Health Consultation

Evaluation of Inorganic Contaminants in Geoduck Tissue from Tracts near Wyckoff/Eagle Harbor Superfund Site
Eagle Harbor, Kitsap County, Washington

September 10, 2009

Prepared by

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

Health Consultation: A Note of Explanation

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

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

HEALTH CONSULTATION

Evaluation of Inorganic Contaminants in Geoduck Tissue from Tracks near

WYCKOFF/EAGLE HARBOR SUPERFUND SITE

EAGLE HARBOR, KITSAP COUNTY, WASHINGTON

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Foreword

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

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

For additional information or questions regarding DOH or the contents of this health consultation, please call the health advisor who prepared this document:

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For people with disabilities, this document is available on request in other formats. To submit a request, please call 1-800-525-0127 (TTY/TDD call 711).

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 and 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 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.
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 Protection Agency (EPA)	United States Environmental Protection Agency. EPA leads the nation's environmental science, research, education and assessment efforts. The mission of the Environmental Protection Agency is to protect human health and the environment. Since 1970, EPA has been working for a cleaner, healthier environment for the American people.
Epidemiology	The study of the occurrence and causes of health effects in human populations. An epidemiological study often compares two groups of people who are alike except for one factor, such as exposure to a chemical or the presence of a health effect. The investigators try to determine if any factor (i.e., age, sex, occupation, economic status) is associated with the health effect.

Exposure	Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [**acute exposure**], of intermediate duration, or long-term [**chronic exposure**].
Hazardous substance	Any material that poses a threat to public health and/or the environment. Typical hazardous substances are materials that are toxic, corrosive, ignitable, explosive, or chemically reactive.
Ingestion	The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see route of exposure].
Ingestion rate (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.
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.
Method Detection Limit (MDL)	MDL is the minimum concentration of a substance (in a given matrix) that can be measured with a 99% confidence that the analyte concentration is greater than zero.
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 (oz.) 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.

Remedial investigation	The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process of determining the type and extent of hazardous material contamination at a site.
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].

Summary

Introduction

The Washington State Department of Health (DOH) prepared this health consultation at the request of the Suquamish Tribe and the DOH Office of Shellfish and Water Protection (OSWP). The purpose of this health consultation is to evaluate geoduck inorganic contaminant data from two commercial geoduck tracts situated east and adjacent to the Wyckoff/Eagle Harbor Superfund site in Washington and make recommendations for actions that ensure the public's health is protected.

Conclusions

DOH concludes that high end geoduck consumers are unlikely to be exposed to harmful levels of inorganic contaminants from eating geoduck near the Wyckoff/Eagle Harbor Superfund site (Tyee Shoal geoduck tract # 07650 and Port Blakely geoduck tract # 07700). Thus, low levels of contaminants present in geoduck are not expected to harm people's health.

Basis for conclusion

Geoduck sampled from tracts near the Wyckoff/Eagle Harbor Superfund site had low levels of inorganic contamination.

Next steps

The Department of Health's Office of Food Safety and Shellfish will use this health consultation in the process used to certify shellfish growing areas.

For More Information

If you have concerns about your health, as it relates to exposure to harmful levels of inorganic contaminants near the Wyckoff/Eagle Harbor Superfund Site, you should contact the Washington State Department of Health, toll free at 1-877-485-7316.

Purpose

The Washington State Department of Health (DOH) prepared this health consultation at the request of the Suquamish Tribe and the DOH Office of Shellfish and Water Protection (OSWP). The purpose of this health consultation is to evaluate geoduck inorganic contaminant data from two commercial geoduck tracts situated east and adjacent to the Wyckoff/Eagle Harbor Superfund site in Washington and 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

Eagle Harbor is a 500 acre inlet on the east side of Bainbridge Island located in Central Puget Sound, Washington (Figure 1). Sediments in Eagle Harbor are contaminated with polycyclic aromatic hydrocarbons (PAHs) and wood treatment compounds from Wyckoff's former wood treating facility located at the harbor's entrance, and metals such as mercury, copper, lead, and zinc from historic shipyards.[1,2]

On the Wyckoff facility, soil and groundwater are contaminated with creosote and its accompanying PAHs, dioxins/furans and pentachlorophenol (PCP), and other wood treatment compounds. As much as one million gallons of creosote product are estimated to remain in the site's soil and groundwater.[1,2] In 1997, DOH completed a chemical contamination assessment of geoduck adjacent to Eagle Harbor and recommended the following due to the potential contamination of geoduck from the Wyckoff/Eagle Harbor Superfund site: 1) geoduck and sediment samples from the proposed harvest area be collected and analyzed to determine organic and metal concentrations, 2) newly collected sediment and tissue data be evaluated in a detailed human health impact assessment, and 3) harvest of geoduck from the area outside of Eagle Harbor be postponed as a matter of prudent public health policy pending the results of recommendations one and two above.[3]

A seafood consumption advisory has been in place at Eagle Harbor since the early 1980's.[1,2] Recreational shellfish harvesting in Eagle Harbor is not advised and commercial harvest of shellfish, including geoducks from tracts near the mouth of Eagle Harbor, is prohibited partly due to chemical contamination concerns, but also as a result of a nearby municipal sewage outfall operated by the City of Bainbridge Island.

The City of Bainbridge Island plans to extend their sewage outfalls further from the shore into deeper water. This will serve to dilute sewage impacts on near shore environments and potentially open up prohibited shellfish harvest sites for commercial harvest classification. However, the outfalls have not been extended due to funding issues.[4]

The Suquamish Tribe requested a health consultation from DOH to evaluate the potential chemical contamination of geoduck associated with the Wyckoff/Eagle Harbor Superfund site from two tracts adjacent to the mouth of Eagle Harbor, one in Port Blakely (#07700) and the other in the Tyee Shoal tract (#07650) in Puget Sound, and to provide information that the Tribe can use when making future tribal harvest management decisions (Figure 1). These tracts are not

currently classified for commercial harvest due to pollution concerns from municipal sewage outfalls and potential chemical contamination associated with the Wyckoff/Eagle Harbor Superfund site. Because it is not known how past and current pollution may impact geoducks in this area, a necessary first step in the process of certifying this area for harvest is to determine whether contaminant concentrations are at an acceptably low level for consumers.

Contaminants of concern

Chemical contaminants in geoduck have not been widely studied in Puget Sound, so relative to other bivalve species, little is known about how contaminant levels in geoduck vary by location or age. Recent studies by King County, Kitsap County, the Suquamish Tribe, and others have revealed that organic contaminants are seldom found in geoduck, even in areas that have been impacted by industrial use in the past.[5,6,7] Conversely, metals are commonly found in geoduck tissue (neck/strap, skin, and gutball; although levels are much higher in the skin and gutball).

In 2005, geoducks were also sampled from the Wyckoff/Eagle Harbor Superfund site and evaluated for organic contaminants. Low levels of PCBs, dioxins and furans were found in some samples, but not at levels of concern for human health. The results of this evaluation can be found in the June 2009 health consultation report.[8]

Based on the results of past geoduck tissue (neck/strap and gutball) sampling, DOH identified arsenic, lead, cadmium, and mercury as the contaminants most likely to build up in geoduck at levels of potential health concern.[9]

Methods

Prior to sampling, a quality assurance project plan (QAPP) was prepared by the Suquamish Tribe and DOH, and submitted to the U.S. EPA for approval.[10] In general, the plan identified contaminants of concern, sample size, sample preparation, and data quality objectives.

Geoduck samples were collected on May 13, 2008. Scuba divers from the Suquamish Tribe collected geoduck samples from three stations situated within the Port Blakely tract, three stations located within the Tyee Shoal tract (Figure 1), and one station located within a commercial geoduck tract in Agate Passage (tract # 06800) (Figure 2). The Agate Passage station is located on the northwestern side of Bainbridge Island and is the background sample station.

