Health Consultation

Rayonier Mill Site
Exposure Investigation

Evaluation of Dioxins in Crab and Geoduck Tissue from a Lower Elwha Klallam Tribe Fishing Area near Port Angeles, Washington

Port Angeles, Clallam County, Washington

EPA Facility ID: WAD000490169

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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 333-071 February 2005

Foreword

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

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

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Glossary

Acute	Occurring over a short time [compare with **chronic**].
Agency for Toxic Substances and Disease Registry (ATSDR)	The principal federal public health agency involved with hazardous waste issues, responsible for preventing or reducing the harmful effects of exposure to hazardous substances on human health and quality of life. ATSDR is part of the U.S. Department of Health and Human Services.
Cancer 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**].
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.
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**].

Ingestion	The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see route of exposure].
Ingestion rate	The amount of an environmental medium that could be ingested typically on a daily basis. Units for IR are usually liter/day for water, and mg/day for soil.
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.
Minimal Risk Level (MRL)	An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified time period (acute, intermediate, or chronic). MRLs should not be used as predictors of harmful (adverse) health effects [see **reference dose**].
No apparent public health hazard	A category used in ATSDR's public health assessments for sites where human exposure to contaminated media might be occurring, might have occurred in the past, or might occur in the future, but where the exposure is not expected to cause any harmful health effects.
No Observed Adverse Effect Level (NOAEL)	The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.
Oral Reference Dose (RfD)	An amount of chemical ingested into the body (i.e., dose) below which health effects are not expected. RfDs are published by EPA.
Organic	Compounds composed of carbon, including materials such as solvents, oils, and pesticides that are not easily dissolved in water.
Parts per billion (ppb)/Parts per million (ppm)	Units commonly used to express low concentrations of contaminants. For example, 1 ounce of trichloroethylene (TCE) in 1 million ounces of water is 1 ppm. 1 ounce of TCE in 1 billion ounces of water is 1 ppb. If one drop of TCE is mixed in a competition size swimming pool, the water will contain about 1 ppb of TCE.
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 purpose of this health consultation is to evaluate health risks associated with consumption of dioxins and furans in shellfish (molluscs and crustaceans) collected from a Lower Elwha Klallam Tribal fishing area east of Port Angeles, Washington. It is important to note that this health consultation differs in scope and purpose from on-going Remedial Investigation (RI) studies associated with hazardous waste cleanup sites in Port Angeles Harbor. While a risk assessment conducted under EPA's Remedial Investigation/Feasibility Study (RI/FS) process is used to support the selection of a remedial measure at a site, the health consultation is a mechanism used to provide the impacted community with information on the public health implications of a specific site, identifying those populations for which further health actions or studies are needed.

Background and Statement of Issues

The Lower Elwha Klallam Tribe (LEKT) requested that the Washington State Department of Health (DOH) evaluate whether their subsistence-level consumption of shellfish, collected in the vicinity of the Port Angeles Harbor, poses a health threat. DOH prepares health consultations as part of a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR).

Historically, Port Angeles Harbor received effluent from numerous sources including two paper mills and the city of Port Angeles. These sources are either potential or known sources of dioxins and furans. The Tribe is concerned about transport of dioxins and furans from municipal and industrial sources and potential bioaccumulation in crab and shellfish tissue in a portion of their usual and accustomed fishing area to the east of Port Angeles Harbor outside the current boundaries of existing cleanup sites.

Dioxins and furans are a large group of chlorinated organic chemicals. Each of the dioxins and furans in this group can be identified as a unique type or congener. Dioxins and furans are not intentionally manufactured but may be formed and released through combustion processes, chlorine bleaching at pulp and paper mills, and chlorination treatment of wastewater.[1] Some dioxins and furans deposited on land or water will be broken down by sunlight, but most remain intact.[a] Dioxins and furans do not dissolve easily in water, so they tend to attach to sediments. Fish and shellfish can be exposed to dioxins and furans in sediments and the food chain. Once exposed, fish and shellfish can concentrate these chemicals in their tissue (primarily fatty tissue) through bioaccumulation.

