# Health Consultation

Evaluation of Contaminants in Geoduck Tissue from Tracts
Near Richmond Beach
Richmond Beach, King County, Washington

May 14, 2009
**Revised Date: September 30, 2009**

**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

DOH 334-205 May 2009

## Health Consultation: A Note of Explanation

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

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

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# HEALTH CONSULTATION

# EVALUATION OF CONTAMINANTS IN GEODUCK TISSUE FROM TRACTS NEAR RICHMOND BEACH

## RICHMOND BEACH, KING COUNTY, WASHINGTON

Prepared By:

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

## 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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# Glossary

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| **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 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. |

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| **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. |
| **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. |

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| **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. |
| **Remedial investigation** | The 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]. |

## 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 contaminant data from one geoduck tract located between Edmonds, Washington, and Shilshoe Bay Marina in Seattle, 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

Richmond Beach tracts are located along the eastern shore of Puget Sound between Point Wells (near Edmonds) and Meadow Point (in northwestern Seattle) (Figure 1). The adjacent upland is a highly urbanized environment characterized mostly by residential and commercial development. There are at least four wastewater outfall sites that may impact the Richmond Beach tracts. The West Point Treatment plant is a King County facility that discharges at an outfall approximately three miles southwest of Meadow Point. The City of Edmonds discharges treated wastewater to an outfall approximately two and a half miles north of Point Wells. King County is also responsible for two additional outfalls, one associated with a treatment plant at Carkeek Park, and a second which discharges near the North Beach neighborhood.

The Suquamish Tribe requested DOH OSWP to certify one geoduck tract (# 06100) in Puget Sound near Richmond Beach for commercial harvest and to provide information that the Tribe can use in 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 contaminant sources described above. 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 concentrations of contaminants 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.[1,2,3] Conversely, metals are commonly found in geoduck tissue. Based on the results of past geoduck tissue sampling, DOH identified arsenic, lead, cadmium, and mercury as the contaminants most likely to build up in geoduck at levels of potential health concern.[4]

**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.[5] In general, the plan identified contaminants of concern, sample size, sample preparation, and data quality objectives.

Geoduck samples were collected during the period of May 9 -16, 2006. Scuba divers from the Suquamish Tribe collected twenty geoducks from three sampling sections (north, middle and south section) at random locations for a total of 60 geoducks. Each geoduck was dissected into two individual tissue samples: one consisting of the neck and strap, and one consisting of the gutball. Each individual sample was homogenized and analyzed for total arsenic, cadmium, chromium, lead, mercury, antimony, total solids, and percent lipids. In addition, the outer skin from a subset of 14 geoducks was homogenized and analyzed for total arsenic, cadmium, chromium, lead, mercury, antimony, total solids, and total lipids. Total arsenic, cadmium, chromium, lead, mercury, antimony, total solids, and total lipids analysis was performed at the King County Environmental Laboratory.

Composite samples were formed and used for arsenic speciation analysis. For each sampling section (north, middle, and south), four composites were formed from measured aliquots of five individual samples, each containing visceral ball or neck/strap tissue. Thus, 24 composite geoduck tissue samples (12 visceral ball and 12 neck/strap) from the Richmond Beach tract were analyzed for organic and inorganic arsenic species. Arsenic speciation analysis was performed at the EPA Region 10 Manchester Laboratory.[6]

Methods, results, quality assurance/quality control (QA/QC), and data validation are summarized in the Richmond Beach Tract geoduck tissue field sampling report.[6]

**Results**

A summary of results is presented in Table 1. Appendix A, Tables A1- A5 lists all sampling results at all locations in more detail, and Table A-6 lists total arsenic and inorganic arsenic in the Richmond Beach sections. Sample locations are shown in Figure 2. In general, the non-edible portions had slightly higher levels of contaminants than the edible portions. 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, cadmium, and mercury) levels tended to be higher in the gutball compared to the neck.

## Discussion

### Contaminant Screening

The main goal of geoduck sampling from tracts near Richmond Beach tract was to determine if geoducks from tracts adjacent to the Richmond Beach area are suitable for commercial harvest based on human health criteria. 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 subsistence 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 edible portion of geoduck (i.e., neck and strap) was used for this analysis.

**Table 1.** Summary of chemical contaminants in Richmond Beach area geoduck compared to consumption screening values (Richmond Beach site, King County, Washington).

| **Contaminant** | **Units** | **Mean** Neck (edible portion) | **Subsistence Comparison Value[a]** *** | **Contaminant of concern** |
|---|---|---|---|---|
| **North Section** | | | | |
| Antimony | ppm | 0.02 (U) | 0.09 | No |
| Arsenic, total | ppm | 2.45 | NA | NA |
| Arsenic, inorganic | **ppm** | **0.009** | **0.0004** | **Yes** |
| Cadmium | ppm | 0.10 | 0.22 | No |
| Chromium, total | ppm | 0.08 | 0.65 | No |
| Lead | ppm | 0.01 | 0.07[b] | No |
| Mercury | ppm | 0.02 | 0.02 | No |
| **Middle Section** | | | | |
| Antimony | ppm | 0.02 (U) | 0.09 | No |
| Arsenic, total | ppm | 2.44 | NA | NA |
| Arsenic, inorganic | **ppm** | **0.009** | **0.0004** | **Yes** |
| Cadmium | ppm | 0.09 | 0.22 | No |
| Chromium, total | ppm | 0.05 | 0.65 | No |
| Lead | ppm | 0.01 | 0.07[b] | No |
| Mercury | ppm | 0.01 | 0.02 | No |
| **South Section** | | | | |
| Antimony | ppm | 0.02 (U) | 0.09 | No |
| Arsenic, total | ppm | 2.91 | NA | NA |
| Arsenic, inorganic | **ppm** | **0.0095** | **0.0004** | **Yes** |
| Cadmium | ppm | 0.11 | 0.22 | No |
| Chromium, total | ppm | 0.09 | 0.65 | No |
| Lead | ppm | 0.02 | 0.07[b] | No |
| Mercury | ppm | 0.02 | 0.02 | No |