A geoduck sample was collected at each of the stations consisting of a composite of five geoduck clams. A total of twelve geoduck tissue samples (eight neck/strap composite samples and four gutball composite samples) were collected during standard geoduck harvesting techniques implemented by the Suquamish Tribe. A diver used a hose pressurized with water to dig the geoduck clams. The depths of the sampling locations ranged from 22 to 54 feet.

Geoduck samples were dissected and homogenized by DOH and Suquamish Tribe staff at the Washington Department of Ecology laboratory using a standard operating procedure (SOP) for geoduck tissue liquid nitrogen grinding.[11] Tissue samples consisted of either the neck and strap (siphon and mantle) or the gutball (viscera). The outer skin of the neck was removed prior to

homogenization and laboratory analysis. These tissues were weighed prior to and after sample dissection (Figure 3).

Homogenized tissue samples were hand-delivered to the EPA Region 10 Manchester Laboratory (Manchester Laboratory) for the analysis of antimony, total arsenic, beryllium, cadmium, chromium, lead, and thallium (EPA Method 200.8); arsenic speciation analysis (Manchester Laboratory SOP method); mercury (EPA Method 245.6); and percent lipids (EPA SW846 Method 3541 modified).

Methods, results, quality assurance/quality control (QA/QC), and data validation are summarized in the final Wyckoff/Eagle Harbor geoduck tissue field sampling report.[10]

Results

A summary of results is presented in Table 1. Appendix A, Tables A1- A6 lists all sampling results at all locations in more detail, and Table A6 lists total arsenic and inorganic arsenic in the Wyckoff/Eagle Harbor sections. In general, the gutball samples had slightly higher levels of contaminants than the neck/strap samples. There are no obvious differences in metal concentrations between locations where samples were taken. Only total arsenic was detected in all samples. For most metals, (excluding antimony, beryllium, cadmium, thallium, and mercury) levels tended to be higher in the gutball compared to the neck/strap (Appendix A, Table A3).

Discussion

Contaminant screening

The main goal of geoduck sampling from tracts near the Wyckoff/Eagle Harbor Superfund site was to determine if site contaminants in geoducks from tracts adjacent to the site (Tyee Shoal and Port Blakely) are a potential human health concern (i.e., determine whether the site is impacted by contaminants that would prevent geoduck harvests). With the exception of mercury, there are no existing regulatory criteria established with regard to chemical contaminant levels in shellfish (personal communication with Michael Antee, U.S. Food and Drug Administration Pacific Region, Regional Shellfish Specialist).

Geoduck contaminant data were screened using values that DOH considers protective of tribal geoduck consumers (Appendix B). Table 1 shows the mean concentration of each contaminant measured in geoduck necks (siphon and strap) compared to health-based high-end consumer comparison values. The fact that a contaminant exceeds its health comparison value does not mean that a public health hazard exists, but rather signifies the need to consider the chemical further. The mean value or central tendency for the neck and strap portion of geoduck was used for this analysis.

Table 1. Summary of chemical contaminants in Wyckoff/Eagle Harbor area geoduck compared to background area levels and tribal consumption screening values (Wyckoff/Eagle Harbor site, Kitsap County, Washington).

Contaminant	Units	Mean Neck (ww)	Background Area (Agate Passage) Neck (ww)	Tribal Use Comparison Value[a] *** (ww)	Contaminant of concern
Antimony	ppm	<0.1 U	0.06 U	0.09	No
Arsenic, total	ppm	3.3	3.91	NA	NA
Arsenic, inorganic	**ppm**	**0.04 U**	**0.0115**	**0.0004†**	**Yes**
Beryllium	ppm	<0.02 U	0.003 U	1.8	No
Cadmium	ppm	0.12	0.11	0.22	No
Chromium, total	ppm	0.40	0.31	NA	NA
Chromium (III)	ppm	NA	NA	1,300	NA
Chromium (VI)	ppm	NA	NA	2.7	NA
Lead	ppm	0.01	0.007 U	0.07[b]	No
Thallium	ppm	0.03 U	0.04 U	0.07	No
Mercury	**ppm**	**0.03**	0.019	**0.02**	**Yes**

NA – Not available
BOLD values exceed comparison value
[a] Derived assuming high-end consumption rate Suquamish 90th percentile all shellfish consumption rate (consumers only) (Appendix B, Table B1)
[b] IEUBK - Integrated Exposure Uptake Biokinetic Model for Lead in Children to be used to predict blood lead levels in children. Comparison value was derived using the IEUBK model and assumes 50% of meat portion of diet is geoduck.
U = undetected value is the method detection limit (MDL)[c]
***Cadmium (Cd), Chromium (Cr), Mercury (Hg) comparison values based on non-cancer reference doses; Arsenic (As) comparison value based on cancer risk of 1×10^{-5} related to inorganic As; Lead (Pb) comparison value based on IEUBK model (child consumption rate of 50 g/day); Cr comparison value assumes all Cr present as Cr^{+6}
† This value is based on EPA IRIS (Integrated Risk Information System) cancer slope factor of 1.5 mg/kg-day
ww = wet weight

Evaluating exposure to contaminants in geoduck

As mentioned above, there are no established regulatory levels with regard to chemical contaminants in seafood and shellfish (excluding mercury). The U.S. Food and Drug Administration (FDA) had previously derived action levels, tolerances, and guidance levels for poisonous deleterious substances in seafood, but these levels were not intended for enforcement purposes.[12,13] More recently, these levels were removed from FDA guidance documents to eliminate confusion.

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[c] MDL is the minimum concentration of a substance (in a given matrix) that can be measured with a 99% confidence that the analyte concentration is greater than zero.

In the absence of existing regulatory levels, DOH will assess human health risk using the methodology described below:

- Estimate how much geoduck meat is consumed by potentially exposed consumers, tribal members, and additional high-end geoduck consuming populations.

- Obtain inorganic contaminant data, or analyze geoduck samples for contaminant concentrations in order to estimate levels in geoduck tissue. In this case, samples taken by the Suquamish Tribe are from two main sampling sections near Wyckoff/Eagle Harbor (i.e., Port Blakely tract (#07700) and Tyee Shoal tract (#07650)) Superfund site.

- Establish what contaminants people are potentially exposed to. DOH will calculate the dose of a contaminant that a person would receive from consuming geoduck. For the purpose of this health consultation, it is assumed that all geoduck consumed are harvested from Port Blakely and Tyee Shoal tracts.

- Determine if the calculated exposure dose is considered safe. This is done by comparing the calculated exposure dose to an oral reference dose (RfD) specific to each chemical of concern, modeling blood lead levels in children and fetuses, and estimating a consumer's lifetime increased theoretical cancer risk.

Geoduck consumption rates

The majority of geoduck harvested in Puget Sound is exported to markets in Asia. The amount of geoduck typically consumed per person in the Asian markets is not known. However, geoducks are costly (~ $20.00 per pound), so frequent consumption is not likely; rather, geoduck are probably eaten only on special occasions. Nevertheless, it is important to estimate a reasonable geoduck consumption rate in order to estimate exposure to chemical contaminants.

Table 2 shows shellfish or geoduck consumption rates for the U.S. population, Puget Sound Native American Tribes, and Asian and Pacific Islanders (API) from King County.[14,15,16,17] Suquamish geoduck consumption rates range from one three-ounce (oz.) meal per month (75th percentile Suquamish children) to 2.7 eight-ounce meals per week (95th percentile Suquamish adults).

Table 2. Adult's and children's shellfish or geoduck consumption rates.