Sample Collection and analysis

Dungeness and red rock crabs

Dungeness crabs were collected from four sample areas located between Morse Creek and the base of Dungeness Spit (Appendix A, Figure A1). Five individual crabs were collected from

[a] Estimates of the half-life of dioxin on the soil surface range from 9 to 15 years, whereas the half-life in subsurface soil may range from 25 to100 years.

each sample area and combined to represent a single composite crab sample for that area. Given the limited resources, this sampling design provided the best combination of sample coverage and sample quantity. Attempts were made to collect crabs from multiple depths to form the composite sample from each area, but following a quick drop nearshore, bottom depths remained relatively constant as far as a mile offshore before rapidly dropping.[2]

Edible portions of the crab muscle tissue (legs and body) and crab butter were removed from the shell and homogenized. Aliquots of the samples were prepared and analyzed for dioxins and furans using EPA method 1613B by AXYS Analytical.

During the course of collecting Dungeness crab, seven red rock crabs were kept. These crabs were archived by the lab and analyzed for dioxins and furans as individuals at a later date when funding became available (Appendix A, Figure A3).

Geoducks

Geoducks, a type of large saltwater clam, were collected from five areas located between Morse Creek and the base of Dungeness Spit (Appendix A, Figure A2). Each composite sample consisted of five individual geoducks from each of the five areas, with the exception of one sample that consisted of four organisms. Edible portions of geoduck muscle tissue (neck) were separated from the shell and gutball, homogenized, and analyzed by AXYS Analytical using EPA method 1613B.

Reference area samples

Rayonier Inc. collected crab and geoduck samples from two reference areas, Dungeness Spit and Freshwater Bay, as part of their Remedial Investigation (RI) of the former Rayonier Mill in Port Angeles. Reference areas are not likely to be significantly impacted by releases from the former mill. The reference areas sampled were Dungeness Bay and Freshwater Bay. Dungeness Bay is a protected, non-urbanized area approximately 15 miles east of Port Angeles Harbor. Freshwater Bay is a semi-protected bay located approximately 10 miles west of Port Angeles (Appendix A, Figure A4). Rayonier agreed to provide the Tribe with splits of their Dungeness crab and geoduck samples from both reference areas so that the Tribe could have them analyzed by a lab of their choice.

The reference shellfish samples were sent overnight from Columbia Analytical in Houston (where Rayonier's dioxin/furan analysis was conducted) to AXYS Analytical for analysis. The six split samples included one individual geoduck, one composited Dungeness crab muscle tissue sample, and one composited Dungeness crab "butter" sample from each of the two reference areas.

Dioxins and Furans TEQ concentrations

Although several dioxin and furan congeners were analyzed in tissue, only a single value, called a dioxin toxic equivalent TEQ, is presented in this health consultation. Each dioxin/furan, or dioxin-like compound, is multiplied by a Toxic Equivalency Factor (TEF) to produce the dioxin TEQ (Appendix C). The TEQs for each chemical are then summed to give the overall 2,3,7,8-

tetrachlorodibenzo-p-dioxin –TEQ. The TEQ approach is based on the premise that many dioxins and furans are structurally and toxicologically similar to 2,3,7,8-tetrachlorodibenzo-p-dioxin. TEFs are used to account for the different potency of dioxins and furans relative to 2,3,7,8-tetrachlorodibenzo-p-dioxin, and are available for 10 chlorinated dibenzofurans and 7 chlorinated dibenzodioxins using World Health Organization (WHO) methodology.[3]

Discussion

Results of the crab and geoduck analyses are presented in Table 1. The mean and maximum TEQ concentration for each species varies depending on how undetected dioxins and dioxin-like compounds were treated when deriving the TEQ. Assuming ½ the detection limit for chemicals not detected yields slightly higher results than assuming a value of "0" for non-detects.

Highest TEQ levels were found in Dungeness crab (0.32 ppt). This is likely due to the fact that crab muscle and crab butter were analyzed together and dioxins and dioxin-like compound disproportionately accumulate in crab butter. TEQ levels in crab muscle tissue are likely to be lower than levels presented in Table 1. Figures A1 and A2 in Appendix A show the geographic location of Dungeness crab and geoduck samples along with the measured TEQ concentration.

