/day was used to calculate exposure doses (see Appendix C, Table C1).

The tribal consumer scenario was based on the EPA Tribal framework for fish and shellfish consumption rates for risk-based decisions (See Appendix D) [14]. The percent of their consumption rate was represented by the category of seafood for the Tulalip Tribe [14,16].

Evaluation of contaminants in bottom fish, crabs, and clams

Theoretical cancer risk estimates for exposure to seafood by the general population is very low (four estimated excess cancer per 100,000 people exposed) (see Appendix C, Table C5). This estimate is within EPA's acceptable risk for fish consumption. The range of cancer risks considered acceptable by EPA is 1 excess cancer risk per 10,000 people exposed to 1 excess cancer risk per 1,000,000 people exposed ($1x10^{-6}$ to $1x10^{-4}$). However, this is based on bottom fish and shellfish data only.

Theoretical cancer risk estimates for exposure to arsenic and dioxin in seafood by Tribal consumers is about two estimated excess cancer risks per 10,000 people exposed (see Appendix D, Table D1); these estimates are above EPA's acceptable cancer range. However, dioxin theoretical cancer risk estimates for exposure to seafood by Tribal consumers are about three estimated excess cancer risks per 100,000 people exposed; these estimates are within EPA's acceptable cancer range (see Appendix D, Table D2).

Uncertainty

Carcinogenic potential of arsenic

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 [12]. 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) [17]
- EPA Office of Drinking Water (2001) [18]
- Consumer Product Safety Commission (2003) [19]
- EPA Office of Pesticide Programs (2003) [20]
- California Office of Environmental Health Hazard Assessment (2004) [21]
- EPA IRIS Review Draft for the SAB (2005) [12]

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 mg/kg-day). 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.

Uncertainty of non-detect data for fish and shellfish

Environmental data frequently contain values that are below detection limits. These "non-detects" (NDs) do not necessarily mean that the contaminant is not present at any level, but simply that any amount of the contaminant present is below the level that could be detected or reliably quantified using a particular analytical method. The primary science policy issue concerning NDs is what value should be assigned to these data when estimating exposure and risk from contaminants in fish and shellfish to ensure adequate protection to the public. In general, Washington DOH's Office of Environmental Health, Safety, and Toxicology (OEHST) recommends using a default value of half (½) the Limit of Detection (LOD) or ½ the Limit of Quantitation (LOQ) for fish tissue data which are reported at the LOD or LOQ. Coupled with this recommendation is the assumption that the underlying dataset have greater than a 10 percent detection frequency above a reported LOD or LOQ.

If OEHST demonstrates that these default assumptions have no effect on the final risk decision, then there is little reason to attempt further refinement of these default values. If OEHST finds that these default values do have a significant effect on the risk estimate or risk decision, or decides that a more refined risk estimate is needed, other approaches may be considered such as statistical methods using probability distributions. These methods would generally be used only in situations where the NDs comprise a significant (but less than half) portion of the data set and the rest of the data are normally or log-normally distributed. Exceptions can be considered on a case-by-case basis.

Furthermore, OEHST may reject results that rely solely on non-detected data regardless of how that data is calculated if the detection limits are deemed too high relative to usual or achievable detection levels for that contaminant. The rationale for this is that potentially an advisory could be based on all or partial non-detected data (e.g., PCBs, dioxins, and metals) when the addition of detection levels or half the detection levels used to determine total congener analysis results in calculated concentrations above known or established background or "safe" levels. In such an instance, OEHST would require or recommend that samples be reanalyzed or resampled and lower detection limits used prior to using the results to advise the public.

Plants

General Information

Native populations use plant materials for a wide variety of purposes. Subsistence use of such plant products as roots and tubers, stalks, leaves, berries, and nuts provide essential nutrients to native people. The use of plants for medicinal purposes is widespread, as is the use of tobacco.

Tobacco, sweet grass, cedar, and sage have important religious and ceremonial significance. The use of grasses and other plant resources for basket, box, and tool making; textiles, matting, dyes, paints, and soaps also can be observed in the cultures of numerous Native American groups.

The use of plant materials by the Tulalip Tribe presents numerous exposure possibilities if plant resources are gathered from contaminated lands. Plants have the potential to accumulate contaminants from soils, surface waters, and sediments. Contaminants may also be deposited on the surface of plants from pollutants that are circulated in the air. In addition, people who harvest plant resources may be exposed to contaminants through frequent contact with contaminated soils and sediments.

In general, plants do not bioaccumulate[f] most contaminants as efficiently as animals since plants are at the bottom of the food chain. Contaminants accumulate in terrestrial vegetation by either: 1) direct uptake (i.e., absorption) of contaminants from soil to the roots, 2) dry deposition of airborne contaminants on the plant's surface, or 3) wet deposition of airborne contaminants on the plant's surface that occurs as water settle on the plant during rain, snow, or dewy conditions. Aquatic plants accumulate most contaminants either in the root systems from sediments or from the surrounding water with wet deposition and adherence to plant parts being more important than dry deposition.

Some plant species called "hyperaccumulators" can accumulate and store contaminants much more readily than other plants, especially certain metals (e.g., selenium and zinc) that provide nutrients to the plant. Under normal circumstances (e.g., non-contaminated soils), organic (e.g., pesticides, PCBs, and other chlorinated compounds) and inorganic (i.e., metals) contaminants are rarely found at concentrations in plant tissues that would pose a human health hazard [22,23,24]. Heavy metals (i.e., metals with high molecular weights) such as lead, cadmium, and mercury may be present in trace amounts in plant tissues. However, these metals are usually not accumulated in edible portions of the plant at levels that would be of human health concern [24].

A review of the scientific literature indicates that most plants do not contain chemical concentrations in their tissues that are higher than the contaminant levels in the soils that they grow on. In fact, when soils contain adequate plant nutrients and are pH-balanced (i.e., not too acidic), metals and other contaminants are generally not absorbed much at all in plant tissues beyond the roots. There are, however, exceptions to this general statement regarding plant accumulation of contaminants. The information presented in the next section is important to consider before deciding whether to harvest and use plant materials for foods, medicines, or other culturally important activities. Washing plants significantly reduces the amount of contaminants present on the outer plant tissues.

Factors that Influence the Accumulation of Contaminants in Plants

The availability of soil contaminants to plants is controlled by many factors. Soil pH is considered one of the most important factors controlling the plant's ability to bioaccumulate certain metals (e.g., cadmium, lead, and zinc). Soil pH is a measure of the acidity or alkalinity in

[f] The term bioaccumulation represents the process that takes place when chemicals accumulate in tissues at higher levels than are found in the environmental media they are exposed to.

the soil. Many heavy metals become more water soluble under acidic conditions. A soil's pH is considered acidic if it is below 7.0 (7.0 is neutral). Any soil pH below 6.0 is considered strongly acidic [25]. Strongly acidic soils allow metals to be absorbed into the root system and distributed more readily throughout the plant [26]. Other important factors that influence the potential for plants to accumulate contaminants and contribute to human exposures include:

- **The portion of the plant that is harvested:** Fruits and berries are less likely to accumulate contaminants from the soil because of physiological processes which prevent metals and some other contaminants from being distributed to the tops of plants. Contaminants can be deposited onto plant surfaces, but exposure can be minimized by washing and/or peeling the edible portions of the plant [24].

- **The soil-plant barrier:** This involves processes that prevent excessive plant uptake of potentially toxic elements. The extent to which this barrier prevents the uptake of metals is dependent on the solubility of the element that is present in the soil. Some elements (e.g., lead) are so insoluble they are not taken up into the edible parts of the plant.

- **Plant-specific characteristics:** Some plant species, referred to as "hyperaccumulators," (e.g., milkvetch or locoweed (*Astragalus mollissimus)* and prince's plume (*Stanleya pinnata*)) can accumulate some elements such as selenium or nickel much more readily than other plants. If these accumulator plants are being harvested for human consumption, exposure to harmful concentrations of metals could occur through the uptake and translocation (movement of soluble materials) into the edible portions of the plant.

- **Soil properties:** The uptake of elements such as zinc, cadmium, and manganese are all very dependent on soil pH. As the soil becomes more acidic, the potential for metals to be absorbed by the roots of the plant increases.

- **Phytoavailability:** The extent that metals are available to be absorbed and taken up by plants. Some metals are used by the plant as nutrients and can be distributed throughout the shoots and leaves. Heavy metals are toxic to most plants, but those plants with higher tolerances for heavy metals tend to store them in the root cells and not in above ground portions of the plant [24].

- **Phytotoxicity:** This occurs when the concentrations of contaminants in the edible portion of the plant harm or kill the plant. In most situations, plant growth is retarded and the phytotoxic effects are evident before the levels become harmful to humans. Plants exhibiting phytotoxicity have visible signs including yellowing of leaves, necrosis of leaf tips, stunting, low yields of fruits or vegetables, and eventual plant death. Common metals that exhibit phytotoxicity at levels below human health concern include zinc, copper, nickel, cobalt, and manganese [24].

- **The bioavailability of metals:** The extent to which plants store contaminants in a form that can be absorbed and metabolized by people.

Potential for Human Exposure

Plants used for traditional activities (e.g., basket weaving) and ceremonial purposes (e.g., smudging) have the potential for human exposure. The practice of making baskets involves certain activities that could result in ingestion or inhalation of plant materials. For example, hand-to-mouth activities could result in the ingestion of contaminants and many of the ceremonies associated with basket weaving involve the burning of plants which could result in inhalation exposures. Other preparations from plant materials such as dyes, paints, and topical ointments (e.g., poultices)[g] may contribute to human exposure through dermal contact.

There are certain factors that contribute to human exposures to environmental contaminants in plants. These factors include the environment in which the plants are grown, the types of plants that are harvested, how the plant materials are used, the quantities of plant materials used, the part of the plant that is used, and how plant materials are prepared and/or preserved.

The following observations about the potential for exposure to contaminants from certain common traditional practices or daily activities are presented below:

- The highest potential of risk at sites contaminated with heavy metals (e.g., copper, zinc, chromium, etc.) is from soil ingestion. Soil can be a potential source of exposure to contaminants, either by skin contact with the surface of plant materials or by ingestion of contaminated soil. As a result of specific activities that bring people into contact with soil much more frequently than the general public, soil ingestion is a much more important risk to people who are dependent on the land and subsistence agriculture. For example, the risk from contaminants taken up by garden vegetables is about one-fifth as high as the risk from exposure to the soil that is brought into the house from being outside in the field harvesting crops or gardening. Eliminating carryover soil from plant materials as well as from clothing and hands is an important step in preventing exposure to these contaminants.

  Specifically, for heavy metals such as lead, cadmium, and arsenic, one should be primarily concerned about the roots and about soil contamination of the lower portion of the fruits or leaves that may be used. Low lying plants (e.g., strawberries), leafy vegetables (e.g., spinach and lettuce), and root crops (e.g., potatoes and carrots) are particularly likely to contribute to human exposure to metals because soil can adhere to these plant surfaces quite readily. Since heavy metals are tightly bound to soil particles, soil is the primary vehicle for heavy metal exposure – not the uptake and translocation of metals from the root to the top of the plant.