Consumption Rate (meals per month)	Daily rate- (g/day) [a]		Grams shellfish consumed per kilogram body weight per day (g/kg/day) [b]		Comparable ingestion rates
	Adults	Children	Adults	Children	
0.25 3 meals per year	1.9	0.7	0.03	0.05	Average U.S. general population marine shellfish consumption rate (1.7 g/day)
					Suquamish Tribe children median (consumers only) geoduck consumption rate (0.053 g/kg/day)
0.5 6 meals per year	3.7	1.4	0.05	0.09	Squaxin Island Tribe adult median shellfish consumption rate (0.065 g/kg/day)
					Suquamish Tribe adult median (consumers only) geoduck consumption rate (0.052 g/kg/day)
1	7.5	2.8	0.11	0.19	Tulalip Tribe adult median shellfish consumption rate (0.153 g/kg/day) Suquamish Tribe children 75th percentile (consumers only) geoduck consumption rate (0.23 g/kg/day)
2	15	5.6	0.22	0.37	Suquamish adults 80th percentile (consumers only) geoduck consumption rate (0.25 g/kg/day).
4	30	11	0.43	0.73	Suquamish adults 90th percentile (including non-consumers) geoduck consumption rate (0.39 g/kg/day)
					Suquamish adults 90th percentile (consumers only) geoduck consumption rate (0.44 g/kg/day) King County Asian and Pacific Islander median all shellfish consumption rate (0.50 g/kg/day)
					Suquamish children 95th percentile (including non-consumers) geoduck consumption rate (0.84 g/kg/day)
10	76	28	1.08	1.9	Suquamish adult 95th percentile geoduck consumption rate consumers only (1.117 g/kg/day)

[a]- assumes eight-ounce meal (227 g) for adults and three-ounce meal (85 g) for children
[b]- assumes a bodyweight of 70 kg for adults and 15 kg for children

The consumption rate used in this evaluation is based on the **95th percentile Suquamish consumers only rate for geoduck** (i.e., 1.117 g/kg/day which corresponds to ~ 2.7 eight-oz. meals per week). This rate represents geoduck as a portion of the total shellfish market basket. The 2000 Suquamish survey presents a range of total seafood ingestion rates that include many species of shellfish, as well as fin fish. Geoduck is a subgroup of all shellfish. The geoduck only rate used in this evaluation is not meant to represent a tribal subsistence consumption rate. Appendix C, Table C1 shows the exposure assumptions.

Non-cancer Hazard Evaluation

Estimated doses for average U.S. and Suquamish Tribe shellfish and geoduck consumption were calculated (shown in Appendix C) in order to evaluate the potential for *non-cancer* adverse health effects in children and adults that might result from exposure to contaminants in geoduck harvested from the study area. This was intended to represent a reasonable range for children's and adult's exposure to contaminants from geoduck consumption. These estimated doses were then compared to either EPA's RfD or ATSDR's minimal risk level (MRL). These are doses below which non-cancer adverse health effects are not expected to occur ("safe" doses). They are derived from toxic effect levels obtained from human population and laboratory animal studies. These toxic effect levels are divided by multiple "safety factors" to give the lower, more protective RfD or MRL. A dose that exceeds the RfD or MRL 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 by the exposure dose. If the estimated exposure dose is only slightly above the RfD or MRL, then that dose will fall well below the toxic effect level. The higher the estimated dose is above the RfD or MRL, the closer it will be to the toxic effect level.

Estimates of non-cancer hazards for Wyckoff/Eagle Harbor area geoduck consumers

Exposure assumptions and dose calculations are shown in Appendix C, Table C1. In order to determine if an exposure dose represents a hazard of non-cancer human health effects, exposure doses are compared to the RfD (or MRL) to obtain a hazard quotient (HQ) where:

HQ = estimated dose/RfD

This provides a convenient method to measure the relative health hazard associated with a dose. As the hazard quotient exceeds one and approaches an actual toxic effect level, the dose becomes more of a health concern.

When this approach is applied to consumption of geoduck from tracts near Wyckoff/Eagle Harbor, children from the Suquamish Tribe consuming geoduck at median rates (~ three 3-oz meals per year) do not exceed a hazard quotient of one for the contaminant of concern (i.e., inorganic arsenic). This means that children would not likely be exposed to contaminants that would result in adverse non-cancer effects from consumption of geoduck. Children that are high-end geoduck consumers (i.e., greater than 75th percentile) from the Suquamish Tribe would also not exceed a hazard quotient of one associated with inorganic arsenic exposure.

Adults eating 2.7 eight-oz. meals per week (high-end consumption equal to Suquamish 95th percentile adults – geoduck consumers only) do not exceed a hazard quotient of one attributable to exposure to inorganic arsenic in geoduck. The same is true for consumers that eat both the neck and gutball (i.e., whole body). Hazard quotients for average U.S. shellfish consumers and typical tribal geoduck consumers are less than one for all contaminants (Appendix C, Table C2). Overall, estimated doses for children and adults are below the RfD indicating that non-cancer health effects are not expected to occur from consumption of geoduck at the Wyckoff/Eagle Harbor site.

Theoretical Cancer Risk

Theoretical cancer risk is estimated by calculating a dose similar to that described in the previous section 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 suggests that there is no "safe dose" of a carcinogen and that a very small dose of a carcinogen will 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 threat because any level of a carcinogenic contaminant carries associated risk. Validity of the "no safe dose" assumption for all cancer-causing chemicals is not clear. Some evidence suggests that certain chemicals considered to be carcinogenic must exceed a threshold of tolerance before initiating cancer. For such chemicals, risk estimates are not appropriate. More recent guidelines on cancer risk from EPA reflect the existence of thresholds for some carcinogens. However, EPA still assumes no threshold unless sufficient data indicate otherwise. This consultation assumes that there is no threshold for carcinogenicity.

Cancer Risk = Estimated Dose x Cancer Slope Factor

Theoretical cancer risk is expressed as a probability. For instance, a theoretical cancer risk of 1 x 10^{-5} can be interpreted to mean that a person's overall risk of obtaining cancer increases by 0.00001, or if 100,000 people were exposed, there might be one extra cancer in that population above normal cancer rates. The reader should note that these estimates are for excess cancers that might result in addition to those normally expected in an unexposed population. Theoretical cancer risks quantified in this document are an upper-bound theoretical estimate. Actual risks are likely to be much lower.

Theoretical cancer Risk

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
moderate	is approximately equal to	1 in 1,000
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

Guidance from EPA recognizes that early life exposures associated with some chemicals requires special consideration with regard to theoretical cancer risk. Mutagenic chemicals in particular have been identified as causing higher cancer risks when exposure occurs early in life when compared with the same amount of exposure during adulthood. Adjustment factors have been established to compensate for higher risks from early life exposures to these chemicals. A factor of ten is used to adjust early life exposures before age two, and a factor of three is used to adjust exposures between the ages of 2 and 15.

Uncertainty arsenic cancer slope factor

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.[18] The following 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) [19]
- EPA Office of Drinking Water (2001) [20]
- Consumer Product Safety Commission (2003) [21]
- EPA Office of Pesticide Programs (2003) [22]
- California Office of Environmental Health Hazard Assessment (2004) [23]
- EPA IRIS Review Draft for the SAB (2005) [18]

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

The following uncertainties correspond to both cancer and non-cancer effects:

Uncertainty for tribal members that consume whole geoduck body

A Suquamish survey indicates that at least some tribal members do consume whole geoduck bodies (adults 12%, children 5%). Whole body includes the neck and gutball. An exposure scenario was assumed for these tribal members. This scenario assumed that half of the weight of geoduck came from the neck and the other half came from the gutball, thus adding the concentrations of both the neck and the gutball divided by two results in the average concentration for the whole body (see Appendix A, Table A6 and Appendix C, Tables C2 and C3). In reality, gutball ratios are much lower when compared to the neck and strap. The sampling results clearly demonstrated this (e.g., the gutball weight was $1/3^{rd}$ -$1/4^{th}$ lower than the neck/strap weight). DOH considers that this approach is very conservative for consumers (i.e., tribal members) that may eat whole bodies, assuming that half of the weight came from the gutball and the other half came from the neck/strap.