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)[b]
***Cadmium (Cd), Chromium (Cr), Mercury (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 (Integrated Risk Information System) cancer slope factor of 1.5 mg/kg-day

## 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.[7,8] More recently, these levels were removed from FDA guidance documents to eliminate confusion.

In 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 contaminant data, or analyze geoduck samples for contaminant concentrations in order to estimate levels in geoduck tissue (in this case from samples taken from three main sampling sections near Richmond beach by the Suquamish Tribe).
- Using this information, DOH can establish what people are potentially exposed to (i.e., DOH can calculate the dose of a contaminant that a person would receive from consuming geoduck). For the purpose of this health consultation, it will be assumed that all geoduck consumed are harvested from Richmond Beach.
- Finally, 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, but 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.

[b] 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.

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.[9,10,11,12] Suquamish geoduck consumption rates range from one three-ounce (oz.) meals per month (75th percentile Suquamish children) to 2.7 eight-ounce meals per week (95th percentile Suquamish adults).

**Table 2.** Adults 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<br>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<br>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)<br>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.

<u>Estimates of non-cancer hazards for Richmond Beach area geoduck consumers</u>

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 Richmond Beach, 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 typical children would not likely be exposed to contaminants from consumption of geoduck that would result in adverse non-cancer effects. Children that are high-end geoduck consumers (i.e., greater than 75$^{th}$ 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 95$^{th}$ percentile adults – Suquamish – 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 Richmond Beach.

*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.

**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 |

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 $1 \times 10^{-5}$ 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.

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 age 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.[13] 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)[14]
- EPA Office of Drinking Water (2001)[15]
- Consumer Product Safety Commission (2003)[16]
- EPA Office of Pesticide Programs (2003)[17]
- California Office of Environmental Health Hazard Assessment (2004)[18]
- EPA IRIS Review Draft for the SAB (2005)[13]

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.

<u>Theoretical cancer Risk estimates for Richmond Beach geoduck consumers</u>

When the above approach is applied to consumption of geoduck from tracts near Richmond Beach, lifetime increased theoretical cancer risks range from $2.6 \times 10^{-7}$ to $4.5 \times 10^{-6}$ for children (low-end to high-end estimates) and $1.7 \times 10^{-6}$ to $6.4 \times 10^{-5}$ for adults (high-end consumption equal to Suquamish 95$^{th}$ percentile adults – Suquamish – 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 $1\times10^{-6}$ to $1\times10^{-4}$. Theoretical cancer risk estimates for consumers that eat both the neck and gutball (i.e., whole body) also falls below EPA's range of cancer risks if cumulative exposure was assumed from childhood into adulthood (average time cancer of 70 years).

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

*Uncertainty for tribal members that consume whole body*

A Suquamish survey indicates that at least some tribal members do consume whole 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 ½ of the weight of geoduck came from the neck and the other ½ 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 A5 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 1/3rd -1/4th 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[c], 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.

## 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.[19] 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.[19] 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

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

known to be considerably less toxic. Exposure to inorganic arsenic is typically the result of consuming contaminated drinking water.

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.[19] 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 Richmond Beach geoduck tissue (~1% of total As is in the inorganic form). 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 an underestimate. 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 by ion chromatography (ICP-MS) determination from King County and EPA laboratories and resulting percentage of total arsenic that is inorganic in geoduck harvested from Richmond Beach site, King County.

| **Contaminant** | **Units** | **Mean (neck) KC Lab** | **Mean (gut) KC Lab** | **Mean (neck) EPA Lab** | **Mean (gut) EPA Lab** | **Certified Reference Material** | |
|---|---|---|---|---|---|---|---|
| | | | | | | **DORM -2, Dogfish muscle** | **BCR-627 Tuna Fish tissue** |
| Arsenic, total | ppm | 2.60 | 3.74 | 2.59 | 3.65 | 17.7 | 4.8 |
| **Arsenic, inorganic** | **ppm** | **0.02 U** | **0.02 U** | **0.02 U** | **0.02 U** | **0.16** | **0.08** |
| Arsenic, inorganic percent of total | % | 0.8 | 0.5 | 0.8 | 0.5 | 0.9 | 1.7 |

KC = King County Lab
U – Undetected, value is the method detection limit
NA - not available

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.

## 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).[2,1,3] Table 4 below 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 from the outfall contaminant sources identified above, results from Richmond Beach tracts were compared to levels in geoduck from other areas. In general, metals levels in geoduck appear to be similar and/or lower in geoduck from Richmond Beach tracts. Total arsenic levels in geoduck necks are similar to levels detected in Brightwater and three times greater than what was found in samples taken by King County for the Kingston Wastewater Treatment Plant Outfall Geoduck Tissue Study. Chromium and lead tend to be lower in geoduck from Richmond Beach tracts compared to levels in geoduck from other locations.