Table 1. Dioxin TEQ results of Geoduck and crab samples taken from the Lower Elwha Klallam Tribe fishing grounds near Port Angeles, WA

Species	N	Mean TEQ Concentration (ppt) (0 DL)	Mean TEQ Concentration (ppt) (1/2 DL)	Max TEQ Concentration (ppt) (0 DL)	Max TEQ Concentration (ppt) (1/2 DL)
Geoduck	5 (composite)	0.019	0.027	0.027	0.034
Dungeness Crab	4 (composite)	0.18	0.18	0.32	0.32
Red Rock Crab	7 (individual)	0.013	0.025	0.034	0.043

Chemical Specific Toxicity

The majority of knowledge concerning the toxicity of dioxins and dioxin-like compounds in humans and animals is related to 2,3,7,8 tetrachlorodibenzo(p)dioxin. This chemical has been studied more than other dioxins and furans. Other dioxins with a similar chemical structure are thought to exert similar toxic effects.

Dioxins cause toxicity primarily through a mechanism involving the aryl hydrocarbon receptor (AhR). The AhR is a protein within a cell that regulates certain enzyme functions. When activated, it can mediate the toxic effect of various contaminants such as dioxins, polychlorinated bipheynls (PCBs), and other hydrocarbons. This interaction may result in gene expression that ultimately can have health consequences.[4]

People exposed to high levels of dioxins through industrial accidents or occupational exposures experienced a severe skin disease called chloracne. Other skin effects may occur including skin rashes and discoloration. In addition to skin effects, reproductive, developmental, and immunologic effects are associated with people and animals that were exposed to dioxin. ATSDR's chronic minimal risk level (MRL) of 1 pg/kg/day[b] (0.000000001 mg/kg/day) for dioxin is based on developmental effects seen in offspring of female monkeys exposed to a level of 5 ppt dioxin in their food while they were pregnant and lactating. EPA has not established an oral reference dose (RfD) for dioxins.

There is some evidence that dioxin may cause cancer in humans and sufficient toxicological data show that dioxin causes cancer at multiple sites (multiple organ systems) in animals. EPA does not currently have a cancer slope factor for dioxin that can be used to estimate cancer risk. EPA's previous cancer slope factor of 156,000 kg-day/mg was withdrawn. Other estimates of a cancer slope factor for dioxin may be an order of magnitude higher than EPA's previous value. The process of estimating cancer risk is described on page 10.

Non-cancer Hazard Evaluation

In order to evaluate the potential for *non-cancer* adverse health effects that might result from exposure to dioxins and dioxin-like compounds in geoduck and crab harvested from the study area, estimated doses for average and high-end consumers were calculated. These estimated doses were then compared to ATSDR's minimal risk level (MRL). MRLs are doses below which non-cancer adverse health effects are not expected to occur (so called "safe" doses).[5] MRLs 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 MRL. A dose that exceeds the 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 MRL, then that dose will fall well below the toxic effect level. The higher the estimated dose is above the MRL, the closer it will be to the toxic effect level.

Minimal Risk Levels (MRLs)

Different methods are used to select the toxic effect levels from which MRLs are derived. The most common method is to use a lowest-observed adverse effect level (LOAEL) or a no-observed adverse effect level (NOAEL). For example, the MRL for dioxin is derived from a LOAEL based on developmental effects seen in offspring of pregnant and lactating monkeys fed dioxin in their diets.

Hazard Calculation

Exposure assumptions and dose calculations are shown in Appendix B, Table B1. In order to determine if an exposure dose represents a hazard of non-cancer human health effects, exposure doses are compared to the MRL to obtain a hazard quotient (HQ) where:

HQ = Estimated dose/MRL

[b] The World Health Organization (WHO) considers a daily intake of 1-4 pg/kg/day to be tolerable, but that efforts should be made to reduce intake levels.