Uncertainty Non-detect Results

One-half the reported detection limit for non-detect samples (U) were included in the sampling data set. Some uncertainty is associated with any approach dealing with non-detected chemicals. Non-detect results do not indicate whether the contaminant is present at a concentration just

below the detection limit[d], present at a concentration just above zero, or absent from the sample. Therefore, contaminants that were evaluated as non-detects can lead to an overestimation of risk if the actual concentrations are just above zero or absent from the sample.

Theoretical cancer risk estimates for Wyckoff/Eagle Harbor geoduck consumers

When the above approach is applied to consumption of geoduck from tracts near Wyckoff/Eagle Harbor, lifetime increased theoretical cancer risks range from 5.3×10^{-7} to 8.9×10^{-6} for children (low-end to high-end estimates) and 3.4×10^{-6} to 1.3×10^{-4} for adults (high-end consumption equal to Suquamish 95th percentile adults –geoduck consumers only). Overall, the theoretical cancer risk is considered to be very low to insignificant. The majority of theoretical cancer risk is attributable to exposure to inorganic arsenic (Appendix C, Table C3). Theoretical cancer risk would not exceed EPA's range of cancer risks if cumulative exposure was assumed from childhood into adulthood (average time cancer of 70 years). The range of cancer risks considered acceptable by EPA is 1×10^{-6} to 1×10^{-4}. The Quality Assurance Project Plan (QAPP) sampling objectives specifies that the cancer risk level should not be greater than 1×10^{-5}. [24] Theoretical cancer risk estimates for consumers that eat both the neck and gutball (i.e., whole body) also falls between EPA's range of cancer risks if cumulative exposure is assumed from childhood into adulthood (average time cancer of 70 years).

Chemical Specific Toxicity

Arsenic

The majority of information concerning the health effects of arsenic exposure in humans comes from studies of populations that were chronically exposed to arsenic in their drinking water and occupational studies in which workers were exposed to arsenic trioxide (As_2O_3) dust in the workplace. Several studies have indicated that workers exposed to As_2O_3 dust in air at smelters have an increased risk of lung cancer.[25] Furthermore, a positive dose response between cumulative exposure to arsenic and lung cancer risk was observed. In other words, the more arsenic workers were exposed to, the more likely they were to develop lung cancer. Chronic exposure to arsenic in drinking water has occurred in large populations in Taiwan, Chile, Mexico, Argentina, and Bangladesh.[25] In Bangladesh, where the water concentrations were frequently greater than 0.5 mg/l and as high as 3.8 mg/l, symptoms included dermatological effects (hyperpigmentation, hypopigmentation, keratosis, cracking skin, lesions, and skin cancers), bladder cancer, and black foot disease that ultimately leads to gangrene. Studies in U.S. populations exposed to arsenic in drinking water have not shown increased cancer incidences, but arsenic concentrations in water were generally less than those reported in Taiwan and Bangladesh. Food sources of arsenic, particularly seafood, present low risk of arsenic toxicity due to the prevalence of arsenic as the organic species. Organic forms of arsenic are known to be considerably less toxic. Exposure to inorganic arsenic is typically the result of consuming contaminated drinking water.

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[d] Detection limit is defined as the lowest concentration of a chemical within an environmental matrix that a method or equipment can detect.

The effects of chronic exposure to arsenic in shellfish have not been studied. Arsenic ingested with shellfish is usually in the relatively nontoxic form of arsenobetaine.[25] 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. This has proven to be the case in Wyckoff/Eagle Harbor geoduck neck tissue (~1% of total As is in the inorganic form) (Table 3). Gutball tissue has a much higher percentage difference ranging from 0.5 to 4.2 percent (Appendix A, Table A5). This issue is further clouded by the fact that arsenic speciation in tissue has proven to be difficult (personal communication with Lon Kissinger, EPA Region 10). In this study, the sum of arsenic species analyzed in geoduck tissue only amounted to roughly 54% - 57% of the total arsenic. This indicates that some arsenic is lost during extraction or during the analytical process, and the resulting inorganic arsenic concentration may be underestimated. Additionally, the amount of inorganic arsenic in shellfish that is absorbed in the human gut is not known. It is probably less available in shellfish than in water, which is thought to be 70-80% absorbed in the human gut (hazard and risk calculations in the previous section assumed arsenic was 100% available).

Table 3. Total arsenic determination from EPA laboratory and resulting percentage of total arsenic that is inorganic in geoduck harvested from Wyckoff/Eagle Harbor site, Kitsap County, Washington.

Contaminant	Units	Mean (neck)	Mean (gut)	Agate Passage (background site)	
				Neck	Gut
Arsenic, total	ppm	3.3	4.6	3.9	5.9
Arsenic, inorganic	**ppm**	**0.04 U**	**0.096**	**0.02 U**	**0.015**
Arsenic, inorganic percent of total	%	0.6	2.1	0.5	0.3

U – Undetected value is the method detection limit. DOH used half of the detection limit
Bold values exceed background site values

The use of the MDL is a conservative approach to show that less than 1% of the total arsenic is inorganic arsenic. However, the actual value could be as low as zero.

Mercury

Mercury exists in the environment in three forms: elemental, inorganic, and organic. Methylmercury is the form of organic mercury related to exposure in fish. Methylmercury is formed from inorganic mercury in the environment by microorganisms in aquatic systems. In the aquatic food chain, methylmercury biomagnifies as it is passed from lower to higher trophic levels through consumption of prey organisms. Fish at the top of the food chain can biomagnify methylmercury, which represents a potential health concern for consumers of fish.

Ingested methylmercury is readily absorbed and complexed with the cysteine amino acid, and crosses the blood-brain barrier. 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 is 0.0001 mg/kg/day.

Mercury evaluated here represents total mercury as opposed to methylmercury. Dose calculations, however, do not attempt to fractionate the mercury concentrations because almost all of the total mercury found in geoduck is methylmercury.

Estimates for non-cancer hazards for mercury

Hazard quotients for children and adults are below levels of health concern. Adults eating 2.7 eight-oz. meals per week (high-end consumption equal to Suquamish 95th percentile adults – geoduck consumers only) do not exceed a hazard quotient of one attributable to exposure to mercury in geoduck. The same is true for consumers that eat both the neck and gutball (i.e., whole body). Hazard quotients for average U.S. shellfish consumers and typical tribal geoduck consumers are less than one for all contaminants [Appendix C, Table C2].

Comparison with Background

Chemical contaminants in geoduck have not been widely studied in Puget Sound, so little is known about how contaminant levels in geoduck vary by location or age. Geoducks were not sampled as part of the Puget Sound Ambient Monitoring Program (PSAMP) or the majority of other studies, but limited data have been collected by King County Department of Natural Resources (Brightwater), Kitsap County, and others (Appendix B).[6,5,7] Table 4 shows a comparison of contaminant levels in geoduck from the current study to levels found in other limited Puget Sound geoduck samples.

In order to evaluate health impacts, results from Wyckoff/Eagle Harbor tracts (Port Blakely and Tyee Shoal) were compared to levels in geoduck from other areas. In general, metal levels in geoduck appear to be similar and/or lower in geoduck from Wyckoff/Eagle Harbor tracts. Total arsenic levels in geoduck necks are slightly higher than levels detected in Brightwater and Richmond Beach, and four times greater than what was found in samples taken by King County in the Kingston Wastewater Treatment Plant Outfall Geoduck Tissue Study. Chromium from Wyckoff/Eagle Harbor tends to be higher than the Brightwater and Richmond Beach locations and lead tends to be similar and/or lower in geoduck from Wyckoff/Eagle Harbor tracts compared to levels in geoduck from other locations.