- Workers (e.g., basket weavers and/or plant harvesters) who spend most of the day in an enclosed environment may inhale substantial amounts of dust and small soil particulates bound to plant materials. If the plant materials, dust, and/or soil particulates contain high concentrations of contaminants, workers may be exposed at levels that could be harmful. Gathering plants for basket weaving involves certain activities that could result in

[g] Poultice is a type of plant preparation described as a paste made from selected plant materials. It is often applied to the skin for medicinal purposes

ingestion and/or inhalation of plant materials. For example, hand-to-mouth activities could result in the ingestion of contaminants and many of the ceremonies associated with basket weaving involve burning of plants which could result in inhalation exposures. The Tulalip Tribe uses cattail for making baskets. The process involves harvesting the plants by children and elders. This practice can possibly increase potential health risks because of contact with dust, soil, and contaminants in the field.

- Some medicinal plant materials are used by native populations, either daily or on a regular basis, to promote health. However, the potential for exposure to metals or other contaminants could present concerns similar to those connected with consuming plants for subsistence purposes. For example, members of the Tulalip Tribe use nettles[h] for ceremonial and medicinal purposes, as well as a food source. Catnip and nettles are an excellent combination for herb tea. Nettles can be used as a vegetable side dish with rice and beans. The food value protein of nettles is much greater than a number of other foods.

- If dyes or paints, especially cosmetics or face paints, are made from the roots of plants, this use of the plant may be a potential exposure scenario. This is not likely to contribute significantly to overall exposure. However, when combined with other exposure pathways this could be a pathway of significant health concern.

- Contaminants from plant materials (e.g., sage) used in sweat lodges, which typically contain red hot lava rocks to heat the room, may volatilize into the air (e.g., mercury, PCBs).

- From an exposure standpoint, it is important to consider which parts of the plants are used. Root crops (e.g., potatoes) and low lying plants (e.g., strawberries) are more likely to be a contaminant source when grown in contaminated soils than are parts of the plants that are higher from the ground. In general, the use of fruits and berries that grow higher from the ground will not be a significant source of exposure to metals or other contaminants from the soil. In most cases, these plant materials will not present an exposure pathway unless there is evidence of significant aerial deposition.

Plant and animal resources sampled at Port Gardner

Table 5 provides a summary of the sampled plant and animal resources that are utilized by the Tulalip Tribe as well as important information that can be used to evaluate the potential that each resource has for contributing to an individual's cumulative exposure. The levels of concern for the consumer, harvester, hunter, or worker represent qualitative evaluations that are based on a review of the literature, available site-specific data, and any anecdotal information regarding how members of the Tulalip Tribe may utilize specific resources. The table is not meant to be used as a tool for developing quantitative risk assessments, but rather as a resource that will assist the tribe and other groups to help prioritize potential environmental concerns and more efficiently allocate resources.

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[h] Nettle is the common name for between 30-45 species of flowering plants of the genus *Urtica*. They are mostly herbaceous perennial plants, but some are annual and a few are shrubby.

Table 5. Common plant and animal resources sampled at Port Gardner, Everett, Snohomish County, Washington.

Name	**Portion of the plant/animal frequently used**	**Exposure concern: Consumer [1]**	**Exposure Concern: Harvester, hunter, and/or worker [2]**	**Supporting Evidence/Scientific literature**	**Sampled at Port Gardner (yes/no)**
Plant Resources					
Tule	Stems	Metals: Medium POPs: Low	Metals: Medium Organics: Low	Tule are commonly used to weave baskets, mats, padding, clothing, floats, slings, swaddling clothes, and balsa.	Yes
Cattails	Stem/roots	Metals: Medium POPs: Low	Metals: Medium Organics: Low	Cattails have the potential to bioaccumulate metals and some species are purposely used in the bioremediation of polluted wetlands and the treatment of industrial wastewater. Low soil pH will increase the potential for metals accumulation in the cattails. Cattail roots and shoots are used to weave mats and baskets. Roots and shoots are also used as food.	Yes

POPs = Persistent organic pollutants

[1] The consumer exposure concern classifications (i.e., low, medium, and high) are based on the assumption that soil and/or sediment and surface water concentrations in the area where the plants are growing exceed human health-based screening values for the contaminant of concern. Under most circumstances, if contaminant-specific concentrations in the media (i.e., soil, water, sediments) where the plants are harvested do not exceed human health-based screening values than the plant materials should not pose an exposure concern.

[2] This includes people who harvest the plants and make products (e.g., baskets, pottery, and clothing) from plant materials. The exposure categories (e.g., low, medium, and high) are assigned assuming that workers are harvesting in areas that may contain levels of contamination that could pose a health concern or hazard. If workers are harvesting from uncontaminated areas or areas where contamination is not of health concern, then exposure is not a concern.

Name	Portion of the plant/animal frequently used	Exposure concern: Consumer [1]	Supporting Evidence/Scientific literature	Sampled at Port Gardner (yes/no)
Crabs	Crab meat, Crab whole† (Hepatopancreas showed high levels of dioxins)	Low/High* *(high risk if hepatopancreas is consumed from these urban areas)	Ecology sampled crab hepatopancreas and meat. Crabs harvested from industrial urban areas are not advised for human consumption. Data have shown that crabs harvested from these areas may contain more contaminants than those from non-urban areas. For example, crab butter has more contaminants than crab muscle.	Yes
Fish (bottom fish)	Whole fish	Low/Medium	Levels of metals in fish were generally low. However, total arsenic was present (Arsenic was evaluated further as a COC). Dioxins were also present at low levels.	Yes
Clams	Meat	Low	Clams have low lipid content, thus are low in organic contaminants. Levels of metals in clams were generally low. However, total arsenic was present in clams and eastern soft shells. Dioxins were also present at very low levels.	Yes

[1] The consumer exposure concern classifications (i.e., low, medium, and high) are based on the assumption that seafood consumption may exceed human health-based screening values for the contaminant of concern.
† Whole crab and meat - Existing fish consumption advisory in industrial and urban areas warn against consumption of crabs.
COC – contaminant of concern

Pesticide residues in food

Appendix A, (Table A7) shows some pesticide residues found in food. The levels of pesticide found in plants compared with pesticide residues found in food are considered insignificant at Port Gardner. Most levels are below detection limits.

Uncertainty of exposure scenarios for plants

American Indians and other Native Tribes routinely use and prepare some plants for non-ingestion purposes, such as basket making, dying, and weaving. It is difficult to explain how metals in plants may be available for ingestion exposure (perhaps by users engaging in hand-to-mouth activity) or inhalation exposure when conducting activities like basket making, dying, and weaving. Thus, determining how the magnitude of such exposures compares to that of food ingestion exposures is fraught with uncertainty. Plant uptake of metals as a route of human exposure compared with exposure from aerosol deposition and soil splash onto plants was studied by Chaney and others [27, 28, 29, 30]. These studies concluded that, in general, people will have greater potential for ingesting, inhaling, or absorbing (via dermal contact) metals and other contaminants from the deposition of soil onto plants than from the actual uptake of these contaminants from the soil into the plants [27, 28, 29, 30].

DOH acknowledges that workers (e.g., basket weavers and/or plant harvesters) who spend most of the day in an enclosed environment may inhale substantial amounts of dust and small soil particulates bound to plant materials. If the plant materials, dust, and/or soil particulates contain high concentrations of contaminants, workers may be exposed at levels that could be harmful. DOH is unable to determine levels of contaminants in these plants (i.e., Cattail and Tule plants) that may cause an adverse health effect in workers due to the lack of ingestion rates and other variables.

Children's Health Considerations

The potential for exposure and subsequent adverse health effects often increases for younger children compared with older children or adults. ATSDR and DOH recognize that children are susceptible to developmental toxicity that can occur at levels much lower than those causing other types of toxicity. The following factors contribute to this vulnerability:

- Children are more likely to play outdoors in contaminated areas by disregarding signs and wandering onto restricted locations.
- Children have more hand-to-mouth activities.
- Children are smaller and receive higher doses of contaminant exposures per body weight.
- Children are shorter than adults; therefore, they have a higher possibility of breathing in dust and soil.
- Fetal and child exposure to contaminants can cause permanent damage during critical growth stages.

These unique vulnerabilities of infants and children demand special attention in communities that have contaminated water, food, soil, or air. 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.

Conclusions

Based on the information provided, DOH concludes the following:

1. Results based on consumption of seafood at tribal scenario rates, cancer and non-cancer health effects

    Results based on consumption of seafood at tribal scenario rates, cancer health effects

    a. Eating seafood (bottom fish, crabs, and clams) at Tribal scenario rates (see Appendix D for Tulalip Tribe consumption rates) could harm the health of an adult. Subsistence fishers (tribes or nations) that eat seafood will most likely be at risk of developing cancer if arsenic exposure is assumed from childhood into adulthood (average cancer risk over a 70 year lifetime exposure). Overall, lifetime increase of cancer risk associated with the estimated exposure to arsenic and dioxin in seafood is two excess cancers to 10,000 people exposed.[i] These levels exceed the U.S. EPA acceptable range of 1 excess cancer risk per 10,000 people exposed to 1 excess cancer risk per 1,000,000 people exposed (10^{-4} and 10^{-6}). Although the excess theoretical cancer risk is considered low, the cancer risk levels are above EPA's acceptable range. The Tulalip tribe or nations fish in this area and it is in their usual and accustomed fishing rights areas. If tribes or nations are harvesting from Port Gardner and consuming at Tribal consumption rates, this would represent a "*public health hazard.*" However, it is unlikely that 100 percent of subsistence consumers (tribes or nations) would be consuming and harvesting seafood from Port Gardner only.

    Results based on consumption of seafood at tribal scenario rates, non-cancer health effects

    b. Non-cancer health effects are not likely if people eat seafood (bottom fish, crab, and clams) at Tribal scenario rates (see Appendix D for Tulalip Tribe consumption rates). Based on exposure assumptions and calculations, contaminants present in bottom fish, crabs, and clams are below levels known to result in harmful non-cancer health effects.

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[i] A lifetime of 1 excess cancer risk in 10,000 people exposed is selected as the point of departure for significant risk. Point of departure is an estimated dose (usually expressed in human-equivalent terms) near the lower end of the observed range, without significant extrapolation to lower doses.

2. Results based on consumption of seafood for the general population, non-cancer and cancer health effects

    a. Eating bottom fish or shellfish from Port Gardner is not expected to harm the health of the general population (children or adults). Based on consumption rates for the general population, the estimated exposures are below levels known to result in harmful non-cancer health effects and does not present an elevated theoretical cancer risk. However, this area falls under the Puget Sound advisory for Recreational Area Marine 8-2 [j]. Overall, a lifetime increase of cancer risk associated with exposure to arsenic and dioxin in bottom fish and shellfish is very low (i.e., theoretical cancer risk estimates are 4 excess cancers to 100,000 people exposed). However, dioxin is insignificant (i.e., theoretical cancer risk estimates are 1 excess cancers in a 1,000,000 people exposed). These levels fall between the U.S. EPA's acceptable range of 10^{-4} and 10^{-6}, meaning that regular exposure to a substance would lead to less than 1 additional theoretical case of cancer per 10,000 or 1,000,000 exposed persons.