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

| **Contaminant** | **Richmond Beach** [a] | **Brightwater** [b] | **Kingston** [c] | **LEKT** [d] |
|---|---|---|---|---|
| N | 60 (I)† | 9 (I) | 2 (C) | 5 (C) |
| Arsenic (total) | 2.6 | 2.4 | 0.87 | NA |
| Cadmium | 0.11 | 0.12 | 0.19 | NA |
| Chromium (total) | 0.07 | 0.18 | 0.82 | NA |
| Lead | 0.013 | 0.053 | 0.16 | NA |
| Mercury | 0.016 | NA | NA | NA |

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 tracts near Richmond Beach 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 and DOH samples from area east of Port Angeles
[e]- Sample size includes one field duplicate

## 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 separate from adults acknowledging that children are more susceptible to arsenic's 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 as part of the diet. 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 Richmond Beach tracts had metal levels lower than other similar study areas[3,2,1,20,21] 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 contaminants while eating geoduck near Richmond Beach (geoduck tract # 06100). Thus, low levels of 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 Richmond Beach geoduck are below health concern levels for high-end consumers (i.e., high-end consumption equal to Suquamish 95$^{th}$ percentile adults – Suquamish – 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 $1x10^{-4}$).
    - Lead 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 Richmond Beach 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 chemical sources (as identified in the background section) near

Richmond Beach tracts are present at levels of health concern.

2. Geoduck contaminant data from Richmond Beach 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 as part of the process used to certify shellfish growing areas.

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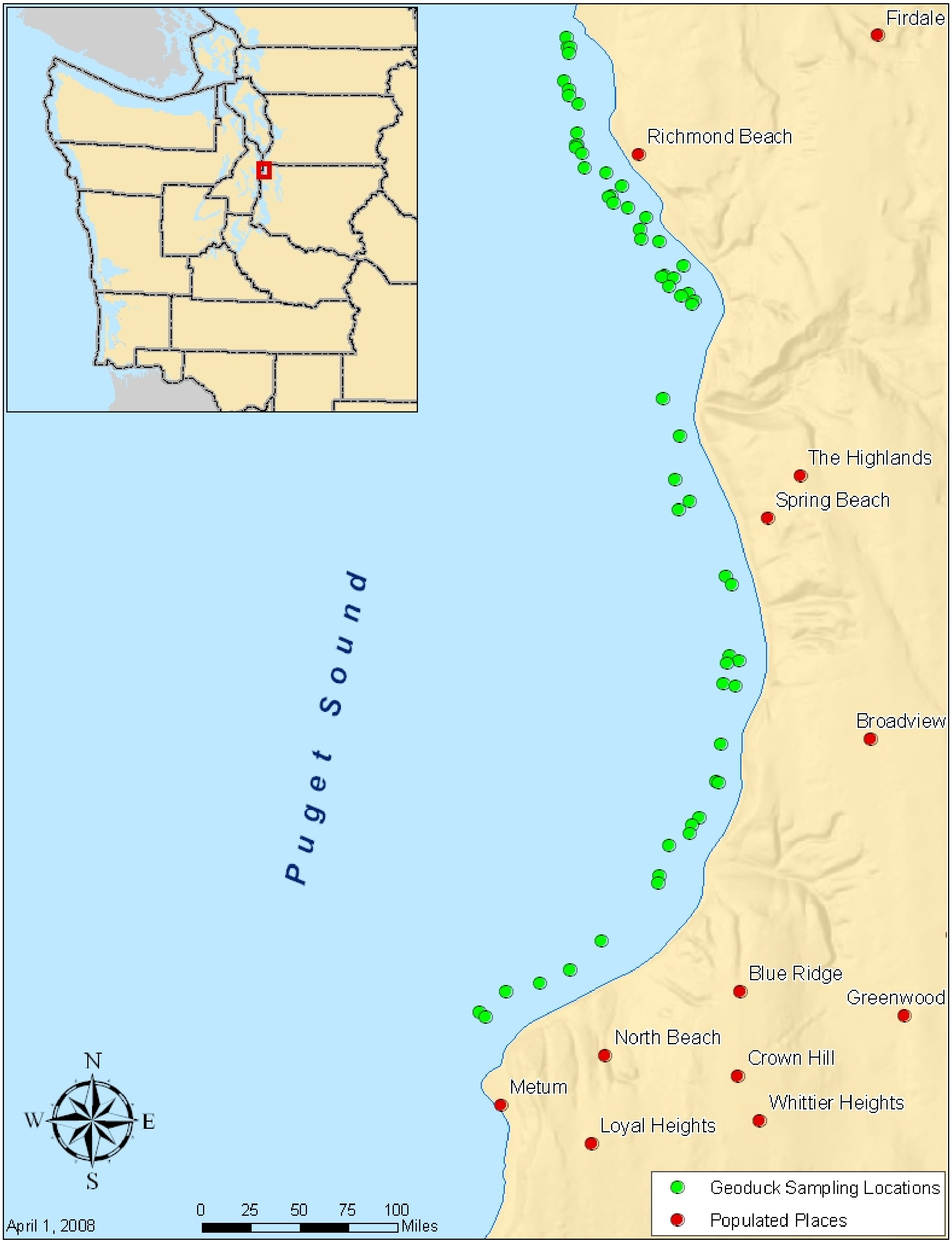
**Figure 1.** Geoduck site location and tracts of interest (Richmond Beach, King County, Washington).