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 crab and geoduck from the LEKT fishing area, none of the hazard quotients for average or high-end shellfish consumers exceeds one. Appendix B, Table B2, shows the hazard quotients for all species and exposure scenarios. The highest hazard quotient (0.75) is related to high-end children's consumption of Dungeness crab. Children eat proportionally more Dungeness crab than adults based on the Suquamish Fish Consumption Study.[5] It is not known if this trend applies to LEKT children, but regardless, neither children nor adults are likely to experience adverse non-cancer heath effects from exposure to dioxins and dioxin-like compound levels observed in crabs and geoducks caught in the LEKT fishing area.

It should be noted that the EPA has questioned ATSDR's MRL because it may not be low enough, but EPA has acknowledged that the MRL is still within the range of 1-4 pg/kg/day that the World Health Organization (WHO) has called tolerable.

Cancer Risk

There is some evidence that dioxins and dioxin-like compounds have the ability to cause cancer in humans. Cancer risk is estimated by calculating a dose similar to that described above and multiplying it by a cancer potency factor, also known as the cancer slope factor. Some cancer potency factors are derived from human population data. Others are derived from laboratory animal studies involving doses much higher than are encountered in the environment. Use of animal data requires extrapolation of the cancer potency obtained from these high dose studies down to real-world exposures. This process involves much uncertainty.

Current regulatory practice 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. 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 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.[6] This consultation assumes that there is no threshold for dioxins.

Cancer Risk Calculation

Cancer is a common illness and its occurrence in a population increases with age. Depending on the type of cancer, a population with no known environmental exposure could be expected to have a substantial number of cancer cases. There are many different forms of cancer that result from a variety of causes; not all are fatal. Approximately 25% to 33% of people living in the United States will develop cancer at some point in their lives.[7]

Exposure assumptions and dose calculations are shown in Appendix B. In order to determine the cancer risk associated with an exposure dose, exposure doses are multiplied by the cancer slope factor to obtain the probability that a person might get cancer from their exposure to a chemical.

Cancer Risk = Estimated Dose X Cancer Slope Factor

Cancer risk is expressed as a probability. For instance, a cancer risk of 1×10^{-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. Cancer risks quantified in this document are an upper-bound theoretical estimate. Actual risks are likely to be much lower. When this approach is applied to consumption of crab and geoduck from the LEKT fishing area, no average consumers exceed a cancer risk of 1×10^{-6}. The highest cancer risk, 2×10^{-5}, is associated with high-end consumption of whole Dungeness crab. Consumption of Dungeness crab muscle tissue only would likely reduce this risk considerably due to the tendency of dioxin and dioxin-like compounds to accumulate disproportionately in crab butter. Appendix B, Table B2, shows cancer risks for all species and exposure scenarios. All cancer risks associated with these exposure scenarios are within a range considered acceptable by EPA.

Comparison with Background

Low levels of dioxins and dioxin-like compounds are ubiquitous in the environment (including in shellfish) and people may be exposed through multiple pathways. EPA has acknowledged that background exposures to dioxin or dioxin-like compounds are not insignificant. Although EPA has not established a reference dose (RfD) for dioxin or dioxin-like compounds, any RfD established by EPA would likely be 2-3 orders of magnitude (100-1,000) below current background intakes and body burdens.[8] With this in mind, EPA has suggested comparing a population's exposure to dioxin to a background exposure.

EPA concedes that overall background exposures need to be reduced and focus should be placed on exposures that are significant contributors to dioxin exposure. Guidance has not yet been established on this issue.

In the case of crab and geoduck caught in the LEKT fishing area, it is useful to compare levels in shellfish that reside in areas likely to have been impacted by industrial sources, such as the former mill site, to levels in shellfish in areas relatively unimpacted by industrial sources (i.e., reference areas). Dungeness crabs and geoduck caught in the LEKT fishing area had levels of dioxin TEQs similar to those caught in Dungeness and Freshwater Bays.[c] TEQ levels measured

[c] Crab muscle and butter were analyzed separately for the reference area samples, but together for the study area samples. In order to make a direct comparison, the reference area samples had to be adjusted based on the relative mass of crab butter and muscle in a typical crab. Recent measurements conducted as part of the Lower Duwamish Waterway cleanup project by Windward Environmental revealed that crab muscle makes up approximately 75% of the overall edible crab tissue with crab butter making up the remaining 25%.

in Dungeness crab in the study area and reference areas are slightly lower than the background level for crabs reported in EPA's Draft Dioxin Reassessment.