3. Results based on surface sediment contaminant exposure, non-cancer and cancer health effects

    a. Touching, breathing, or accidentally eating surface sediment containing arsenic and cPAHs approximately 5 days per week or 250 days per year (adult) and/or 52 days per year (a child) from Port Gardner is not expected to harm people's health. The maximum levels of arsenic and cPAHs found in the surface sediment in this exposure scenario are below levels known to result in harmful non-cancer and theoretical cancer health effects for an adult and children. Overall, a lifetime increase of cancer risk (adult) associated with exposure to arsenic in the surface sediment is low (i.e., theoretical cancer risk estimates are 1 excess cancer to 10,000 people exposed) [k] and cPAHs is insignificant (i.e., theoretical cancer risk estimates are 3 excess cancers in a 1,000,000 people exposed) (Appendix B, Table B3). Similarly, theoretical cancer risks for children associated with exposure to arsenic in the surface sediment is very low (i.e., theoretical cancer risk estimates are 5 excess cancer risk estimates in 100,000 people exposed) and cPAHs is insignificant (i.e., theoretical cancer risk estimates are 1 excess cancer risk estimates in a 1,000.000 people exposed) (Appendix B, Table B3). These levels fall between the U.S. EPA acceptable range of 10^{-4} and 10^{-6}, meaning that

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[j] ***Note:*** *Puget Sound advisory for recreational Marine Area 8-2 recommends: a)* Eat no more than two meals per month for rockfish and flat fish (e.g., sole, sanddab, and flounder), and no more than two meals per month for Chinook salmon, and b) Eat Dungeness and Red Rock crab from non-urban areas and do not eat the "crab butter" (viscera). Data have shown that crabs from industrial urban areas may contain more contaminants than those from non-urban areas, and that crab butter (viscera) has more contaminants than crab muscle.

[k] A lifetime of 1 excess cancer risk in 10,000 people exposed is selected as the point of departure for significant risk. Point of departure is an estimated dose (usually expressed in human-equivalent terms) near the lower end of the observed range, without significant extrapolation to lower doses.

regular exposure to a substance would lead to 1 additional case of cancer per 10,000 to 1 additional case of cancer per 1,000,000 people exposed.

4. Results based on plant tissue data

    a. Based on available information related to the contaminant levels of chemicals (i.e., metals) in plant tissue, DOH cannot currently conclude whether eating or inhaling plant tissue could harm people's health. Plant ingestion rates were not available to quantify human exposure to site-specific contaminants in Port Gardner. DOH acknowledges that workers (e.g., basket weavers and/or plant harvesters) who spend most of the day in an enclosed environment may inhale substantial amounts of dust and small soil particulates bound to plant materials. If the plant materials, dust, and/or soil particulates contain high concentrations of contaminants, workers may be exposed at levels that could be harmful.

Recommendations

1. DOH recommends that the general population and the Tulalip Tribe follow the Puget Sound fish consumption advisory for Recreational Marine Area 8-2 (Port Susan and Port Gardner) and the Puget Sound crab consumption advisory for Port Gardner, which has meal restrictions for seafood harvested in urban areas. More information regarding these advisories is available at http://www.doh.wa.gov/fish or by calling toll-free 1-877-485-7316.

2. As a prudent public health measure, DOH recommends following advice for cleaning and preparing fish and shellfish to reduce exposure to contaminants that accumulate in the fat of fish and shellfish. Also, to reduce dust and small soil particulates bound to plant materials. This method of preparation can be found in the General Advice section of this document along with other ways to minimize exposures.

General Advice

Fish

DOH encourages all Washingtonians to eat at least two fish meals per week as part of a heart healthy diet in accordance with the American Heart Association (AHA) recommendations. People may eat fish more than two times weekly, but such frequent consumers should take the following steps to reduce exposure to contaminants in the fish that they eat.

- Eat a variety of fish that are low in contaminants according to guidance provided on our website at http://ww.doh.wa.gov/fish.

- Follow fish advisory advice provided by DOH and local health agencies for water bodies where you fish. http://ww.doh.wa.gov/fish
- Young children and small adults should eat smaller meal sizes proportionate to body weight.
- Grill, bake, or broil fish so that fat drips off while cooking to reduce the amount of contaminants that collect in the fatty parts of fish.
- Eat fillets without the skin.
- Mercury and other metals are stored in the muscle or bones of the fish and will be reduced by preparing fish in the way recommended for reducing contaminants.

Plant resources

- Avoid vegetation that appears to be stressed (e.g., wilting, brown or burnt leaves, premature coloration, or leaf drop). Avoid harvesting fruits, vegetables, or any plant materials that will be used as food or for medicinal purposes if plants do not appear healthy. This could be an indicator of contamination.

- As a rule, the higher off the ground the fruit, vegetable, or portion of the plant to be harvested is, the less likely it will be impacted by contamination from the soil.

- Always wash fruits and vegetables and any portion of the plant that will be ingested or used. This is by far the most efficient way of preventing exposure to contaminants that are in the soil or sediments, either by soil adhering root crops like tubers or from soil spray that results in contaminant deposition onto the above ground portion of plants.

- Peel away the skin or top surface layer of the fruit or vegetable.

Public Health Action Plan

Actions Planned

1. DOH will develop a fact sheet that summarizes the findings of this health consultation.

2. DOH will coordinate with Ecology on the development of the fact sheet. DOH will plan to distribute the fact sheet within two months of the health consultation being approved.

3. DOH will provide copies of this health consultation to Ecology and concerned parties when the report is approved.

4. DOH will be available any time to answer health related questions regarding Port Gardner site contaminants.

Figure 1. Port Gardner and Lower Snohomish River Estuary, Snohomish County, Washington.

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Appendix A - Contaminant Screening Process

Screening value calculations

Non-cancer Health Effects

SV = [(MRL or RfD)*BW]/CR [31]

SV = Screening value (mg/kg or ppm)
MRL = Minimal risk level (mg/kg/day)
RfD = Reference dose (mg/kg/day)
BW = Mean body weight (kg)
CR = Mean daily consumption rate (kg/day)

BW (adult) = 70 kg
General population CR = 17.5 g/day
Subsistence population CR = 142.4 g/day

If maximum concentration is greater than screening value, further evaluation is required.

Cancer Health Effects

Total arsenic and carcinogenic PAHs in surface sediment and total arsenic and total dioxins in bottom fish, crabs, and clams were evaluated further as contaminants of concern for cancer.

Table A1. Maximum concentrations of contaminants detected in surface sediment at the Port Gardner site, Everett, Snohomish County, Washington.

Compounds	Maximum Concentration (ppm)	Comparison Value (ppm)	EPA Cancer Class	Comparison Value Reference	Contaminant of Concern (COC)
Arsenic	**50**	20	A	EMEG	**Yes**
Cadmium	3.7	5	B1	EMEG	No
Chromium	68	230 [a]	A	EPA regional [d]	No
Copper	137	500	D	IM EMEG	No
Lead	56	250	B2	MTCA	No
Mercury	0.7	1	D	MTCA	No
Silver	1.0	300	D	RMEG	No
Zinc	415	20,000	D	EMEG	No
2-Methylnaphthalene	0.12	2,000		EMEG	No
1-Methylnaphthalene	0.075	4,000		EMEG	No
Acenaphthene	0.2	3000		RMEG	No
Acenaphthylene	0.2	2000*	D		No
Anthracene	0.25	20000	D	RMEG	No
Benzo(a)anthracene	**0.45**	0.15	B2	EPA regional [d]	**cPAH Yes**
Benzo(a)pyrene	**0.42**	0.1	B2	CREG	**cPAH Yes**
Benzo(b)fluoranthene	**0.62**	0.15	B2	EPA regional [d]	**cPAH Yes**
Benzo(k)fluoranthene	0.42	1.5	B2	EPA regional [d]	cPAH
Benzo(ghi)perylene	0.14	2000*	D		No
Chrysene	0.7	15	B2	EPA regional [d]	cPAH
Dibenz(a,h)anthracene	0.059	0.1**		CREG	cPAH
Dibenzofuran	0.17	290	D	EPA regional [d]	No
Fluoranthene	1.1	2000	D	RMEG	No
Fluorene	0.21	2000	D	RMEG	No
Indeno(1,2,3-cd)pyrene	0.14	0.15	B2	EPA regional [d]	cPAH
Naphthalene	0.4	30000	C	IM EMEG	No
Phenanthrene	0.54	2000*	D		No
1-Phenanthrene carboxylic acid, 1,2,3,4,4a,9,10,10a-	2.6	2000*	D		No
Pyrene	0.89	2000	D	RMEG	No
Hexachlorobenzene	0.059 U	0.4	B2	CREG	No
Hexachlorobutadiene	0.059 U	9	C	CREG	No
1,2,4-Trichlorobenzene	0.059 U	500	D	RMEG	No
1,2-Dichlorobenzene	0.059 U	5000	D	RMEG	No
1,3-Dichlorobenzene	0.059 U	2000	D	IM EMEG	No

Compounds	Maximum Concentration (ppm)	Comparison Value (ppm)	EPA Cancer Class	Comparison Value Reference	Contaminant of Concern (COC)
1,4-Dichlorobenzene	0.059 U	4000	C	IM EMEG	No
4,4-DDD 4,4-DDE 4,4-DDT	0.002 U 0.002 U 0.002 U	3 2 2	B2	CREG	No
Benzoic acid	0.59 U	200000		RMEG	No
Benzyl alcohol	0.059 U	31000		EPA regional [d]	No
Bis(2-ethylhexyl)phthalate	0.20 J	3000	B2	EMEG	No
Butyl benzyl phthalate	0.059 U	10000	C	RMEG	No
Butyltin	0.004 U	300 [A]	NA	IM EMEG	No
Dibutyltin	0.0057 U	300 [A]	NA	IM EMEG	No
Tributyltin	0.0038 U	300 [A]	NA	IM EMEG	No
Di-n-butyl phthalate	0.059 U	5000	D	RMEG	No
Di-n-octylphthalate	0.059 U	20000		IM EMEG	No
Diethyl phthalate	0.059 U	300000	D	IM EMEG	No
Dimethyl phthalate	0.059 U	7800 [e]	D	EPA regional [d]	No
N-Nitrosodiphenylamine	0.059 U	99	B2	EPA regional [d]	No
Pentachlorophenol	0.3 U	6	B2	CREG	No
Phenol 2,4-Dimethylphenol 2-Methylphenol 4-Methylphenol	0.14 0.059 U 0.014 U 1.2	20000 3100 ψ 3100 ψ 310	D	RMEG EPA regional [d]	No No No No
Guaicol (2-methoxyphenol)	0.002 U	20000 [f]	D	RMEG	No
Tetrachloroguaiacol	0.02 U	20000 [f]	D	RMEG	No
3,4,5-Trichloroguaiacol (Ac)	0.02 U	20000 [f]	D	RMEG	No
4,5,6-Trichloroguaiacol	0.02 U	20000 [f]	D	RMEG	No
4,5-Dichloroguaiacol	0.02 U	20000 [f]	D	RMEG	No
Cis-chlordane Trans-chlordane Oxychlordane	0.00098U 0.00098U 0.002 U	30‡	B2	EMEG	No
Cis-nonachlor Trans-nonachlor	0.0002U 0.0002U	3*‡	B2	CREG	No
Dieldrin	0.002 U	3	B2	EMEG	No
Heptachlor	0.00098 U	0.2	B2	CREG	No
Isopimaric acid Pimaric acid Abietic acid	0.49 U ψ* 0.49 U ψ* 1.6 ψ*	NA	NA	NA	NA
Lindane	0.00098 U	3*‡‡	B2	EMEG	No
o-cresol p-cresol	0.059 U 1.2	200	C	IM EMEG	No