Table 4. Average metal concentrations (mg/kg) in geoduck (neck and strap).

Contaminant	Wyckoff/Eagle Harbor [a][*]	Brightwater [b]	Kingston [c]	LEKT [d]	Richmond Beach [e]
N	7 (C)	9 (I)	2 (C)	5 (C)	60 (I)†
Arsenic (total)	3.3	2.4	0.87	NA	2.6
Cadmium	0.12	0.12	0.19	NA	0.11
Chromium (total)	0.4	0.18	0.82	NA	0.07
Lead	0.01	0.053	0.16	NA	0.013
Mercury	0.03	NA	NA	NA	0.016

NA – Not analyzed
N = Number of samples
(C) - Composite sample (5 geoducks per sample)
(I) – Individual sample
† Six additional samples were located in the west section of the site
[a]- Suquamish Tribe samples from Port Blakely and Tyee Shoal tracts near Wyckoff/Eagle Harbor average in all sample locations
[b]- King County Department of Resources and Parks Brightwater Marine Outfall Geoduck Tissue Study
[c]- Kingston Wastewater Treatment Plant Outfall Project
[d]- Lower Elwha Klallam Tribe (LEKT) and DOH samples from area east of Port Angeles
[e]- Suquamish Tribe samples from tracts near Richmond Beach average in all sample locations
* Sample size includes one field duplicate
Note: Range contaminant concentrations from these studies is not available

Child Health Considerations

ATSDR recognizes that infants and children may be more vulnerable to exposures than adults when faced with contamination of air, water, soil, or food. This vulnerability is a result of the following factors:

- Children are smaller and receive higher doses of chemical exposure per body weight.

- Children's developing body systems are more vulnerable to toxic exposures, especially during critical growth stages in which permanent damage may be incurred.

Special consideration was given to children's exposure to contaminants in this health consultation by evaluating children's exposure to arsenic in geoduck separately from adults, acknowledging that children are more susceptible to arsenic toxicity than adults**.**

Conclusions

Although there are some uncertainties in this evaluation, DOH used conservative assumptions to determine the public health implications of exposures to contaminants while consuming geoduck. The true risk to the public is difficult to assess accurately and depends on a number of factors such as the concentration of chemicals, consumption rates, frequency and duration of exposure, and the genetic susceptibility of an individual. In general:

1. Geoduck sampled from Wyckoff/Eagle Harbor tracts (Port Blakely and Tyee Shoal) had metal levels lower than other similar study areas[5,6,7,26,27] and did not appear to be impacted by the potential contaminant sources. DOH concludes that high end geoduck consumers are unlikely to be exposed to harmful levels of inorganic contaminants from eating geoduck near the Wyckoff/Eagle Harbor Superfund site (Tyee Shoal geoduck tract # 07650 and Port Blakely geoduck tract # 07700). Thus, low levels of inorganic contaminants present in geoduck are not expected to harm people's health.

   - Arsenic (inorganic arsenic) was evaluated in the health consultation due to its presence in geoduck above screening values.
     - Inorganic arsenic levels in Wyckoff/Eagle Harbor geoduck are below health concern levels for high-end consumers (i.e., high-end consumption equal to Suquamish 95th percentile adults – geoduck consumers only). The potential for non-cancer hazards and theoretical cancer risk is low. The overall lifetime cancer risk of cumulative exposure assumed from childhood into adulthood is considered acceptable by EPA ($1x10^{-6}$ to $1x10^{-4}$). This is also within the range of $1x10^{-5}$ cancer risk level specified in the QAPP sampling objectives.[24]
   - Lead was present in geoduck at levels below health concern for children and women who are pregnant or might become pregnant.
   - Mercury was present in geoduck at levels below health concern for children and women who are pregnant or might become pregnant.

2. Geoducks have not been widely sampled in Puget Sound and therefore, little is known about intra-species and geographic variability of contaminants in tissue.

3. Human bioavailability of metals from shellfish consumption is a source of uncertainty.

Recommendations

1. The OSWP should use this health consultation to guide their decision of certifying geoduck from Wyckoff/Eagle Harbor tracts in Puget Sound.

2. Future monitoring projects should identify contaminant sources and consider analysis of metals in geoduck over a broader area in order to determine intra-species variability of contaminant levels throughout Puget Sound.

Public Health Action Plan

Actions Taken

1. Sampling and analysis of geoduck for contaminants has been conducted to determine whether or not potential chemicals from the Wyckoff/Eagle Harbor Superfund site are present at levels of health concern in two tracts adjacent to the mouth of Eagle Harbor (Port Blakely and Tyee Shoal).

2. Geoduck contaminant data from the Port Blakely and Tyee Shoal tracts have been evaluated by DOH and presented within this health consultation.

Actions Planned

1. The Department of Health's Office of Food Safety and Shellfish will use this health consultation in the process used to certify shellfish growing areas.

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Figure 1. Geoduck site location and tracts of interest (Wyckoff/ Eagle Harbor Superfund Site, Kitsap County, Washington).