**Figure 2.** Geoduck site location and tracts of interest (Richmond Beach, King County, Washington).



## Appendices

# Appendix A: Sampling results

**Table A1.** Summary table of sampling results in the north (N) section of Richmond Beach, King County, Washington.

| Sample Location ID | | | Arsenic (ppm) | | Cadmium (ppm) | | Chromium (ppm) | | Lead (ppm) | | Mercury (ppm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Neck | Gut | Neck | Gut | Neck | Gut | Gut | Neck | Gut | Neck | Gut | Neck |
| N Geo 1 | 0.02 U | 0.02 U | 1.88 | 3.06 | 0.07 | 0.06 | 0.09 | 0.01 U | 0.06 | 0.01 J | 0.01 | 0.01 |
| N Geo 2 | 0.02 U | 0.02 U | 1.67 | 3.15 | 0.02 | 0.07 | 0.16 | 0.01 U | 0.15 | 0.00 U | 0.01 | 0.00 |
| N Geo 3 | 0.02 U | 0.02 U | 2.07 | 3.03 | 0.02 | 0.11 | 0.09 | 0.02 J | 0.06 | 0.00 U | 0.01 | 0.01 |
| N Geo 4 | 0.02 U | 0.02 U | 3.15 | 2.7 | 0.09 | 0.09 | 0.15 | 0.13 | 0.04 J | 0.02 J | 0.01 | 0.01 |
| N Geo 5 | 0.02 U | 0.02 U | 3.05 | 3.32 | 0.08 | 0.05 | 0.14 | 0.13 | 0.04 J | 0.02 J | 0.02 | 0.04 |
| N Geo 6 | 0.02 U | 0.02 U | 2.42 | 2.66 | 0.15 | 0.13 | 0.13 | 0.06 J | 0.04 J | 0.01 J | 0.01 | 0.02 |
| N Geo 7 | 0.02 U | 0.02 U | 2.63 | 3.26 | 0.11 | 0.07 | 0.14 | 0.06 J | 0.06 | 0.00 U | 0.01 | 0.01 |
| N Geo 8 | 0.02 U | 0.02 U | 1.65 | 2.18 | 0.02 | 0.07 | 0.02 J | 0.01 U | 0.03 J | 0.01 J | 0.00 | 0.00 |
| N Geo 9 | 0.02 U | 0.02 U | 3.21 | 5.92 | 0.15 | 0.11 | 0.52 | 0.23 | 0.17 | 0.02 J | 0.04 | 0.04 |
| N Geo 10 | 0.02 U | 0.02 U | 3.43 | 5.07 | 0.23 | 0.13 | 0.60 | 0.24 | 0.14 | 0.02 J | 0.05 | 0.05 |
| N Geo 11 | 0.02 U | 0.02 U | 3.75 | 6.15 | 0.24 | 0.21 | 0.61 | 0.21 | 0.11 | 0.01 J | 0.03 | 0.03 |
| N Geo 12 | 0.02 U | 0.02 U | 2.47 | 2.99 | 0.07 | 0.07 | 0.14 | 0.06 J | 0.07 | 0.02 J | 0.01 | 0.02 |
| N Geo 13 | 0.02 U | 0.02 U | 2.12 | 2.77 | 0.12 | 0.10 | 0.23 | 0.05 J | 0.13 | 0.02 J | 0.02 | 0.02 |
| N Geo 14 | 0.02 U | 0.02 U | 1.93 | 3.25 | 0.05 | 0.08 | 0.14 | 0.02 J | 0.10 | 0.01 J | 0.01 | 0.01 |
| N Geo 15 | 0.02 U | 0.02 U | 3.65 | 4.16 | 0.11 | 0.09 | 0.24 | 0.11 | 0.06 | 0.01 J | 0.03 | 0.03 |
| N Geo 16 | 0.02 U | 0.02 U | 3.12 | 5.24 | 0.09 | 0.18 | 0.42 | 0.13 | 0.15 | 0.01 J | 0.07 | 0.02 |
| N Geo 17 | 0.02 U | 0.02 U | 1.73 | 3.7 | 0.09 | 0.18 | 0.26 | 0.02 J | 0.20 | 0.00 U | 0.02 | 0.01 |
| N Geo 18 | 0.02 U | 0.02 U | 1.39 | 3.37 | 0.07 | 0.10 | 0.12 | 0.03 J | 0.06 | 0.01 J | 0.01 | 0.01 |
| N Geo 19 | 0.02 U | 0.02 U | 1.27 | 3.48 | 0.07 | 0.11 | 0.37 | 0.02 J | 0.23 | 0.01 J | 0.02 | 0.01 |
| N Geo 20 | 0.02 U | 0.02 U | 2.36 | 4.31 | 0.10 | 0.11 | 0.48 | 0.08 | 0.23 | 0.01 | 0.04 | 0.02 |

J – Below reporting limit, value is an estimate
U – Undetected, value is the method detection limit. All results are reported in wet weight.