Compounds	Maximum Concentration (ppm)	Comparison Value (ppm)	EPA Cancer Class	Comparison Value Reference	Contaminant of Concern (COC)
Sulfide	3780 J	NA	IN	NA	NA
PCB-1016	0.0066 U	3.9		EPA regional [d]	No
PCB-1221	0.0066 U	0.17			
PCB-1232	0.0066 U	0.17			
PCB-1242	0.0066 U	0.22			
PCB-1248	0.0066 U	0.22			
PCB-1254	0.15	0.22			
PCB-1260	0.028	0.22			
PCB-1262	0.0066 U	0.22			
PCB-1268	0.0066 U	0.22		EMEG	
Total Aroclors	0.23[†]	1***			No
Total cPAH TEQ	**0.61**	0.1 [b]	B2	CREG	**Yes**
Total Dioxin TEQ	0.000047	0.00005 [c] [32]	B2	EMEG	No

CREG - ATSDR's Cancer Risk Evaluation Guide (child)
RMEG - ATSDR's Reference Dose Media Evaluation Guide (child)
EMEG - ATSDR's Environmental Media Evaluation Guide (child)
IM EMEG - ATSDR's Intermediate Environmental Media Evaluation Guide (child)
J, E - data qualifier: The associated numerical result is an estimate
U- Data qualifier: The analyte was not detected at this level. Half of the detection limit was used to calculate total
NJ – The analysis indicates the presence of a "tentatively identified" analyte. Reported value is approximate
A – Human carcinogen
B1 – Probable human carcinogen (limited human, sufficient animal studies)
B2 - EPA: Probable human carcinogen (inadequate human, sufficient animal studies)
C - EPA: Possible human carcinogen (no human, limited animal studies)
D - EPA: Not classifiable as to health carcinogenicity
NA – Not available
[a] – It assumes Hexavalent chromium (particulates)
[b] – Corresponds to CREG for benzo(a)pyrene
[c] – Corresponds to ATSDR chronic EMEG (child) for 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin
[d] Derived from EPA's regional screening levels for chemical contaminants at Superfund sites, July 7, 2008: Preliminary Remediation Goals
[e] – Used surrogate for this, dimethylterephthalate
[f] – Use phenol as a surrogate
* Fluoranthene RMEG value was used as a surrogate.
* * Benzo(a)pyrene CREG value was used as a surrogate.
* * * Aroclor 1254 EMEG value was used as a surrogate.
‡ Chronic EMEG, chlordane value was used as surrogate.
ψ* Tentatively identified compounds were not confirmed, commonly seen in plant's breakdown products (e.g., pine resins).
[†] Value is based on the highest Aroclor found at the site.
Ψ 2-Methylphenol value was used as a surrogate.
*‡‡ Dieldrin EMEG value was used as a surrogate.
[A] – Dibutyltin dichloride value was used as a surrogate.
Total Dioxin TEQ – sum of dioxin/furans toxic equivalent (TEQ)
Total cPAH TEQ – sum of all carcinogenic polycyclic aromatic hydrocarbons (cPAH) toxic equivalent (TEQ); all cPAHs in COC are added using the TEQ approach to obtain Total cPAH TEQ.
DDD (1,1-dichloro-2,2-bis(p-chlorophenyl)ethane)
DDE (1,1-dichloro-2,2-bis(p-chlorophenyl)ethylene)
DDT (1,1,1-trichloro-2,2-bis(p-chlorophenyl) ethane)
PCB (Polychlorinated biphenyl)
BOLD – Values exceed comparison values
ppm – parts per million
MTCA – Model Toxics Control Act

Table A2. Range concentrations of contaminants detected in English sole and clams at the Port Gardner site, Everett, Snohomish County, Washington.

Compounds	English Sole [a]	Varnish Clam [b]	Eastern Softshell [c]	Comparison Value Reference [d]		Contaminant of Concern (COC)
				General population	Non-Tribal High end consumer	
Metals in mg/kg ww						
Arsenic	**1.0 – 3.0**	0.1 U – 1.0	**2.0**	1.2	0.147	**Yes**
Cadmium	0.004 U	0.004 U	0.07 – 0.08	4	0.49	No ††
Chromium	0.3 J – 0.6 J	0.5 – 0.8	0.7 – 0.8	12	1.47	No
Copper	1.02 – 2.04	2.2 – 2.9	2.2 – 2.7	160	19.7	No
Lead	0.04 U	0.04 U	0.04 U	n/a	n/a	No ††
Mercury	0.01 – 0.04	0.0009U – 0.01	0.01	0.4	0.049	No
Silver	0.022 UJ	0.022 UJ	0.021 UJ	20	2.46	No
Zinc	13.7 – 15.3	22.7 – 35.2	13.1 – 14.2	1200	147.5	No
PCBs in ug/kg ww						
Aroclor-1221	6.6 U - 20 U	6.6 U	6.6 U	80	9.8	
Aroclor-1232	6.6 U - 20 U	6.6 U	6.6 U	80	9.8	
Aroclor-1242	6.6 U - 20 U	6.6 U	6.6 U	80	9.8	
Aroclor-1016	6.6 U - 20 U	6.6 U	6.6 U	80	9.8	
Aroclor-1248	6.6 U - 20 U	6.6 U	6.6 U	80	9.8	
Aroclor-1254	6.6 U - 20 U	6.6 U	6.6 U	80	9.8	
Aroclor-1260	6.6 U - 20 U	6.6 U	6.6 U	80	9.8	
Aroclor-1262	6.6 U - 20 U	6.6 U	6.6 U	80	9.8	
Aroclor-1268	6.6 U - 20 U	6.6 U	6.6 U	80	9.8	
Total PCBs	6.6 U - 20 U	6.6 U	6.6 U	80	9.8	No ††
Dioxin/Furan pg TEQ/g ww						
TEQ 1/2 DL	0.128 – 0.306	0.0258 – 0.104	0.0156 – 0.034	4.0	0.49	No

BOLD – Values exceed comparison values
U - The compound was analyzed for, but was not detected ("non-detect") at or above the MDL. DOH used half of the detection limit (DL).
J - The analyte was positively identified; the associated value is the approximate concentration.
UJ – The analyte was not detected above the quantitation limit. However, the quantitation limit is considered approximate.
[a] – Three English sole tissue samples were collected from Port Gardner site.
[b] – Two Purple varnish clam tissue samples were collected from Port Gardner site.
[c] – Two Eastern softshell clam tissue samples were collected from Port Gardner site.
[d] – Source of screening values are listed in Appendix A
†† Levels are considered non-detects (see uncertainty section on non-detect data)
n/a – not available
ww – wet weight
DL - detection limit
mg/kg – milligram/kilogram
ug/kg – microgram/kilogram
pg/g – picogram/gram
TEQ - toxic equivalent

Table A3. Concentrations of contaminants detected in Dungeness crab at the Port Gardner site, Everett, Snohomish County, Washington.

Location	A1-T3	A1-T3	A2-T1	A2-T1	A2-T2	A2-T2	Average Meat†
	Hepato	Meat	Hepato	Meat	Hepato	Meat	
Lipid	7.39	0.24	13.8	0.238	4.77	0.198	
Metals in mg/kg ww							
Arsenic	5	5	3	3	3	3	3.7
Cadmium	1.18	0.08	1.39	0.11	0.52	0.04	0.06
Chromium	0.2	0.05 U	0.4	0.1	0.1	0.1	0.075
Copper	54.8	12.4	50.3	16.2	61.8	11.9	13.5
Lead	0.04 U	0.04 U	0.08 U	0.04 U	0.04 U	0.04 U	0.04 U ††
Mercury	0.044	0.044	0.04	0.07	0.02	0.03	0.048
Silver	0.74	0.11	0.3	0.11	0.43	0.09	0.103
Zinc	36.4	45.3	35.7	38.3	17.8	31.5	38.4
PCBs in ug/kg ww							
Aroclor-1221	6.6 U	6.6 U	6.6 U	6.6 U	6.5 U	6.6 U	6.6 U
Aroclor-1232	6.6 U	6.6 U	6.6 U	6.6 U	6.5 U	6.6 U	6.6 U
Aroclor-1242	6.6 U	6.6 U	6.6 U	6.6 U	6.5 U	6.6 U	6.6 U
Aroclor-1016	6.6 U	6.6 U	6.6 U	6.6 U	6.5 U	6.6 U	6.6 U
Aroclor-1248	6.6 U	6.6 U	6.6 U	6.6 U	6.5 U	6.6 U	6.6 U
Aroclor-1254	85	6.6 U	130	6.6 U	52	6.6 U	6.6 U
Aroclor-1260	74	6.6 U	130	6.6 U	41	6.6 U	6.6 U
Aroclor-1262	6.6 U	6.6 U	6.6 U	6.6 U	6.5 U	6.6 U	6.6 U
Aroclor-1268	6.6 U	6.6 U	6.6 U	6.6 U	6.5 U	6.6 U	6.6 U
Total PCBs	159	6.6 U††	260	6.6 U††	93	6.6 U††	6.6 U††
Dioxin/Furan pg TEQ/g ww							
TEQ 1/2 DL	3.48	0.155	4.38	0.0886	3.6	0.136	0.127
Axys Lipids	9.97	0.28	13.1	0.23	11.5	0.26	

Hepato - Hepatopancreas
ww - wet weight
DL - detection limit
U - The compound was analyzed for, but was not detected ("non-detect") at or above the MDL. DOH used half of the detection limit.
mg/kg – milligram/kilogram
ug/kg – microgram/kilogram
pg/g – picogram/gram
TEQ - toxic equivalent

† Only crab meat data is used for this evaluation. Hepatopancreas won't be considered in the analysis because as mentioned above there are existing fish consumption advisories placed in this area that warns against consumption of Dungeness crab from industrial or urban areas. http://www.doh.wa.gov/fish
†† Levels are considered non-detects (see uncertainty section on non-detect data).

Table A4. Metal concentrations (mg/kg) found in plants at the Port Gardner site, Everett, Snohomish County, Washington.

Metals in mg/kg ww	Cattail #1	Tule #1	Cattail #2	Tule #2
Arsenic	0.5 U	0.51 U	0.48 U	0.51 U
Cadmium	0.019 U	0.02 U	0.018 U	0.02 U
Chromium	2.2	0.274 U	1.9	0.7
Copper	2.5	0.8	6.3	0.9
Lead	0.19 U	0.2 U	0.18 U	0.2 U
Mercury	0.0036 U	0.004 U	0.0042 U	0.004 U
Selenium	0.97 U	0.99 U	0.93 U	0.99 U
Silver	0.105 U	0.108 U	0.101 U	0.108 U
Zinc	7	4	9.6	3

ww - wet weight
U - The compound was analyzed for, but was not detected ("non-detect") at or above the Method Detection Limit.
mg/kg – milligrams per kilograms

Table A5. PCB concentrations found in plants at the Port Gardner site, Everett, Snohomish County, Washington.