Table 2. Comparison of Lower Elwha TEQ results with reference areas and published values

Lower Elwha Species	Lower Elwha TEQ Concentration	Reference Dungeness Bay TEQ Concentration	Reference Freshwater Bay	Dioxin Reassessment TEQ Concentration [a]
Geoduck	0.019 (0DL) 0.027 (1/2 DL)	0.055 (0DL) 0.071 (1/2 DL)	0.018 (0DL) 0.041 (1/2 DL)	NA
Dungeness crab butter	NA	0.47 (0 DL) 0.50 (1/2 DL)	0.72 (0 DL) 0.74 (1/2 DL)	NA
Dungeness crab muscle	NA	0.016 (0DL) 0.043 (1/2 DL)	0.005 (0DL) 0.033 (1/2 DL)	NA
Whole Dungeness	0.18	0.12 (0 DL) [b] 0.15 (1/2 DL) [b]	0.17 (0 DL) [b] 0.20 (1/2 DL) [b]	0.23 (0 DL) [c] 0.36 (1/2 DL) [c]
Red Rock	0.013 (0DL) 0.025 (1/2 DL)	NA	NA	NA

a- No data were included that were collected near known uncommon point sources (pulp and paper mills, POTWs, etc.). Background data for freshwater and marine fish and shellfish were based on species-specific data from various studies, including a national survey conducted by EPA, market basket surveys conducted by FDA, and individual site-specific studies.

b- Assumes 75% of tissue by mass is comprised of muscle and 25% crab butter. [9]

c- Type of crab not specified.