**Table A2.** Summary table of sampling results in the mid (M) section of Richmond Beach, King County, Washington.

| Sample Location ID | | | Arsenic (ppm) | | Cadmium (ppm) | | Chromium (ppm) | | Lead (ppm) | | Mercury (ppm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Neck | Gut | Neck | Gut | Neck | Gut | Gut | Neck | Gut | Neck | Gut | Neck |
| M Geo 1 | 0.02 U | 0.02 U | 3.34 | 4.4 | 0.10 | 0.04 | 0.17 | 0.08 J | 0.06 | 0.02 J | 0.01 | 0.03 |
| M Geo 2 | 0.02 U | 0.02 U | 1.59 | 2.22 | 0.19 | 0.13 | 0.35 | 0.09 | 0.16 | 0.01 J | 0.02 | 0.01 |
| M Geo 3 | 0.02 U | 0.02 U | 1.48 | 3.19 | 0.11 | 0.23 | 0.19 | 0.01 U | 0.14 | 0.01 J | 0.01 | 0.01 |
| M Geo 4 | 0.02 U | 0.02 U | 2.15 | 2.73 | 0.04 | 0.06 | 0.26 | 0.01 U | 0.21 | 0.02 J | 0.01 | 0.01 |
| M Geo 5 | 0.02 U | 0.02 U | 3.93 | 5.64 | 0.19 | 0.25 | 0.55 | 0.17 | 0.08 | 0.00 U | 0.05 | 0.02 |
| M Geo 6 | 0.02 U | 0.02 U | 1.11 | 3.24 | 0.03 | 0.09 | 0.63 | 0.01 U | 0.30 | 0.00 U | 0.01 | 0.00 J |
| M Geo 7 | 0.02 U | 0.02 U | 2.51 | 3.46 | 0.06 | 0.06 | 0.22 | 0.04 J | 0.11 | 0.01 J | 0.01 | 0.01 |
| M Geo 8 | 0.02 U | 0.02 U | 1.5 | 3.1 | 0.04 | 0.14 | 0.16 | 0.01 U | 0.10 | 0.00 U | 0.01 | 0.00 |
| M Geo 9 | 0.02 U | 0.02 U | 1.81 | 3.39 | 0.07 | 0.07 | 0.42 | 0.03 J | 0.27 | 0.01 J | 0.01 | 0.01 |
| M Geo 10 | 0.02 U | 0.02 U | 3.56 | 3.79 | 0.21 | 0.26 | 0.33 | 0.12 | 0.07 | 0.01 J | 0.04 | 0.03 |
| M Geo 11 | 0.02 U | 0.02 U | 2.8 | 4.87 | 0.05 | 0.06 | 0.22 | 0.02 J | 0.14 | 0.02 J | 0.01 | 0.01 |
| M Geo 12 | 0.02 U | 0.02 U | 1.95 | 2.41 | 0.09 | 0.05 | 0.18 | 0.02 J | 0.09 | 0.01 J | 0.00 J | 0.01 |
| M Geo 13 | 0.02 U | 0.02 U | 3.36 | 3.19 | 0.11 | 0.13 | 0.33 | 0.06 J | 0.15 | 0.02 J | 0.01 | 0.02 |
| M Geo 14 | 0.02 U | 0.02 U | 1.57 | 2.63 | 0.05 | 0.12 | 0.11 | 0.01 U | 0.07 | 0.01 J | 0.01 | 0.01 |
| M Geo 15 | 0.02 U | 0.02 U | 2.76 | 2.96 | 0.06 | 0.04 | 0.12 | 0.08 | 0.03 J | 0.01 J | 0.02 | 0.01 |
| M Geo 16 | 0.02 U | 0.02 U | 1.43 | 2.35 | 0.07 | 0.21 | 0.22 | 0.02 J | 0.10 | 0.00 U | 0.01 | 0.01 |
| M Geo 17 | 0.02 U | 0.02 U | 2.84 | 2.78 | 0.07 | 0.09 | 0.11 | 0.06 J | 0.02 J | 0.01 J | 0.01 | 0.01 |
| M Geo 18 | 0.02 U | 0.02 U | 1.91 | 3.87 | 0.17 | 0.09 | 0.46 | 0.06 J | 0.23 | 0.01 J | 0.02 | 0.02 |
| M Geo 19 | 0.02 U | 0.02 U | 4.29 | 5.91 | 0.06 | 0.06 | 0.17 | 0.05 J | 0.06 | 0.00 U | 0.02 | 0.01 |
| M Geo 20 | 0.02 U | 0.02 U | 2.96 | 3.99 | 0.13 | 0.11 | 0.37 | 0.09 | 0.09 | 0.01 J | 0.04 | 0.02 |

J – Below reporting limit, value is an estimate
U – Undetected, value is the method detection limit. All results are reported in wet weight.