PCBs in ug/kg ww	Cattail #1	Tule #1	Cattail #2	Tule #2
Aroclor 1221	3.8 U	3.8 U	3.7 U	3.7 U
Aroclor 1232	3.8 U	3.8 U	3.7 U	3.7 U
Aroclor 1242	3.8 U	3.8 U	3.7 U	3.7 U
Aroclor 1016	3.8 U	3.8 U	3.7 U	3.7 U
Aroclor 1248	3.8 U	3.8 U	3.7 U	3.7 U
Aroclor 1254	3.8 U	3.8 U	3.7 U	3.7 U
Aroclor 1260	3.8 U	3.8 U	3.7 U	3.7 U
Total PCBs	3.8 U ††	3.8 U ††	3.7 U ††	3.7 U ††

ww - wet weight
U- The compound was analyzed for, but was not detected ("non-detect") at or above the MDL.
†† Levels are considered non-detects (see uncertainty section on non-detect data).
ug/kg –micrograms per kilograms

Table A6. Pesticide concentrations found in plants at the Port Gardner site, Everett, Snohomish, County, Washington.

Pesticides in ug/kg ww ††	Cattail #1	Tule #1	Cattail #2	Tule #2
4-4'-DDT	0.69 U	0.7 U	0.68 U	0.68 U
4-4'-DDE	0.61 U	0.62 U	0.6 U	0.6 U
4-4'-DDD	0.74 U	0.75 U	0.73 U	0.73 U
Gamma-BHC (Lindane)	0.33 U	0.33 U	0.32 U	0.33 U
Alpha-BHC	0.5 U	0.5 U	0.49 U	0.49 U
Beta-BHC	0.74 U	0.74 U	0.72 U	0.73 U
Delta-BHC	0.47 U	0.48 U	0.46 U	0.47 U
Heptachlor	0.35 U	0.35 U	0.34 U	0.35 U
Heptachlor Epoxide	0.41 U	0.41 U	0.4 U	0.4 U
Aldrin	0.33 U	0.33 U	0.32 U	0.32 U
Dieldrin	0.55 U	0.55 U	0.54 U	0.54 U
Endrin	0.6 U	0.6 U	0.58 U	0.59 U
Endrin Ketone	1.1 U	1.1 U	1.1 U	1.1 U
Endrin Aldehyde	1.3 U	1.4 U	1.3 U	1.3 U
Gamma Chlordane	0.29 U	0.29 U	0.28 U	0.28 U
Alpha Chlordane	0.29 U	0.29 U	0.28 U	0.28 U
Methoxychlor	3.7 U	3.7 U	3.6 U	3.7 U
Endosulfan I	0.5 U	0.51 U	0.49 U	0.5 U
Endosulfan II	0.58 U	0.58 U	0.57 U	0.57 U
Endosulfan Sulfate	1.1 U	1.1 U	1.1 U	1.1 U
Hexachlorobenzene	0.35 U	0.35 U	0.34 U	0.34 U
Hexachlorobutadiene	0.64 U	0.65 U	0.63 U	0.63 U
Toxaphene	95 U	96 U	93 U	94 U

ww - wet weight
DDD (1,1-dichloro-2,2-bis(p-chlorophenyl)ethane)
DDE (1,1-dichloro-2,2-bis(p-chlorophenyl)ethylene)
DDT (1,1,1-trichloro-2,2-bis(p-chlorophenyl) ethane)
Gamma-1,2,3,4,5,6-hexachlorocyclohexane (BHC)
U - The compound was analyzed for, but was not detected ("non-detect") at or above the MDL.
†† Levels are considered non-detects (see uncertainty section on non-detect data).
ug/kg – micrograms per kilograms

Table A7. Extraneous maximum residues limits (EMRL) in ppm (mg/kg) of pesticides found in some agricultural commodities (foods) by the Food and Agriculture Organization of the United Nations (FAO) and World Health Organization (WHO).

ALDRIN AND DIELDRIN			
Commodity	*EMRL (mg/kg)*	*Symbols*	*Footnote*
Bulb vegetables	0.05		
Cereal grains	0.02		
Citrus fruits	0.05		
Eggs	0.1		
Fruiting vegetables, Cucurbits	0.1		
Leafy vegetables	0.05		
Legume vegetables	0.05		
Meat (from mammals other than marine mammals)	0.2	(fat)	
Milks	0.006	(fat)	
Pome fruits	0.05		
Poultry meat	0.2	(fat)	
Pulses	0.05		
Root and tuber vegetables	0.1		
CHLORDANE			
Commodity	*EMRL (mg/kg)*	*Symbols*	*Footnote*
Almonds	0.02		
Cotton seed oil, Crude	0.05		
Eggs	0.02		
Fruits and vegetables	0.02		
Hazelnuts	0.02		
Linseed oil, Crude	0.05		
Maize	0.02		
Meat (from mammals other than marine mammals)	0.05	(fat)	

Commodity	*EMRL (mg/kg)*	*Symbols*	*Footnote*
Milks	0.002	(fat)	
Oats	0.02		
Pecan	0.02		
Poultry meat	0.5	(fat)	
Rice, Polished	0.02		
Rye	0.02		
Sorghum	0.02		
Soya bean oil, Crude	0.05		
Soya bean oil, Refined	0.02		
Walnuts	0.02		
Wheat	0.02		
ENDOSULFAN			
Commodity	*MRL (mg/kg)*	*Symbols*	*Footnote*
Avocado	0.5		
Cacao beans	0.2		
Coffee beans	0.2		
Cotton seed	0.3		
Cucumber	1		
Custard Apple	0.5		
Egg plant	0.1		
Eggs	0.03		
Hazelnuts	0.02		
Kidney of cattle, goats, pigs & sheep	0.03		
Litchi	2		
Liver of cattle, goats, pigs & sheep	0.1		

Commodity	*EMRL (mg/kg)*	*Symbols*	*Footnote*
Macadamia nuts	0.02		
Mango	0.5		
Meat (from mammals other than marine mammals)	0.2	(fat)	
Melons, except watermelon	2		
Milk fats	0.1		
Milks	0.01		
Papaya	0.5		
Persimmon	2		
Potato	0.05		
Poultry meat	0.03		
Poultry, Edible offal of	0.03		
Soya bean (dry)	1		
Soya bean oil, Crude	2		
Squash, Summer	0.5		
Sweet potato	0.05		
Tea, Green, Black	30		

Data taken from the FAO/WHO shows the maximum residue limits (MRL), and extraneous maximum residue limits (EMRL) found in some foods that contain pesticide residues. (http://www.codexalimentarius.net/mrls/pestdes/jsp/pest_q-e.jsp)

Appendix B - Exposure Assumptions and Dose Calculations

This section provides calculated exposure doses and assumptions used for exposure to chemicals in surface sediments at the Port Gardner site. An exposure scenario was developed to model exposures that might occur for marina workers (250 days/year) and children (52 days/year). This scenario was devised to represent exposures to an adult and a child. The following exposure parameters and dose equations were used to estimate exposure doses from direct contact with chemicals in sediments.

Exposure to chemicals in surface sediment via ingestion, inhalation, and dermal absorption

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

Ingestion Route

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

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

Dermal Route

$$\text{Dermal Transfer (DT)} = \frac{C \times AF \times ABS \times AD \times CF}{ORAF}$$

$$Dose_{\text{non-cancer (mg/kg-day)}} = \frac{DT \times SA \times EF \times ED}{BW \times AT_{\text{non-cancer}}}$$

$$\text{Cancer Risk} = \frac{DT \times SA \times EF \times CPF \times ED}{BW \times AT_{\text{cancer}}}$$

Inhalation Route

$$Dose_{\text{non-cancer (mg/kg-day)}} = \frac{C \times SMF \times IHR \times EF \times ED \times 1/PEF}{BW \times AT_{\text{non-cancer}}}$$

$$\text{Cancer Risk} = \frac{C \times SMF \times IHR \times EF \times ED \times CPF \times 1/PEF}{BW \times AT_{\text{cancer}}}$$

Table B1. Exposure assumptions used to estimate arsenic and cPAH doses from direct contact with surface sediments at the Port Gardner site, Everett, Snohomish County, Washington.

Parameter	Value	Unit	Comments
Concentration (C)	Variable	mg/kg	Maximum detected value
Conversion Factor (CF)	0.000001	kg/mg	Converts contaminant concentration from milligrams (mg) to kilograms (kg)
Ingestion Rate (IR) – adult	100	mg/day	Exposure Factors Handbook [33, 34]
Ingestion Rate (IR) – older child	100		
Ingestion Rate (IR) - child	200		
Exposure Frequency (EF)	250	days/year	About 52 weeks per year (full time marina worker)
	52		One day/ per week/ per year (number of years playing or digging in surface sediment (child))
Exposure Duration (ED)	5	years	Number of years playing or digging in surface sediment (child)
	10		Number of years playing or digging in surface sediment (older child)
	30		Number of years working at Port Gardner (adult yrs).
Body Weight (BW)	72	kg	Adult mean body weight
	41		Older child mean body weight
	15		0-5 year-old child average body weight
Surface area (SA) - adult	5700	cm^2	Exposure Factors Handbook [33, 34]
Surface area (SA) – older child	2900		
Surface area (SA) - child	2900		
Averaging $Time_{non-cancer}$ (AT)	1825	days	5 years (child)
	3650		10 years (older child)
	10950		30 years (adult)
Averaging $Time_{cancer}$ (AT)	27375	days	75 years
Cancer Potency Factor (CPF)	variable	$[mg/kg\text{-}day]^{-1}$	Source: EPA
24 hr. absorption factor (ABS)	As = 0.03 PAH = 0.13	unitless	Source: EPA (Chemical Specific) Total arsenic and PAH
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 [33, 34]
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)	1.2E+9	m^3/kg	Model Parameters

Hazard quotient formula:

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

Port Gardner Surface Sediment Exposure Route – Non-cancer

Table B2. Non-cancer hazard calculations resulting from exposure to inorganic arsenic and total cPAHs in surface sediments from Port Gardner, Everett, Snohomish County, Washington.

Contaminant	**Concentration (ppm) (mg/kg)**	**Scenarios**	**Estimated Dose** (mg/kg/day)			**Total Dose** mg/kg/day	**MRL/ LOAEL** (mg/kg/day)	**Total Dose/ (MRL/ LOAEL)**
			Incidental Ingestion of Soil	Dermal Contact with Soil	Inhalation of Particulates			
Inorganic Arsenic	50	Child	9.5E-05	8.3E-06	3.3E-09	1.03E-04	0.0003 [b]	0.34
		Older Child	1.7E-05	3.0E-06	2.0E-09	2.00E-05		0.07
		Adult [a]	4.8E-5	5.7E-6	6.0E-09	5.37E-05		0.2
Total cPAH TEQ	0.61	Child	1.2E-06	4.4E-07	4.0E-11	1.64E-06	1.0E+1[c]	0.0000016
		Older Child	2.1E-07	1.6E-07	2.5E-11	3.70E-07		0.00000037
		Adult [a]	5.8E-7	3.0E-7	7.4E-11	8.80E-07		0.00000088

Children exposure frequency assumes that they are exposed by digging and/or playing in the surface sediment for 52 days/year at the Port Gardener site's public access areas.
a – Adult - Corresponds to 30 years exposure duration
b – Agency for Toxic Substances and Disease Registry (ATSDR) chronic oral Minimal Risk Level (MRL)
c – Lowest-observed-adverse-effect level (LOAEL)
Total cPAH TEQ – sum of all carcinogenic polycyclic aromatic hydrocarbons (cPAH) toxic equivalent (TEQ); all cPAHs in COC are added using the TEQ approach to obtain Total cPAH TEQ.
cPAH – polycyclic aromatic hydrocarbon
mg/kg/day – milligrams per kilograms per day
RfD –Reference dose
MRL – Minimal risk level
LOAEL – Lowest-observed-adverse effect level
ppm – parts per million

Port Gardner Surface Sediment Exposure Route – Cancer

Table B3. Cancer hazard calculations resulting from exposure to inorganic arsenic and total cPAHs in surface sediments from Port Gardner, Everett, Snohomish County, Washington.