Figure 2. Geoduck background site location and tracts of interest (Wyckoff/Eagle Harbor Superfund Site, Kitsap County, Washington).
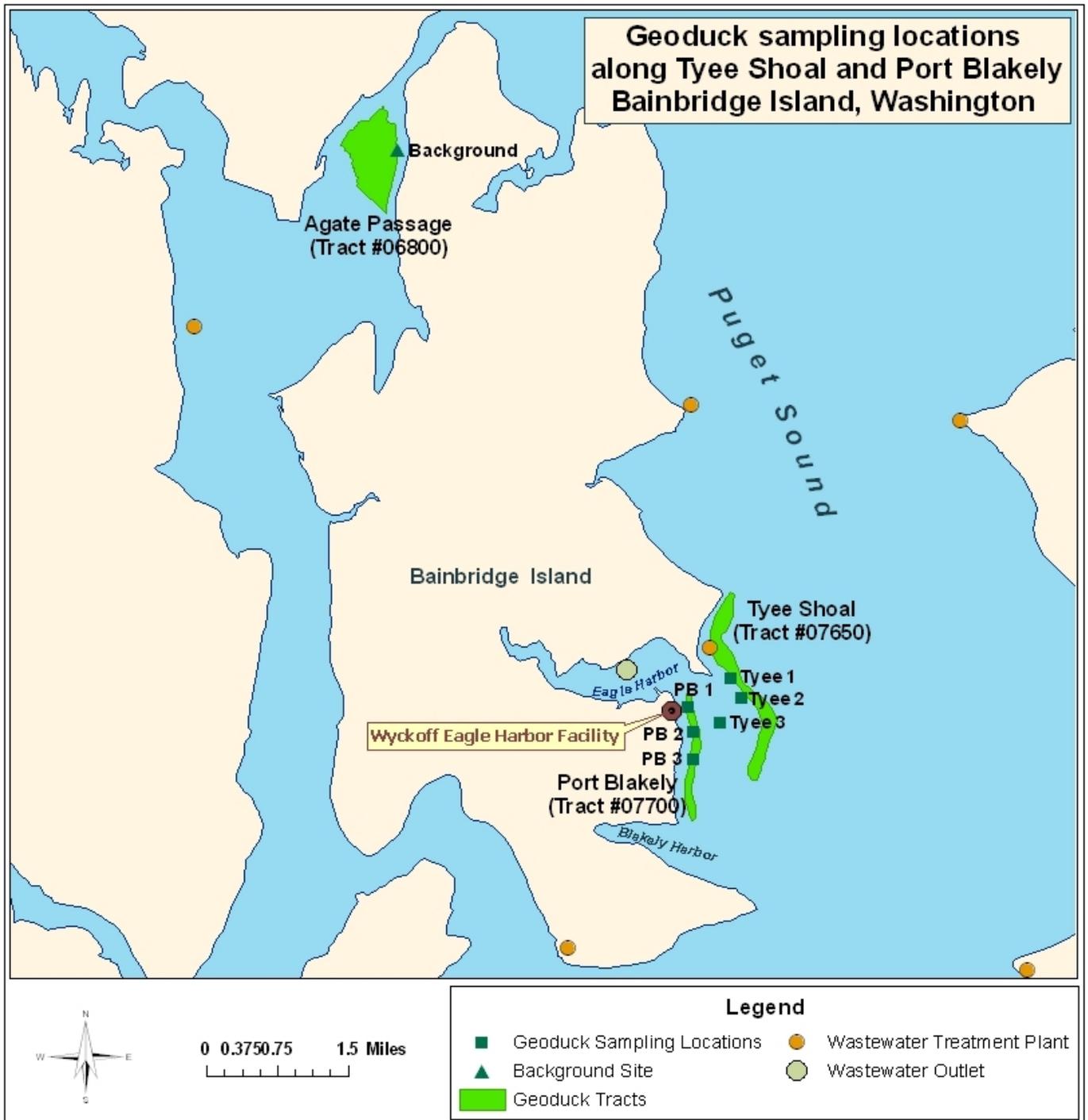
Figure 3. Geoduck sample processing at Department of Ecology laboratory (Wyckoff/Eagle Harbor, Kitsap County, Washington).
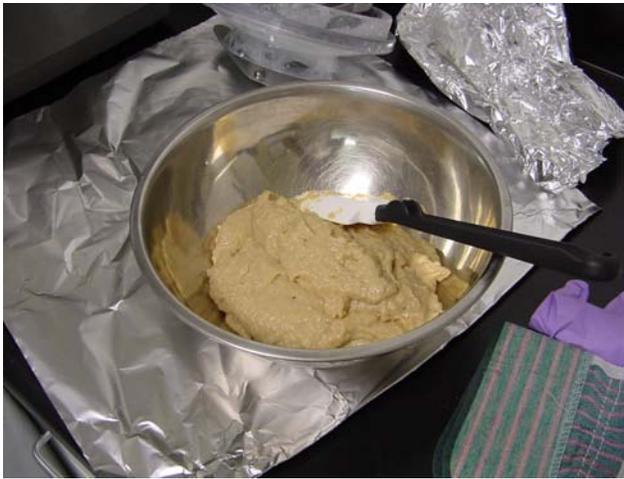
Appendices

Appendix A: Sampling Results

Table A1. Summary table of analytical sampling results for geoduck collected from Wyckoff/Eagle Harbor Superfund Site, Bainbridge Island, Kitsap County, Washington.

Samples (Necks)	Antimony Ww (mg/kg)	Arsenic Ww (mg/kg)	Beryllium Ww (mg/kg)	Cadmium Ww (mg/kg)	Chromium Ww (mg/kg)	Lead Ww (mg/kg)	Thallium Ww (mg/kg)	Mercury Ww (mg/kg)
Sample # 08204000	0.048 U	3.184	0.002 U	0.098	0.451	0.02	0.015 U	0.0147
Sample # 08204002	0.044 U	3.11	0.002 U	0.17	0.34	0.019	0.027 U	0.0259
Sample # 08204004	0.049 U	2.82	0.0025 U	0.0568	0.519	0.0062 U	0.031 U	0.0112
Sample # 08204005	0.047 U	2.86	0.0024 U	0.106	0.288	0.006 U	0.03 U	0.0193
Sample # 08204006	0.046 U	3.14	0.0022 U	0.119	0.351	0.019	0.028 U	0.0506
Sample # 08204008	0.049 U	4.96	0.0024 U	0.199	0.523	0.019	0.0299 U	0.033
Sample # 08204009	0.047 U	3.28	0.0024 U	0.099	0.337	0.0135	0.0289 U	0.0302
Sample # 08204010	0.058 U	3.91	0.0029 U	0.108	0.305	0.0072 U	0.036 U	0.0198

Ww = wet weight

J – Below reporting limit value is an estimate

U – Undetected value is the method detection limit. Half the detection limit was used for undetected samples.

Table A2. Summary table of analytical sampling results for geoduck collected from Wyckoff/Eagle Harbor Superfund Site, Bainbridge Island, Kitsap County, Washington.

Samples (Gut)	Antimony Ww (mg/kg)	Arsenic Ww (mg/kg)	Beryllium Ww (mg/kg)	Cadmium Ww (mg/kg)	Chromium Ww (mg/kg)	Lead Ww (mg/kg)	Thallium Ww (mg/kg)	Mercury Ww (mg/kg)
Sample # 08204001	0.037 UJ	4.55	0.007	0.10	0.879	0.302	0.024 U	0.0141
Sample # 08204003	0.03 UJ	4.15	0.005	0.086	1.04	0.223	0.019 U	0.0162
Sample # 08204007	0.034 UJ	5.4	0.012	0.164	1.56	0.508	0.022 U	0.0455
Sample # 08204011	0.035 UJ	5.9	0.004	0.104	0.512	0.058	0.0223 U	0.0153

Ww = wet weight
J – Below reporting limit value is an estimate
U – Undetected value is the method detection limit. Half the detection limit was used for undetected samples.

Table A3. Summary of chemical contaminants in Eagle Harbor area geoduck compared to background area levels and Tribal consumption screening values (Wyckoff/Eagle Harbor Superfund Site, Kitsap County, Washington).

Contaminant	Units	Mean		Maximum		Reference Area (Agate Passage)		Tribal Use Comparison Value (ww)***†
		Neck (ww)	Gut (ww)	Neck (ww)	Gut (ww)	Neck (ww)	Gut (ww)	
Antimony	ppm	<0.1 U	<0.1 UJ	<0.1 U	<0.1	0.06 U	0.04 UJ	0.09
Arsenic, total	ppm	3.3	4.7	5.0	5.4	3.91	5.9	NA
Arsenic, inorganic	**ppm**	**0.04 U**	**0.08**	**0.04 U**	**0.13**	**0.023 U**	**0.015 U**	**0.0004***
Beryllium	ppm	<0.02 U	<0.02	<0.02 U	0.01	0.003 U	0.004	1.8
Cadmium	ppm	0.12	0.12	0.2	0.16	0.11	0.104	0.22
Chromium, total	ppm	0.40	1.2	0.5	1.6	0.31	0.512	NA
Chromium (III)	ppm	NA	NA	NA	NA	NA	NA	1,300
Chromium (VI)	ppm	NA	NA	NA	NA	NA	NA	2.7
Lead	**ppm**	0.01	**0.34**	0.02	**0.5**	0.007 U	0.06	0.07[a]
Thallium	ppm	0.03 U	0.02 U	0.03 U	0.02	0.04 U	0.02 U	0.07
Mercury	**ppm**	**0.03**	**0.03**	**0.05**	**0.05**	0.019	0.015	**0.02**

NA – Not available
BOLD values exceed comparison value
†Derived assuming high-end consumption rate Suquamish 90th percentile all shellfish consumption rate (consumers only) (Appendix B, Table B1)
[a] IEUBK - Integrated Exposure Uptake Biokinetic Model for Lead in Children to be used to predict blood lead levels in children. Comparison value was derived using the IEUBK model and assumes 50% of meat portion of diet is geoduck.
* This value is based on EPA Integrated Risk Information System (IRIS) cancer slope factor of 1.5 mg/kg-day
***Cd, Cr, Hg comparison values based on non-cancer reference doses; As comparison value based on cancer risk of 1×10^{-5} related to inorganic As; Pb comparison value based on IEUBK model (child consumption rate of 50 g/day); Cr comparison value assumes all Cr present as Cr^{+6}
ww = wet weight
J – Below reporting limit value is an estimate
U – Undetected value is the method detection limit. Half the detection limit was used for undetected samples.