**Table A3.** Summary table of sampling results in the south (S) section of Richmond Beach, King County, Washington.

| Sample Location ID | | | Arsenic (ppm) | | Cadmium (ppm) | | Chromium (ppm) | | Lead (ppm) | | Mercury (ppm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Neck | Gut | Neck | Gut | Neck | Gut | Gut | Neck | Gut | Neck | Gut | Neck |
| S Geo 1 | 0.02 U | 0.02 U | 2.1 | 3.41 | 0.04 | 0.08 | 0.19 | 0.01 U | 0.08 | 0.00 U | 0.01 | 0.01 |
| S Geo 2 | 0.02 U | 0.02 U | 3.51 | 4.42 | 0.15 | 0.11 | 0.17 | 0.04 J | 0.09 | 0.01 J | 0.02 | 0.01 |
| S Geo 3 | 0.02 U | 0.02 U | 2.93 | 4.44 | 0.12 | 0.27 | 0.69 | 0.08 | 0.23 | 0.01 J | 0.07 | 0.02 |
| S Geo 4 | 0.02 U | 0.02 U | 2.97 | 4.03 | 0.11 | 0.08 | 0.79 | 0.20 | 0.22 | 0.05 | 0.02 | 0.02 |
| S Geo 5 | 0.02 U | 0.02 U | 3.43 | 10.2 | 0.11 | 0.15 | 0.68 | 0.18 | 0.16 | 0.02 J | 0.07 | 0.04 |
| S Geo 6 | 0.02 U | 0.02 U | 1.84 | 2.81 | 0.04 | 0.10 | 0.38 | 0.03 J | 0.21 | 0.01 J | 0.01 | 0.01 |
| S Geo 7 | 0.02 U | 0.02 U | 4.09 | 4.01 | 0.23 | 0.08 | 0.40 | 0.15 | 0.13 | 0.04 | 0.02 | 0.03 |
| S Geo 8 | 0.02 U | 0.02 U | 2.57 | 4.98 | 0.07 | 0.20 | 0.48 | 0.06 J | 0.14 | 0.01 J | 0.04 | 0.02 |
| S Geo 9 | 0.02 U | 0.02 U | 3.88 | 4.94 | 0.13 | 0.11 | 0.36 | 0.11 | 0.06 | 0.02 J | 0.04 | 0.02 |
| S Geo 10 | 0.02 U | 0.02 U | 3.3 | 3.71 | 0.13 | 0.08 | 0.25 | 0.07 J | 0.09 | 0.00 U | 0.03 | 0.02 |
| S Geo 11 | 0.02 U | 0.02 U | 2.99 | 2.86 | 0.10 | 0.21 | 0.22 | 0.09 | 0.05 | 0.02 J | 0.02 | 0.02 |
| S Geo 12 | 0.02 U | 0.02 U | 1.62 | 2.47 | 0.03 | 0.10 | 0.22 | 0.02 J | 0.16 | 0.01 J | 0.01 | 0.01 |
| S Geo 13 | 0.02 U | 0.02 U | 2.91 | 4.65 | 0.10 | 0.08 | 0.25 | 0.10 | 0.04 J | 0.02 J | 0.03 | 0.03 |
| S Geo 14 | 0.02 U | 0.02 U | 1.55 | 3.29 | 0.05 | 0.10 | 0.24 | 0.02 J | 0.09 | 0.01 J | 0.01 | 0.01 |
| S Geo 15 | 0.02 U | 0.02 U | 1.32 | 2.01 | 0.05 | 0.06 | 0.20 | 0.01 U | 0.10 | 0.01 J | 0.01 | 0.00 J |
| S Geo 16 | 0.02 U | 0.02 U | 3.62 | 2.71 | 0.17 | 0.06 | 0.39 | 0.18 | 0.03 J | 0.02 J | 0.03 | 0.03 |
| S Geo 17 | 0.02 U | 0.02 U | 3.28 | 5.21 | 0.19 | 0.13 | 0.32 | 0.13 | 0.06 | 0.03 J | 0.04 | 0.03 |
| S Geo 18 | 0.02 U | 0.02 U | 2.76 | 3.09 | 0.11 | 0.06 | 0.25 | 0.09 | 0.05 | 0.01 J | 0.02 | 0.02 |
| S Geo 19 | 0.02 U | 0.02 U | 3.88 | 4.48 | 0.11 | 0.08 | 0.21 | 0.12 | 0.03 J | 0.01 J | 0.03 | 0.02 |
| S Geo 20 | 0.02 U | 0.02 U | 3.73 | 3.00 | 0.20 | 0.12 | 0.13 | 0.06 J | 0.04 J | 0.00 U | 0.01 | 0.02 |

J – Below reporting limit, value is an estimate
U – Undetected, value is the method detection limit. All results are reported in wet weight.

**Table A4.** Mean and maximum values of chemical contaminants in Richmond Beach area geoduck compared to consumption screening values (Richmond Beach site, King County, Washington).