Contaminant	Concentration (ppm)	EPA Cancer Class	Cancer Potency Factor (mg/kg-day^{-1})	Scenarios	Increased Cancer Risk			Total Cancer Risk
					Incidental Ingestion of Soil	Dermal Contact with Soil	Inhalation of Particulates	
Inorganic Arsenic	50	A	5.7	Child	3.6E-05	3.1E-06	1.3E-09	3.91E-05
				Older Child	1.3E-5	2.3E-06	1.5E-09	1.53E-05
				Total children [a]	4.9E-05	5.4E-06	2.8E-09	5.4E-05
				Adult [b]	1.08E-4	1.30E-5	1.4E-08	1.21E-04
Total cPAH TEQ	0.61	B2	7.3	Child	5.6E-07	2.1E-07	1.9E-11	7.70E-07
				Older Child	2.1E-7	1.6E-07	2.4E-11	3.70E-07
				Total children [a]	7.70E-07	3.70E-07	4.30E-11	1.14E-06
				Adult [b]	1.69E-6	8.8E-7	2.2E-10	2.57E-06

Children exposure frequency assumes that they are exposed by digging and/or playing in the surface sediment for 52 days/year at the Port gardener site's public access areas

[a] Total children corresponds to 15 years exposure duration

[b] Adult - Corresponds to 30 years exposure duration

Total cPAH TEQ – sum of all carcinogenic polycyclic aromatic hydrocarbons (cPAH) toxic equivalent (TEQ); all cPAHs in contaminants of concern (COC) are added using the TEQ approach to obtain Total cPAH TEQ.

A – Human carcinogen

B2 - EPA: Probable human carcinogen (inadequate human, sufficient animal studies)

cPAH – Polycyclic Aromatic Hydrocarbons

mg/kg/day – milligrams per kilograms per day

ppm – parts per million

Appendix C - Exposure Assumptions and Dose Calculations

This section provides calculated exposure doses and exposure assumptions used for chemicals in bottom fish, shellfish, and crab samples taken from the Port Gardner site. These exposure scenarios were developed to model exposures that might occur and were devised to represent exposures to the general population. The following exposure parameters and dose equations were used to estimate exposure doses from ingestion of contaminants in bottom fish and shellfish.

Ingestion Route

$$Dose_{\text{non-cancer (mg/kg-day)}} = \frac{C \times CF_1 \times IR \times CF_2 \times EF \times ED}{BW \times AT_{\text{non-cancer}}}$$

$$\text{Cancer Risk} = \frac{C \times CF_1 \times IR \times CF_2 \times EF \times CPF \times ED}{BW \times AT_{\text{cancer}}}$$

Table C1. Exposure assumptions used in the exposure evaluation of contaminants in bottom fish, shellfish, and crab samples taken from the Port Gardner site in Everett, Snohomish County, Washington.

Parameter	Value	Unit	Comments
Concentration (C)	Variable	ug/kg	Average detected value
Conversion Factor (CF_1)	0.001	mg/ug	Converts contaminant concentration from milligrams (mg) to kilograms (kg)
Conversion Factor (CF_2)	0.001	kg/g	Converts mass of shellfish from grams (g) to kilograms (kg)
Ingestion Rate (IR)	0.57	g/day	Body weight-adjusted shellfish consumption rates to account for children eating nearly 1.6 times as much fish per body weight as do adults (see Table C2)
Ingestion Rate (IR)	0.28		Average general population child – bottom fish (see Table C3)
Ingestion Rate (IR)	0.81		Body weight-adjusted shellfish consumption rates to account for an older child eating 0.81 times as much fish per body weight as do adults (see Table C2)
Ingestion Rate (IR)	0.36		Average general population older child – bottom fish (see Table C3)
Ingestion Rate (IR)	1.7		Average general population adult - shellfish
Ingestion Rate (IR)	0.7		Average general population adult – bottom fish (see Table C3)
Exposure Frequency (EF)	365	days/year	Assumes daily exposure
Exposure Duration (ED)	6.5	years	Number of years eating fish and/or shellfish (younger child)
	15		Number of years eating fish and/or shellfish (older child)
Exposure Duration (ED)	70		Number of years eating fish and/or shellfish
Body weight (BW)	15	kg	Mean body weight child
	41		Mean body weight older child
Body weight (BW)	70		Mean body weight adult
Averaging Time$_{\text{non-cancer}}$ (AT)	Variable	days	Equal to Exposure Duration
Averaging Time$_{\text{cancer}}$ (AT)	25550	days	70 years
Cancer Potency Factor (CPF)	Variable	$[mg/kg\text{-}day]^{-1}$	Source: EPA – Chemical specific

Table C2. Derivation of a child's shellfish consumption rate for the general U.S. population.

Row	Parameter	Adult	Older Child (6-17 yrs)	Child (0-6 yrs)
1	Reported All Fish Consumption Rate- gram of fish per kg bodyweight per day (g/kg/day)	0.277	0.225	0.433
2	Ratio to Adult All Fish Consumption Rate	1	0.81	1.6
3	Reported Shellfish Consumption (g/day)	1.70 (average)	Not Reported	Not Reported
4	Average Body Weight (kg)	70	41	15
5	Ratio to Adult BW	1	0.59	0.21
6	Adjusted Shellfish Consumption Rates (g/day) = Row 2 x Row 3 x Row 5	1.70 (average)	0.81 (average)	0.57 (average)

BW – body weight

Table C3. Derivation of bottom fish consumption rate for the general U.S. population based on 4 percent of total fish intake.

Row	Parameter	Adult	Older Child (6-17 yrs)	Child (0-6 yrs)
1	Reported All Fish Consumption Rate- (g/day)	17.5	9.0	7.0
2	Assume bottom fish intake rate similar to tribal at about 4 percent	0.04	0.04	0.04
3	Adjusted bottom fish rates (g/day) = Row 1 x Row 2	0.70	0.36	0.28

Table C4. Exposure dose and non-cancer risk from ingesting seafood at the average concentrations of contaminants in English sole fish, clams, and crab samples taken from the Port Gardner site, Everett, Snohomish County, Washington.

Species	Contaminant	Average Concentration (ppm)		Estimated Dose (mg/kg/day) General population Average	MRL or RfD mg/kg/day	Hazard quotient General population Average
Eastern softshell clams [a]	Total arsenic	2.0	Child	3.7E-7	3.00E-4 [c]	< 0.01
			Older child	4.0E-7		< 0.01
			Adult	4.9E-7		< 0.01
Crabs [b]†		3.7	Child	6.9E-7		0.002
			Older child	7.3E-7		0.002
			Adult	9.0E-7		0.003
English sole [b]		2.0	Child	3.7E-6		0.01
			Older child	4.0E-6		0.01
			Adult	4.9E-6		0.02
Crabs †	Mercury	0.048	Child	9.0E-7	1.00E-4 [d]	0.01
			Older child	2.2E-6		0.02
			Adult	1.2E-6		0.01
Crabs †	Total Dioxin TEQ	1.6E-7	Child	3.0E-12	1.0E-9 [e]	0.003
			Older child	3.2E-12		< 0.001
			Adult	3.9E-12		0.004
English sole		3.06E-7	Child	5.7E-12		0.006
			Older child	6.0E-12		0.01
			Adult	3.1E-12		0.003
Eastern softshell clam		3.4E-8	Child	6.3E-13		0.001
			Older child	6.7E-13		< 0.001
			Adult	8.3E-13		0.001

PPM – parts per million
† - Includes only crab meat
[a] – Used 1% for inorganic arsenic; inorganic forms are usually present in shellfish (clams & crabs) in only minor amounts, and most assumptions are that 10% or less of total arsenic in shellfish is in the inorganic form
[b] – Used 10% for inorganic arsenic in bottom fish; inorganic forms are usually present in shellfish in only minor amounts, and most assumptions are that 10% or less of total arsenic in shellfish is in the inorganic form
[c] - Agency for Toxic Substances and Disease Registry (ATSDR) chronic oral Minimal Risk Level (MRL)
[d] – EPA's Reference Dose for methylmercury
[e]- ATSDR Minimal Risk Level (MRL) for Dioxin total equivalent (TEQ)
MRL – Minimal Risk Level
RfD – Reference Dose

Table C5. Theoretical cancer risk from ingesting seafood at the average concentrations of contaminants in bottom fish, clams, and crab samples taken from the Port Gardner site, Everett, Snohomish County, Washington.

Species	Contaminant	Average Concentration (ppm)		Increased Cancer Risk General population Average	Cancer Potency Factor (mg/kg-day^{-1})	Total Cancer Risk General population Average
Eastern softshell clams [a]	Total arsenic	2.0	Child	2.0E-7	5.7	4.12E-5
			Older child	2.1E-7		
			Adult	2.8E-6		
Crabs [b]†		3.7	Child	3.7E-7		
			Older child	3.87E-7		
			Adult	5.1E-6		
English sole [b]		2.0	Child	2.0E-6		
			Older child	2.1E-6		
			Adult	2.8E-5		
Crabs [b]†	Dioxin	1.6E-7	Child	4.2E-8	1.5E+5	1.43E-6
			Older child	4.4E-8		
			Adult	5.8E-7		
English sole		3.06E-7	Child	7.95E-8		
			Older child	8.4E-8		
			Adult	4.6E-7		
Eastern softshell clam		3.4E-8	Child	8.8E-9		
			Older child	9.4E-9		
			Adult	1.2E-7		
Sum of cancer risk						4.3E-5

PPM – parts per million
† - Includes only crab meat
[a] – Used 1% for inorganic arsenic; inorganic forms are usually present in shellfish (clams & crabs) in only minor amounts, and most assumptions are that 10% or less of total arsenic in shellfish is in the inorganic form
[b] – Used 10% for inorganic arsenic in bottom fish; inorganic forms are usually present in shellfish in only minor amounts, and most assumptions are that 10% or less of total arsenic in shellfish is in the inorganic form

Appendix D - Exposure Assumptions and Dose Calculations

This section provides calculated exposure doses and assumptions used for exposure to chemicals in seafood at the Port Gardner site using Tulalip Tribe consumption rates. It is based on the EPA Tribal framework for fish and shellfish consumption rates for risk-based decisions [14].