Table A4. Summary table of total arsenic and inorganic arsenic in wet weight (neck tissue) at Wyckoff/Eagle Harbor Superfund Site, Kitsap County, Washington.

EPA sample ID	Tissue	Total As in sample ug/kg (ng/g)	Total As in extract (ng/g)	ASB + Cation ng/g	DMA ng/g	MMA ng/g	$As^{+3} + As^{+5}$ ng/g	Unknown (ng/g)	Sum of all species ng/g	% of Inorganic As
8204000	neck	3172	2586.4	478.2	140.5	20.0 U	20.0 U	1268.8	1887.6	1.06
8204000D	neck dup	3172	2347.3	522.2	138.8	20.0 U	20.0 U	1239.5	1900.5	1.05
8204002	Neck	3109.9	2176.9	381.4	119.6	18.6 U	18.6 U	1255.3	1756.3	1.06
8204004	Neck	2815.8	2042.7	296.4	122.0	20.3 U	20.3 U	1168.3	1586.7	1.28
8204005	Neck	2856	2049.6	439.2	97.7	19.7 U	19.7 U	1089.6	1626.5	1.21
8204006	Neck	3135.6	2269.8	461	96.4	19.2 U	19.2 U	1242.5	1799.9	1.07
8204008	Neck	4955.1	3610.5	336.2	221.9	20.4 U	20.4 U	2368	2926	0.70
8204009	Neck	3277.6	2434.1	356.7	194.7	19.7 U	19.8 U	1291.8	1843.1	1.07
8204010	Agate neck	3905.7	2936.2	326.9	150.7	22.7 U	22.7 U	1869.8	2347.3	0.97

U – Undetected value is the method detection limit. Half the detection limit was used for undetected samples.

ng/g = nanograms/grams = ppb (parts per billion)

ASB = arsenobetaine

DMA = dimethyl arsenic

MMA = monomethyl arsenic

$As^{+3} + As^{+5}$ = arsenite + arsenate

dup = duplicate sample

Table A5. Summary table of total arsenic and inorganic arsenic in wet weight (gutball tissue) at Wyckoff/Eagle Harbor Superfund Site, Kitsap County, Washington.

EPA sample ID	Tissue	Total As in sample ug/kg (ng/g)	Total As in extract (ng/g)	ASB + Cation ng/g	DMA ng/g	MMA ng/g	$As^{+3} + As^{+5}$ ng/g	Unknown (ng/g)	Sum of all species ng/g	% of Inorganic As
8204001	Gut	4460.4	3231.9	317.5	300.5	15.5 U	102.2	1890.0	2610.3	3.9
8204001D	Gut dup	4460.4	3213.0	293.0	240.0	15.5 U	82.0	1640.5	2255.5	3.6
8204003	Gut	4149.9	2941.5	259.2	276.7	13.0 U	67.6	1685.4	2288.8	3.0
8204007	Gut	5400.0	4014.0	387.0	342.0	14.8 U	133.9	2304.0	3166.9	4.2
8204011	Agate gut	5896.2	4092.0	219.5	253.0	15.3 U	15.3	2752.8	3225.2	0.5

U – Undetected value is the method detection limit. Half the detection limit was used for undetected samples.
ng/g = nanograms/grams = ppb (parts per billion)
ASB = arsenobetaine
DMA = dimethyl arsenic
MMA = monomethyl arsenic
$As^{+3} + As^{+5}$ = arsenite + arsenate
dup = duplicate sample

Table A6. Mean values of chemical contaminants for neck and gutball in Wyckoff/Eagle Harbor area geoduck compared to Tribal consumption screening values (Wyckoff/Eagle Harbor Superfund Site, Kitsap County, Washington).

Contaminant	Units	Mean		Whole body† (average of neck and gut)	Tribal Use Comparison Value[a] ***
		Neck	Gut		
Antimony	ppm	<0.1 U	<0.1 UJ	<0.1 U	0.09
Arsenic, total	ppm	3.3	4.7	4.0	NA
Arsenic, inorganic	**ppm**	**0.04 U**	**0.08**	**0.05**	**0.0004***
Beryllium	ppm	<0.02 U	<0.02	<0.02	1.8
Cadmium	ppm	0.12	0.12	0.12	0.22
Chromium, total	ppm	0.40	1.2	0.8	NA
Chromium (III)	ppm	NA	NA	NA	1,300
Lead	**ppm**	0.01	**0.34**	0.18	0.07[a]
Thallium	ppm	0.03 U	0.02 U	0.02 U	0.07
Mercury	**ppm**	**0.03**	**0.03**	**0.03**	**0.02**

† See uncertainty section for tribal members that consume whole geoduck body.

NA – Not available

BOLD values exceed comparison value

[a] Derived assuming high-end consumption rate Suquamish 90th percentile all shellfish consumption rate (consumers only) (Appendix B, Table B1)

[b]IEUBK - Integrated Exposure Uptake Biokinetic Model for Lead in Children to be used to predict blood lead levels in children. Comparison value was derived using the IEUBK model and assumes 50% of meat portion of diet is geoduck.

U = undetected value is the method detection limit. Half the detection limit was used for undetected samples.

J – Below reporting limit; value is an estimate

***Cd, Cr, Hg comparison values based on non-cancer reference doses; As comparison value based on cancer risk of 1 x 10^{-5} related to inorganic As; Pb comparison value based on IEUBK model (child consumption rate of 50 g/day); Cr comparison value assumes all Cr present as Cr^{+6}

† This value is based on EPA (IRIS) cancer slope factor of 1.5 mg/kg-day

All results are reported in wet weight.

Appendix B: Contaminant Screening Process

The information in this section describes how the contaminants of concern in shellfish were chosen from a set of many contaminants. A contaminant's maximum shellfish concentration was compared to a screening value (comparison value), and if the contaminant's concentration is greater than that value, then it is considered further.

Comparison values were calculated using EPA's chronic reference doses (RfDs) and cancer slope factors (CSFs). RfDs represent an estimate of daily human exposure to a contaminant below which non-cancer adverse health effects are unlikely.

This screening method ensured consideration of contaminants that may be of concern for shellfish consumers. The equations below show how comparison values were calculated for both non-cancer and cancer endpoints associated with consumption of shellfish.

$$CV_{non-cancer} = \frac{RfD * BW}{SIR * CF}$$

$$CV_{cancer} = \frac{AT * BW}{Risk\ Level * SIR * CF * EF * ED}$$

Table B1. Parameters used to calculate comparison values used in the shellfish contaminant screening process (Wyckoff/Eagle Harbor Superfund Site, Kitsap County, Washington).

Abbreviation	Parameter	Units	Value	Comments
CV	Comparison Value	mg/kg	Calculated	
RfD	Reference Dose	mg/kg-day	Chemical Specific	Published by EPA
SIR	Shellfish Ingestion Rate	g/day	34.76	Suquamish 90th percentile geoduck consumption rate (consumers only)
			142.4	EPA fish consumption advisory guidance
			363.4	Suquamish 90th percentile all shellfish consumption rate (consumers only)
BW	Bodyweight	kg	79	Adult
			17	Child
CF	Conversion Factor	kg/g	0.001	kilograms per gram
AT	Averaging Time	Days	25550	Days in 70 year lifetime
EF	Exposure Frequency	Days	365	Days per year

ED	Exposure Duration	Years	70	Years consuming geoduck
Risk Level	Lifetime cancer risk	Unitless	1×10^{-5}	
CPF	Cancer Potency Factor	kg-day/mg	Chemical Specific	Published by EPA

Screening values for arsenic and mercury in shellfish

For screening purposes, DOH used a high consumption scenario for shellfish harvesters. This scenario represents the Suquamish 90th percentile all shellfish consumption rate (consumers only) which is 363.4 g/day.