| Contaminant | Units | Mean | | Maximum | | Mean | Maximum | Subsistence Comparison Value[a] *** |
|---|---|---|---|---|---|---|---|---|
| | | Neck | Gut | Neck | Gut | Outer Skin | | |
| **North Section** | | | | | | | | |
| Antimony | ppm | 0.02 (U) | 0.02 (U) | 0.02 (U) | 0.02 (U) | NA | NA | 0.09 |
| Arsenic, total | ppm | 2.45 | 3.69 | 3.75 | 6.15 | NA | NA | NA |
| Arsenic, inorganic | **ppm** | **0.018 (U)** | **0.017** | **0.019 (U)** | **0.025** | NA | NA | **0.0004** |
| Cadmium | **ppm** | 0.10 | 0.10 | **0.24** | 0.21 | NA | NA | 0.22 |
| Chromium, total | ppm | 0.08 | 0.25 | 0.24 | 0.61 | NA | NA | 0.65 |
| Lead | **ppm** | 0.01 | **0.11** | 0.02 | **0.23** | NA | NA | 0.07[b] |
| Mercury | **ppm** | 0.02 | 0.02 | **0.05** | **0.07** | NA | NA | 0.02 |
| **Middle Section** | | | | | | | | |
| Antimony | ppm | 0.02 (U) | 0.02 (U) | 0.02 (U) | 0.02 (U) | NA | NA | 0.09 |
| Arsenic, total | ppm | 2.44 | 3.51 | 4.29 | 5.91 | NA | NA | NA |
| Arsenic, inorganic | **ppm** | **0.018 (U)** | **0.016** | **0.019 (U)** | **0.022** | NA | NA | **0.0004** |
| Cadmium | **ppm** | 0.09 | 0.11 | 0.21 | **0.26** | NA | NA | 0.22 |
| Chromium, total | ppm | 0.05 | 0.28 | 0.17 | 0.63 | NA | NA | 0.65 |
| Lead | **ppm** | 0.01 | **0.12** | 0.02 | **0.30** | NA | NA | 0.07[b] |
| Mercury | **ppm** | 0.01 | 0.02 | **0.03** | **0.05** | NA | NA | 0.02 |
| **South Section** | | | | | | | | |
| Antimony | **ppm** | 0.02 (U) | 0.02 (U) | 0.02 (U) | 0.02 (U) | **0.27** | **0.56** | 0.09 |
| Arsenic, total | ppm | 2.91 | 4.04 | 4.09 | 10.2 | 7.34 | 20.90 | NA |
| Arsenic, inorganic | **ppm** | **0.019 (U)** | **0.013 (U)** | **0.02 (U)** | **0.014 (U)** | NA | NA | **0.0004** |
| Cadmium | **ppm** | 0.11 | 0.11 | **0.23** | **0.27** | **1.62** | **5.07** | 0.22 |
| Chromium, total | **ppm** | 0.09 | 0.34 | 0.20 | **0.79** | **1.07** | **2.09** | 0.65 |
| Lead | **ppm** | 0.02 | **0.10** | 0.05 | **0.23** | **24.9** | **71.2** | 0.07[b] |
| Mercury | **ppm** | 0.02 | **0.03** | **0.04** | **0.07** | 0.01 | **0.04** | 0.02 |

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.
Gut is not considered edible
U = undetected, value is the method detection limit
***Cd, Cr, Hg comparison values based on non-cancer reference doses; As comparison value based on cancer risk of $1 \times 10^{-5}$ 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.

**Table A5.** Mean values of chemical contaminants for neck and gutball in Richmond Beach area geoduck compared to consumption screening values (Richmond Beach site, King County, Washington).

| **Contaminant** | **Units** | **Mean** | | **Whole body† (average of neck and gut)** | **Subsistence Comparison Value[a] ***** |
|---|---|---|---|---|---|
| | | Neck | Gut | | |
| **North Section** | | | | | |
| Antimony | ppm | 0.02 (U) | 0.02 (U) | 0.02 (U) | 0.09 |
| Arsenic, total | ppm | 2.45 | 3.69 | 3.07 | NA |
| Arsenic, inorganic | **ppm** | **0.018 (U)** | **0.017** | **0.05** | **0.0004** |
| Cadmium | ppm | 0.10 | 0.10 | 0.10 | 0.22 |
| Chromium, total | ppm | 0.08 | 0.25 | 0.17 | 0.65 |
| Lead | **ppm** | 0.01 | **0.11** | 0.06 | 0.07[b] |
| Mercury | ppm | 0.02 | 0.02 | 0.02 | 0.02 |
| **Middle Section** | | | | | |
| Antimony | ppm | 0.02 (U) | 0.02 (U) | 0.02 (U) | 0.09 |
| Arsenic, total | ppm | 2.44 | 3.51 | 2.98 | NA |
| Arsenic, inorganic | **ppm** | **0.018 (U)** | **0.016** | **0.053** | **0.0004** |
| Cadmium | ppm | 0.09 | 0.11 | 0.1 | 0.22 |
| Chromium, total | ppm | 0.05 | 0.28 | 0.17 | 0.65 |
| Lead | **ppm** | 0.01 | **0.12** | 0.065 | 0.07[b] |
| Mercury | ppm | 0.01 | 0.02 | 0.015 | 0.02 |
| **South Section** | | | | | |
| Antimony | ppm | 0.02 (U) | 0.02 (U) | 0.02 (U) | 0.09 |
| Arsenic, total | ppm | 2.91 | 4.04 | 3.5 | NA |
| Arsenic, inorganic | **ppm** | **0.019 (U)** | **0.013 (U)** | **0.008** | **0.0004** |
| Cadmium | ppm | 0.11 | 0.11 | 0.11 | 0.22 |
| Chromium, total | ppm | 0.09 | 0.34 | 0.215 | 0.65 |
| Lead | **ppm** | 0.02 | **0.10** | 0.06 | 0.07[b] |
| Mercury | **ppm** | 0.02 | **0.03** | 0.025 | 0.02 |

† See uncertainty section above.
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
***Cd, Cr, Hg comparison values based on non-cancer reference doses; As comparison value based on cancer risk of $1 \times 10^{-5}$ 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.