Intake of contaminant in mg/kg-day (IR_c) = (CF_i x CR_{PS} x $\%_i$ x UCF_1) /BW [Equation 1]

Where:
IR_c = Intake rate of contaminant by category of fish/shellfish
CF_i = Contaminant concentration (mg/kg) in the tissue of the particular fish or shellfish category
CR_{PS} = Total consumption rate of fish and shellfish harvested from Puget Sound, 194 grams per day
$\%_i$ = Percentage of the ingestion rate that consists of the category of fish or shellfish, unitless
BW = Body weight, 81.8 kilograms, observed from the Tulalip Tribes' study
UCF_1 = Conversion factor 1, 0.001 kilograms per gram

Estimated cancer risk (ECR) = (IR_{total} x ED x EF x CSF) / (AT x UCF_2) [Equation 2]

Where:
IR_{total} = Total intake of contaminant from site-related fish and shellfish consumption
ED = Exposure duration, 70 years
EF = Exposure frequency, 365 days per year
CSF = Oral cancer slope factor for contaminant
AT = Averaging time, 70 years for carcinogens
UCF_2 = Conversion factor 2, (365 days/year)

Estimated hazard index (EHI) = (IR_{total} x ED x EF x UCF_2) / (RfD x AT) [Equation 3]

Where:
IR_{total} = Total intake of contaminant from site-related fish and shellfish consumption,
ED = Exposure duration, 70 years
EF = Exposure frequency, 365 days per year
RfD = Oral reference dose for contaminant
AT = Averaging time, the same as exposure duration for non-carcinogenic effects
UCF_2 = Conversion factor 2, (1 yr/365 days)

Table D1. Port Gardner total arsenic intake rate based on the Tulalip Tribe seafood consumption rate, Everett, Snohomish County, Washington.

Overall Fish/Shellfish Consumption Rate, g/day	Category	Percent of Consumption Rate Represented by Category	Site-related concentration of arsenic, mg/kg in tissue	Category Specific Exposure mg/kg-day
194	Salmon	49.7	0	0
194	Pelagic fish	4.2	0	0
194	Bottom fish (English sole) [a]	3.9	0.02	0.00000185
194	Shellfish (clams and crabs) * [b]	42.2	0.029	0.000029
Sum, Ingestion Rate (IR_{total})				0.0000309

*Crabs tissues and clams average (i.e., [3.7 + 2.0]/2 = 2.85 mg/kg)

[a] Used 10% for inorganic arsenic in bottom fish; inorganic forms are usually present in shellfish in only minor amounts, and most assumptions are that 10% or less of total arsenic in shellfish is in the inorganic form

[b] Used 1% for inorganic arsenic; inorganic forms are usually present in shellfish in only minor amounts, and most assumptions are that 10% or less of total arsenic in shellfish is in the inorganic form

mg/kg/day –milligrams per kilograms per day

Arsenic Estimated Hazard Index = 0.103 (Sum IR total)

Arsenic Estimated Cancer Risk = 1.76E-4 (Sum IR total)

Intake of contaminant in mg/kg-day (IR_c) = (CF_i x CR_{PS} x $\%_i$ x UCF_1) /BW

IR c = 0.029 mg/kg x 194 g/day x 0.422 x 0.001/81.8 Kg
IR c = 2.9E-05 mg/kg-day

IR c = 0.02 mg/kg x 194 g/day x 0.039 x 0.001/81.8 Kg
IR c = 1.85E-06 mg/kg-day

Sum of both doses (IR total) = 3.09E-05 mg/kg-day

Estimated cancer risk (ECR) = (IR_{total} x ED x EF x CSF) / (AT x UCF_2)

ECR = (3.09E-05 mg/kg-day x 70 yrs x 365 yrs x 5.7 mg/kg-day) / (70 x365)
ECR = 1.76 E-04

Estimated hazard index (EHI) = (IR_{total} x ED x EF x UCF_2) / (RfD x AT)

EHI = 3.09E-05 mg/kg-day x 70 yrs x 365 x 0.002739)/ 3.0E-04 mg/kg-day x 70 yrs
EHI = 1.03E-01

Table D2. Port Gardner dioxin intake rate based on the Tulalip Tribe seafood consumption rate, Everett, Snohomish County, Washington.

Overall Fish/Shellfish Consumption Rate, g/day	Category	Percent of Consumption Rate Represented by Category	Site-related concentration of dioxin, mg/kg in tissue	Category Specific Exposure mg/kg-day
194	Salmon	49.7	0	0
194	Pelagic fish	4.2	0	0
194	Bottom fish (English sole)	3.9	3.06E-7	2.8E-11
194	Shellfish*(clams and crabs)	42.2	1.94E-7	1.9E-10
Sum, Ingestion Rate (IR_{total})				2.2E-10

*Crabs tissues and clams average (i.e., [1.6E-7 + 3.4E-8]/2 = 1.94E-7 mg/kg)
Dioxin Estimated Hazard Index = 0.22 (Sum IR total)
Dioxin Estimated Cancer Risk = 3.3E-5 (Sum IR total)
mg/kg/day – milligrams per kilograms per day

Table D3. Port Gardner mercury intake rate based on the Tulalip Tribe seafood consumption rate Everett, Snohomish County, Washington.

Overall Fish/Shellfish Consumption Rate, g/day	Category	Percent of Consumption Rate Represented by Category	Site-related concentration of mercury, mg/kg in tissue	Category Specific Exposure mg/kg-day
194	Salmon	49.7	0	0
194	Pelagic fish	4.2	0	0
194	Bottom fish	3.9	0	0
194	Shellfish*	42.2	0.048	0.000048
Sum, Ingestion Rate (IR_{total})				0.000048

*Crabs tissues only average
Mercury Estimated Hazard Index = 0.48
mg/kg/day – milligrams per kilograms per day

Appendix E - Meal Limit Calculations

For contaminants of concern (non-carcinogenic health effects):

Meal limits (ML) were calculated for clams, crabs, and bottom fish based on contaminants of concern in each species. Additionally, meal limits were calculated based on developmental and immunologic endpoints for dioxin and mercury. Meal limits were calculated using the equation below in conjunction with the MRL or RfD as the target risk value and the exposure parameters provided in Table E1 below. The developmental and immunologic endpoints are based on the additive effects of dioxin and mercury as recommended in the ATSDR interaction profile for toxic contaminants found in fish. Tables E2, E3, and E4 provide meal limits that would be protective of women and children who eat clams, crabs, and bottom fish from Port Gardner based on contaminants of concern in each species.

ML = [(RfD or MRL)*BW* DM]/C * MS
ML = recommended fish meal limit per month (meal/month)
RfD = reference dose (EPA)
MRL = minimal risk level (ATSDR)
BW = body weight; DM = days per month; C = concentration; MS = meal size

Many factors must be considered when one is recommending limits on the consumption of fish, including the very real health benefits of eating fish, the quality and comprehensiveness of environmental data, and the availability of alternate sources of nutrition. In addition, these limits do not consider that multiple species are consumed, a consideration that would require weighting of the percent of each species consumed. These allowable ingestion rates also do not consider the fact that cooking reduces exposure to some contaminants in fish. Therefore, allowable consumption limits for prepared fish would be greater than those shown in Tables E2, E3, and E4.

Table E1. Exposure parameters used to calculate recommended meal limits for clams, crabs, and bottom fish from Port Gardner in Everett, Snohomish County, Washington.

Exposure Parameter	RfD/ MRL	**Endpoint**		**Units**
		Developmental RfD/MRL	Immunological RfD/MRL	
Average Concentration (C)	Variable			ug/kg
Arsenic	0.3			
Dioxin	0.000001	0.000001	0.00002	
Mercury	0.1	0.1	0.3	ug/kg/day
Days per month (DM)	30.4			days/month
Mean Body Weight (BW)	60.0			kg
Meal size (MS)	0.227			kg

RfD – Reference dose
MRL – Minimal risk level
ug/kg – micrograms per kilograms
kg - kilograms
ug/kg/day – micrograms per kilograms per day

Table E2. Calculated meal limits per month for shellfish (clams and crabs) from Port Gardner, Everett, Snohomish County, Washington.

Contamination	Concentration (ppm)	Meals based on RfD/ MRL	Lowest meals per month (rounded to single digit)
Arsenic [a]	0.029	83.1	17
Dioxin	1.94E-7	41.4	
Mercury*	0.048	16.7	

* Crab tissue only
[a] Used 1% for inorganic arsenic; inorganic forms are usually present in shellfish in only minor amounts, and most assumptions are that 10% or less of total arsenic in shellfish is in the inorganic form
ppm – parts per million

Table E3. Calculated meal limits per month for crabs only from Port Gardner, Everett, Snohomish County, Washington.

Contamination	Concentration (ppm)	Meals based on RfD/ MRL	Meals based on Developmental additive endpoint	Meals based on Immune additive endpoint	Lowest meals per month (rounded to single digit)
Arsenic [a]	0.037	65.2			17
Dioxin	1.6E-7	50.2	66.9	150.6	
Mercury	0.048	16.7			

[a] Used 1% for inorganic arsenic; inorganic forms are usually present in shellfish in only minor amounts, and most assumptions are that 10% or less of total arsenic in shellfish is in the inorganic form
ppm – parts per million

Table E4. Calculated meal limits per month for bottom fish from Port Gardner, Everett, Snohomish County, Washington.

Contamination	Concentration (ppm)	Meals based on RfD/ MRL	Meals based on Developmental additive endpoint	Meals based on Immune additive endpoint	Lowest meals per month (rounded to single digit)
Arsenic	0.02	120.5			26
Dioxin	3.06E-7	26.3	26.3	52.5	

[a] Used 1% for inorganic arsenic; inorganic forms are usually present in shellfish in only minor amounts, and most assumptions are that 10% or less of total arsenic in shellfish is in the inorganic form
ppm – parts per million

Applying meal limits from Tables E2, E3, and E4 across the general population assumes that meal size will decrease or increase proportionately with body weight. Such an assumption could result in underestimating exposure for consumers who eat proportionately more fish per unit of body weight. Table E5 demonstrates how an eight-ounce meal for a 70-kilogram adult would change to remain proportional with body weight.

Table E5. Adjustment of fish meal size based on the body weight of the consumer.

Body Weight		Meal Size	
Pounds	**Kilograms**	**Ounces**	**Grams**
19	9	1	28
39	18	2	57
58	26	3	85
77	35	4	113
96	44	5	142
116	53	6	170
135	61	7	199
154	70	8	227
173	79	9	255
193	88	10	284
212	96	11	312
231	105	12	340
250	113	13	369
270	123	14	397
289	131	15	425
308	140	16	454

Appendix F - Responsiveness Summary

Comments, questions and answers on the health consultation report

Department of Ecology's comments - March 3, 2010

1) **Messaging:** The messaging regarding Ecology and DOH's conclusions and purposes is important. Perhaps we could use the document that is currently being drafted by our agencies as a guide for this document.
2) **Clarity:** The document would be improved if the conclusion and discussion sections were more comprehensive and included concise information from the rest of the document. There is a lot of detailed information in this document so it can be somewhat awkward to search multiple sections to find answers about what the risks mean to the public and consumption limitations (amounts and specific food).
3) **Conclusions:** It would be helpful if Conclusion 2 specifically referred to the Puget Sound fish consumption advisories and risk levels. It may be confusing for the public to read that there is no general public health hazard without providing the details of what limits are currently in place to ensure risk is minimized. In addition, it may be helpful to the public to understand what the risks are from consuming crab butter.
4) **Plant tissue:** It is unclear if or how the plant tissue exposure "chewing" scenario was incorporated into the assessment. The Tulalip tribe chews the reeds to make baskets etc. Because of their concerns of possible toxic effects, this was Ecology's primary reason for sampling and analyzing this plant tissue. It would be helpful if it was made clear how this scenario was used to make conclusions.
5) **Dioxin:** DOH does not list dioxin as a COC. However, dioxin is a carcinogenic chemical of concern for sediment cleanup as it is highly likely that the concentrations are above MTCA 1E -6 excess cancer risk levels in both sediment and tissue samples (using the seafood ingestion pathway). In addition, Table 4 shows maximum concentrations of dioxins in tissue above screening levels (including meat portions). We need to understand how to message this apparent dichotomy. In addition, Table 2 lists the contaminant maximum concentration for total dioxin as 1.6E-04 ppm but it should be 1.6E-07 ppm. It is also unclear why dioxins are not classified as a B2 human carcinogen.
6) **Tribal Consumption Rates:** Ecology will likely be using the established Tulalip fish consumption rates when conducting risk analysis for sediment cleanup. It would be helpful if it was made clear what rates DOH used to make conclusions.
7) **Data:** Discrepancies were noticed between the data presented in the DOH report and data housed in Ecology's EIM database. This may be something to verify.
8) **Screening Levels:** It is unclear if DOH is required to use the 2004 EPA Region 9 soil screening values. But the current Region 9 PRG table is December 2009. The Region 9 PRGs have been harmonized with similar risk-based screening levels used by Regions 3 and 6 into a single table: "Regional Screening Levels (RSL) for Chemical Contaminants at Superfund Sites."
9) **Risk from Direct Contact with Surface Sediment**: Risk from direct contact with sediment was evaluated for an adult worker. However, some areas of the text suggest that

exposure doses were estimated for a child (see Page 12) and Appendix B includes exposure assumptions for a child, older child, and adult. This may need to be made clearer.