The levels of arsenic and mercury in Wyckoff/Eagle Harbor geoduck exceeded screening values based on documented high end consumption rates for the Suquamish Tribe (Table 1). Appendix C, Tables C2 and C3 show non-cancer and theoretical cancer risk associated with exposure to the contaminants of concern at the Wyckoff/Eagle Harbor site.

Developing comparison values for lead in shellfish

Since the biokinetics of lead are different from many chemicals, a different approach was used for deriving comparison values. The IEUBK model was used with the following assumptions to determine a level of lead in shellfish that would be protective of children who eat geoduck at a rate documented at the high end for the Suquamish Tribe.

Table B2. Assumptions (other than default values) used in the IEUBK to determine comparison values for lead in shellfish.

Parameter	Value	Units	Notes
Seafood Concentration	0.02 (the maximum value from edible portion)	ppm	Solve for value that results in > 5% of 12-24 month old children with blood lead levels greater than 10 ug/dl
Percentage meat intake that is fish [a]	50 and 12	percent	Solve for value that results in > 5% of 12-24 month old children with blood lead levels greater than 10 ug/dl
Lower end consumption rate	0.07 [b]	ppm	Solve for value that results in > 5% of 12-24 month old children with blood lead levels greater than 10 ug/dl
Higher end consumption rate	0.27 [c]	ppm	Solve for value that results in > 5% of 12-24 month old children with blood lead levels greater than 10 ug/dl

[a] assumes that a child's total meat intake is 93.5 g/day
[b] assumes that 50% of meat portion of diet is geoduck
[c] assumes that 12 % of meat portion of diet is geoduck

Appendix C: Exposure dose calculations and assumptions

Average and upper-bound general population exposure scenarios were evaluated for consumption of shellfish from Wyckoff/Eagle Harbor. Exposure assumptions given in Table C1 below were used with the following equations to estimate contaminant doses associated with shellfish consumption.

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

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

Table C1. Exposure Assumptions

Parameter	Value	Unit	Comments
Concentration (C) – High-end	Variable	ug/kg	Average value.
Conversion Factor$_1$ (CF$_1$)	0.001	mg/ug	Converts contaminant concentration from micrograms (ug) to milligrams (mg)
Ingestion Rate (IR) – median Suquamish children - geoduck	0.05	g/kg/day	~ 3 three-oz. meals per year
Ingestion Rate (IR) – 75th percentile Suquamish children - geoduck	0.23		~ 1 three-oz. meal per month
Ingestion Rate (IR) – 95th percentile Suquamish children (includes non-consumers) - geoduck	0.84		~ 1 three-oz. meal per week
Ingestion Rate (IR) – U.S. average adults - all shellfish	0.03		~ 3 eight-oz. meals per year
Ingestion Rate (IR) – median Tulalip adults - all shellfish	0.11		~ 1 eight-oz. meal per month
Ingestion Rate (IR) – 95th percentile adults Suquamish – geoduck (consumers only)	1.117		~ 2.7 eight-oz. meal per week
Conversion Factor$_2$ (CF$_2$)	0.001	kg/g	Converts mass of fish from grams (g) to kilograms (kg)
Exposure Frequency (EF)	365	days/year	Assumes daily exposure consistent with units of ingestion rate given in g/day
Exposure Duration (ED)	70	years	Number of years eating shellfish (adults)
Averaging Time$_{\text{non-cancer}}$ (AT)	25550	days	70 years
Averaging Time$_{\text{cancer}}$ (AT)	25550	days	70 years
Minimal Risk Level (MRL) or Oral Reference Dose (RfD)	Contaminant-specific	mg/kg/day	Source: ATSDR, EPA
Cancer Potency Factor (CPF)	Contaminant-specific	mg/kg-day^{-1}	Source: EPA

Table C2. Non-cancer hazards associated with exposure to contaminants of concern in geoduck sampled from tracts #s 07650 and 07700 at Wyckoff/Eagle Harbor Superfund Site, Kitsap County, Washington.

Chemical	Mean Concentration (ppm)	RfD (mg/kg/day)	Child Hazard Quotient			Adult Hazard Quotient		
			Median Suquamish	75th Suquamish	95th Suquamish (includes non-consumers)	Average U.S	Median Tulalip (All Shellfish)	95th Suquamish*
Arsenic (inorganic)	0.02[a]	0.0003	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Arsenic (inorganic) †	0.05‡	0.0003	<0.1	<0.1	0.1	<0.1	<0.1	0.2
Mercury	0.03	0.0001	<0.1	<0.1	0.25	<0.1	<0.1	0.34

* 95th Suquamish includes consumers only.
† See uncertainty section for tribal members that consume whole geoduck body.
‡ Value derived from whole body (Table A6).
[a] This value corresponds to ½ the detection limit of the mean concentration for neck/strap tissue.

Table C3. Theoretical cancer risk associated with exposure to contaminants of concern in geoduck sampled from tracts #s 07650 and 07700 at Wyckoff/Eagle Harbor Superfund Site, Kitsap County, Washington.

Chemical	Mean Concentration (ppm)	CSF (mg/kg/day)	Child Cancer Risk [a]			Adult Cancer Risk [a]		
			Median Suquamish	75th Suquamish	95th Suquamish (includes non-consumers)	Average U.S	Median Tulalip (All Shellfish)	95th Suquamish*
Arsenic (inorganic)	0.02[c]	5.7 [b]	5.3e-7	2.4e-6	8.9e-6	3.4e-6	1.7e-5	1.3e-4
Total Theoretical Cancer Risk			5.3e-7	2.4e-6	8.9e-6	3.4e-6	1.7e-5	1.3e-4
Arsenic (inorganic) †	0.05‡	5.7 [b]	1.3e-6	6.1e-6	2.2e-5	8.6e-6	4.4e-5	3.2e-4
Total Theoretical Cancer Risk			1.3e-6	6.1e-6	2.2e-5	8.6e-6	4.4e-5	3.2e-4
Mercury	0.03	NA	NA	NA	NA	NA	NA	NA

[a] Cancer risks do not represent cumulative lifetime exposure from childhood to adulthood due to lack of consumption data from 7 to 15 year old children.
[b] See uncertainty section on page 14th for the rationale of using this value.
* 95th Suquamish includes consumers only
† See uncertainty section for tribal members that consume whole geoduck body.
‡ Value derived from whole body (Table A6).
[c] This value corresponds to ½ the detection limit of the mean concentration for neck/strap tissue.

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Certification

This Health Consultation was prepared by the Washington State Department of Health under a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry (ATSDR). It was completed in accordance with approved methodology and procedures existing at the time the Health Consultation was initiated. Editorial review was completed by the Cooperative Agreement partner.

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The ATSDR Division of Health Assessment and Consultation (DHAC) has reviewed this health consultation and concurs with the findings.
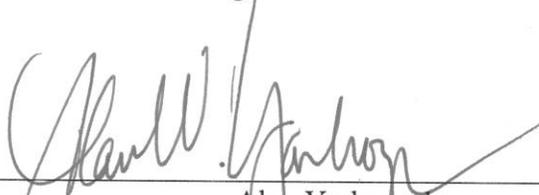
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