**Table A6.** Summary table of total arsenic and inorganic arsenic in the Richmond Beach sections, King County, Washington.

| Location | Total Arsenic Wet Weight (ppm) | | | | RPD | | Inorganic Arsenic - Wet Weight (ppm) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | KC LAB* | | EPA LAB | | | | | | | |
| | Gut | Neck | Gut | Neck | Gut | Neck | Gut | | Neck | |
| North 1-5 | 3.05 | 2.36 | 2.93 | 2.48 | 4.06% | 4.72% | 0.014 | U | 0.019 | U |
| North 6-10 | 3.82 | 2.67 | 3.86 | 2.64 | 1.19% | 1.02% | 0.014 | U | 0.017 | U |
| North 11-15 | 3.86 | 2.78 | 3.75 | 2.76 | 3.14% | 0.98% | 0.013 | U | 0.017 | U |
| North 16-20 | 4.02 | 1.97 | 3.79 | 2.03 | 5.74% | 2.93% | 0.025 | J | 0.017 | U |
| Mid 1-5 | 3.64 | 2.50 | 3.44 | 2.29 | 5.51% | 8.75% | 0.013 | U | 0.019 | U |
| Mid 6-10 | 3.40 | 2.10 | 3.39 | 2.11 | 0.09% | 0.61% | 0.022 | J | 0.017 | U |
| Mid 11-15 | 3.21 | 2.49 | 3.19 | 2.33 | 0.82% | 6.57% | 0.014 | U | 0.019 | U |
| Mid 16-20 | 3.78 | 2.67 | 3.89 | 2.58 | 2.91% | 3.89% | 0.014 | U | 0.019 | U |
| South 1-5 | 5.30 | 2.99 | 5.10 | 3.11 | 3.88% | 4.14% | 0.014 | U | 0.019 | U |
| South 6-10 | 4.09 | 3.14 | 3.97 | 3.11 | 3.06% | 0.94% | 0.013 | U | 0.020 | U |
| South 11-15 | 3.06 | 2.08 | 2.99 | 2.11 | 2.21% | 1.44% | 0.014 | U | 0.018 | U |
| South 16-20 | 3.70 | 3.45 | 3.51 | 3.52 | 5.27% | 1.81% | 0.012 | U | 0.018 | U |

* Average of analytical results from samples used to form referenced composites
Total arsenic was adjusted from dry wet to wet weight
RPD = relative percent difference between EPA Lab results and King County Lab results
U = undetected, value is the method detection limit
J = below reporting limit, value is an estimate
KC = King County Lab

## **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 chronic EPA's 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.

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

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

**Table B1.** Parameters used to calculate comparison values used in the shellfish contaminant screening process (Richmond Bay - King County, Washington).

| Abbreviation | Parameter | Units | Value | Comments |
|---|---|---|---|---|
| CV | Comparison Value | mg/kg | Calculated | |
| RfD | Reference Dose | mg/kg-day | Chemical Specific | 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 | Body weight | 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 | $1x10^{-5}$ | |
| CPF | Cancer Potency Factor | kg-day/mg | Chemical Specific | EPA |

**Screening values for arsenic in shellfish**

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

The levels of arsenic in Richmond Beach 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 inorganic arsenic at the Richmond Beach 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 Richmond Beach. Exposure assumptions given in Table C1 below were used with the following equations to estimate contaminant doses associated with shellfish consumption.

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

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

**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) – 75$^{th}$ percentile Suquamish children - geoduck | 0.23 | | ~ 1 three-oz. meal per month |
| Ingestion Rate (IR) – 95$^{th}$ 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) – 95$^{th}$ 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$_{non\text{-}cancer}$ (AT) | 25550 | days | 70 years |
| Averaging Time$_{cancer}$ (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 tract 06100 near Richmond Beach, King County, Washington

| Chemical | Mean Concentration | 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* |
| | 0.01 | 0.0003 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| | 0.05‡ | 0.0003 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |

* 95th Suquamish includes consumers only.
† See uncertainty section above.
‡ Value derived from whole body (Table A5).

**Table C3.** Theoretical cancer risk associated with exposure to contaminants of concern in geoduck sampled from tract 06100 near Richmond Beach, King County, Washington.

| Chemical | Mean Concentration | 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) (ppm) | 0.01 | 5.7 [b] | 2.6e-7 | 1.2e-6 | 4.5e-6 | 1.7e-6 | 8.7e-6 | 6.4e-5 |
| Total Theoretical Cancer Risk | | | 2.6e-7 | 1.2e-6 | 4.5e-6 | 1.7e-6 | 8.7e-6 | 6.4e-5 |
| Arsenic (inorganic) (ppm)† | 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 |

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 11th for the rationale of using this value.
* 95th Suquamish includes consumers only.
† See uncertainty section above.
‡ Value derived from whole body (Table A5).

## Certification

This Evaluation of Contaminants in Geoduck Tissue from Tracts near Richmond Beach 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 Evaluation of Contaminants in Geoduck Tissue from Tracts near Richmond Beach Health Consultation were initiated. Editorial review was completed by the Cooperative Agreement partner.

Audra Henry, Technical Project Officer, CAT, SPAB, DHAC, ATSDR

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

Alan Yarbrough, Team Lead, CAT, SPAB, DHAC, ATSDR

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