10) **Location of Maximum cPAH Sediment Concentrations**: It is stated in the text that levels of contaminants in surface sediment, including arsenic and cPAHs, were highest in the East Waterway. Based on this, direct contact with sediment risk was assessed for a marine worker. Please be aware that the highest cPAH concentrations were identified along the banks of the Snohomish River and in Steamboat Slough which would likely have some recreational exposure.
11) **Exposure Dose and Risk Calculations**: It would be helpful to present exposure dose and risk calculations to allow the reader to reproduce the calculations.
12) **Reference to Asarco Smelter in Tacoma** (see Page 11): It may be necessary to reference the Everett Asarco Smelter since this study is in Port Gardner. Parts of Everett had high arsenic concentrations in soil due to fallout from the smelter.

DOH response: All comments were noted and/or modified in the report. DOH staff held a meeting with Ecology staff to discuss their comments in detail. DOH staff notified Ecology explaining risk messages and differences between our agencies would not be added since the agencies are still working on this risk messaging document. For clarity purposes, DOH agreed to add an executive summary in the report.

Tulalip Tribe comments - March 31, 2010

Background and conclusions

1. Section titled Background and Statement of Issues needs to adequately describe Tulalip historical and current use of Port Gardner area (i.e., within Tribe's U&As for fish and shellfish and within area long used by Tulalip ancestors and the Tulalip tribal community). As written this section does not provide proper context and importance of Port Gardner area to Tulalip tribal community.

DOH response: Comment has been noted in the report. A brief historical description was added as follows:

"Native American Tribes and Nations in the Puget Sound have reserved the right to take fish and shellfish at their usual and accustomed grounds and stations. In addition to fishing, other reserved cultural activities include hunting, gathering traditional and medicinal plants, and more. These usual and accustomed treaty fishing areas include the freshwater areas of the Snohomish-Snoqualmie-Skykomish river basin and certain marine waters of the Puget Sound.
The Tulalip Indian Tribal Community stated that Port Gardner is an important historic harvest site that has been impacted by contamination that currently limits the Tulalip tribal community from access and use of treaty protected natural resources within their treaty protected areas."

2. Conclusion 1: Does not address potentially higher exposure rates of the Tulalip tribal community to soil contamination. This conclusion is based on 30 years of exposure of a marine worker. Tribal community exposure could be higher.

DOH response: DOH evaluated children and adult exposures based on 250 days/year for workers and 52 days/year for a child. In general, EPA recommends the central tendency of 350 days/year for residential exposures to soil and Reasonable Maximum Exposure (RME) of 250 days/year for industrial scenarios for workers. EPA suggests that exposure duration may be adjusted to reflect site-specific conditions. There are no standard default factors for sediment exposure. Therefore, exposure assumptions at beaches are based on recreational and marine worker scenarios. The assumption is that exposure to beach sediment would be less than a marine worker RME scenario. Thus, current exposure assumptions used in this health evaluation were very conservative and represented actual occurrences as accurately as possible.

DOH has no information regarding potential exposures of tribal members greater than 30 years. Potential exposures in public access areas and/or areas commonly used by tribal members are less than 30 years. The scenarios and assumptions used to estimate potential exposures overestimated daily exposures over 30 years. Thus, DOH is not evaluating tribal community exposures beyond 30 years exposure.

3. Conclusion 3: Concludes that consumption of seafood at Tribal consumption rates used in health assessment “is expected to harm people’s health.” DOH next steps do not adequately address this conclusion: The loss of this treaty protected resource is unacceptable to the Tulalip tribal community.

DOH response: The purpose of this document is to assess the potential human health threat of exposure to contaminants from Port Gardner, suggest general recommendations for people to protect themselves from these contaminants, and help the regulatory agency make decisions to protect public health. The loss of treaty protected resources is outside of the health-focused purview of this report.

4. Conclusion 4: Concludes that levels of chemicals in plants are “not expected to harm peoples’ health” but then the conclusion also states that inhalation of dust and small soil particulates could contain high concentrations of contaminants and “workers may be exposed at levels that could be harmful.” These two statements are inconsistent.

Data

- Levels of chemicals in plants are based on a very small sample size … Conclusions about human health and health to the Tulalip tribal community should not be made from such a limited amount of data. Additional sampling (larger extent and additional plants) should be investigated.
- Plant section discusses general exposure pathways it does not reflect an actual evaluation and quantification of Tulalip tribal community uses of plants and exposures to contaminants through plant gathering.
- Since the analysis was based on a small amount of data the report should identify assumptions and needs for further research (i.e. fill data gaps).

DOH response: DOH acknowledges there are uncertainties when evaluating contaminants in plants. The following uncertainty section was added to the report to describe the lack of information on plant ingestion rates and exposures.

Uncertainty of exposure scenarios for plants

American Indians and other Native Tribes routinely use and prepare some plants for non-ingestion purposes, such as basket making, dying, and weaving. Non-ingestion exposure pathways (e.g., basket weaving and face painting) were not evaluated in this report because of the lack of plant ingestion rates to quantify human exposure to site-specific contaminants. It is difficult to explain how metals in plants may be available for ingestion exposure (perhaps by users engaging in hand-to-mouth activity) or inhalation exposure. Thus, determining how the magnitude of such exposures compares to that of food ingestion exposures is fraught with uncertainty. Plant uptake of metals as a route of human exposure compared with exposure from aerosol deposition and soil splash onto plants was studied by Chaney and others. These studies concluded that, in general, people will have greater potential for ingesting, inhaling, or absorbing (via dermal contact) metals and other contaminants from the deposition of soil onto plants than from the actual uptake of these contaminants from the soil into the plants [27, 28, 29, 30].

Conclusion 4 regarding plants has been modified as follows:

"Based on available information related to the contaminant levels of chemicals (i.e., metals) in plant tissue, DOH cannot make a definite statement about the potential exposures for basket weavers. Plant ingestion rates were not available to quantify human exposure to site-specific contaminants in Port Gardner. DOH acknowledges that workers (e.g., basket weavers and/or plant harvesters) who spend most of the day in an enclosed environment may inhale substantial amounts of dust and small soil particulates bound to plant materials. If the plant materials, dust, and/or soil particulates contain high concentrations of contaminants, workers may be exposed at levels that could be harmful." DOH is unable to determine levels of contaminants in these plants (i.e., Cattail and Tule plants) that may cause an adverse health effect in workers due to the lack of data.

Plant tissue sample size

DOH considers that collecting more plant tissue is not necessary. The levels of contaminants (mostly metals, copper, total chromium, and zinc) found in plants are very low to insignificant. In general, these plants (Cattails and Tule) cannot accumulate contaminants from the soil because of physiological processes which prevent metals and some other contaminants from being distributed to the tops of plants. Heavy metals such as lead, cadmium, and arsenic are generally bound to soil particles, thus soil is the primary vehicle for heavy metal exposure – not the uptake and translocation of metals from the root to the top of the plant.

Analysis

5. How are existing consumption advisories considered when evaluating risk? If there is an advisory, as for the recreational marine area 8-2, is the assumption that no fish and shellfish resources are being consumed? This assumption should be tested. The Tulalip tribal community may be at higher risk for exposure from contaminants because of the cumulative exposure pathways throughout the region.

DOH response: Existing consumption advisories are not considered in this and/or any evaluation when calculating risks. The purpose of a fish/shellfish advisory is to recommend safe levels of fish/shellfish consumption. An advisory is not enforceable; it provides health advice to the public based on previous studies. A fish/shellfish advisory for recreational marine area 8-2 is currently in place. This advisory recommends:

"Puget Sound advisory for recreational Marine Area 8-2 recommends: a) Eat no more than two meals per month for rockfish and flat fish (e.g., sole, sanddab, and flounder), and no more than two meals per month for Chinook salmon, and b) Eat Dungeness and Red Rock crab from non-urban areas and do not eat the "crab butter" (viscera). Data have shown that crabs from industrial urban areas may contain more contaminants than those from non-urban areas, and that crab butter (viscera) has more contaminants than crab muscle."

6. The tribal consumption rates used in this health consultation, although based on data collected at Tulalip, may underestimate the risk to the Tulalip tribal community (compare to tribal consumption rates used in Swinomish study).

DOH response: The EPA's tribal framework for risk based consumption rates of fish and shellfish at Cleanup Sites in Puget Sound and the Strait of Georgia was used in this evaluation. DOH used a maximum concentration and the Tulalip tribal consumption rate of 194 g/day to calculate exposures. DOH used the EPA tribal framework for fish and shellfish consumption rates. The Swinomish study is not final and there are no definite consumption rates. The assumptions used to calculate exposures in this health consultation were very conservative and tended to overestimate exposures.

7. How are baseline health factors (i.e., predisposition) and cumulative exposures factored into risk calculations? Baseline health and exposure pathways for the Tulalip tribal community may result in higher risks than accounted for in this health assessment.

DOH response: DOH calculated cumulative exposures from contaminants in seafood. Overall, lifetime increase of cancer risks was calculated associated with exposures for all contaminants of concern. The sum of cancer risk is listed for total arsenic and dioxins in Appendix C, Table C5. DOH used conservative assumptions and sensitive populations such as children to derive non-cancer and cancer risks.

8. Sediment exposure pathways do not seem to adequately address the different ways that the Tulalip tribal community might come into contact with contaminated sediments. What about ingestion of sediments during the process of cooking and eating fish and shellfish? What about skin exposure to contaminated sediments during plant gathering, shellfish harvest and fishing?

DOH response: Three exposure pathways were addressed in this health evaluation. DOH considered ingestion exposure (swallowing sediment/seafood), inhaling exposure (breathing contaminants present in the sediment), and dermal contact (skin exposure to contaminants present in the sediment). Appendix B and C provides exposure doses and assumptions used for exposure to chemicals in sediments. Exposure to chemicals in sediment includes ingestion, inhalation, and dermal absorption.