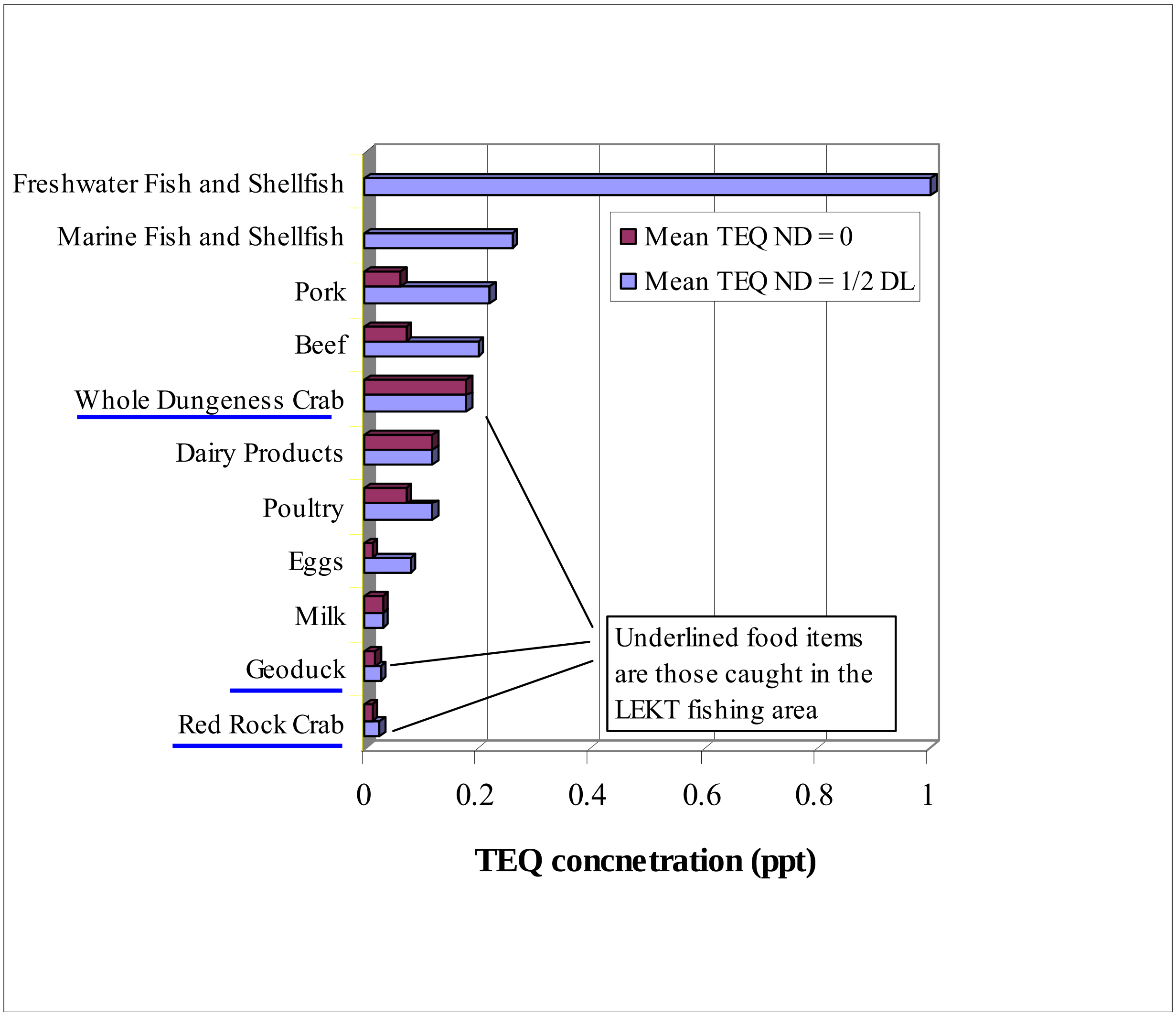
Comparison with other foods

Another way to frame the risks of consuming crab and geoducks caught in the LEKT fishing area is to compare concentrations of dioxin TEQs found in these tissues with other types of commonly eaten foods. Although comparative risks are not appropriate for determining cleanup levels at a cleanup site, especially since the goal of public health agencies is to reduce overall levels of dioxins in the environment, they are useful for providing advice on alternative food sources to eat when food sources are impacted by industrial pollution at a site.

Figure 1 shows measured levels of dioxin TEQs in commonly eaten foods and crab and geoduck. Geoduck and red rock crab from the LEKT fish area have the lowest dioxin TEQ levels of the reported foods. Whole Dungeness crabs have similar levels as other types of animal protein such as beef and pork.

Food alternatives to crab and geoduck from the LEKT fishing area do not have lower or substantially lower levels of dioxin. For instance, eating beef or pork instead of Dungeness crab would not reduce a person's exposure to dioxin or dioxin-like compounds.

Figure 1. Dioxin TEQ concentrations (ppt) found in different types of animal protein in the United States.[7]



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 assuming that children eat proportionately more crab and shellfish than adults.

Conclusions

1. Consumption of geoduck and crab caught in the LEKT fishing area represents *no apparent public health hazard* for average and high-end LEKT fish consumers.

2. Crab and geoduck caught in the LEKT fishing area contain levels of dioxin and dioxin-like compounds similar to those caught in reference areas.

3. Levels of dioxin TEQs in crab and geoduck caught in the LEKT fishing area are as low or lower than levels measured in other typical food sources.

Recommendations

There are no recommendations or advice against consumption of crab and geoduck caught in the LEKT fishing area.

Public Health Action Plan

Actions Taken

1. Sampling and analysis of crab and geoduck for dioxin and dioxin-like compounds has been conducted to ensure that past and current industrial and municipal processes have not significantly impacted a fishing area used by the LEKT.

2. These data have been interpreted by DOH and presented within this health consultation.

Actions Planned

1. Copies of this health consultation will be mailed to the Lower Elwha Klallam Tribe, the Washington State Department of Ecology, EPA, and Rayonier, Inc.

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Appendices

Figure A1. Dungeness Crab Sample Locations and Dioxin TEQ Concentration (ppt)

Figure A2. Geoduck Sample Locations and Dioxin TEQ Concentration (ppt)

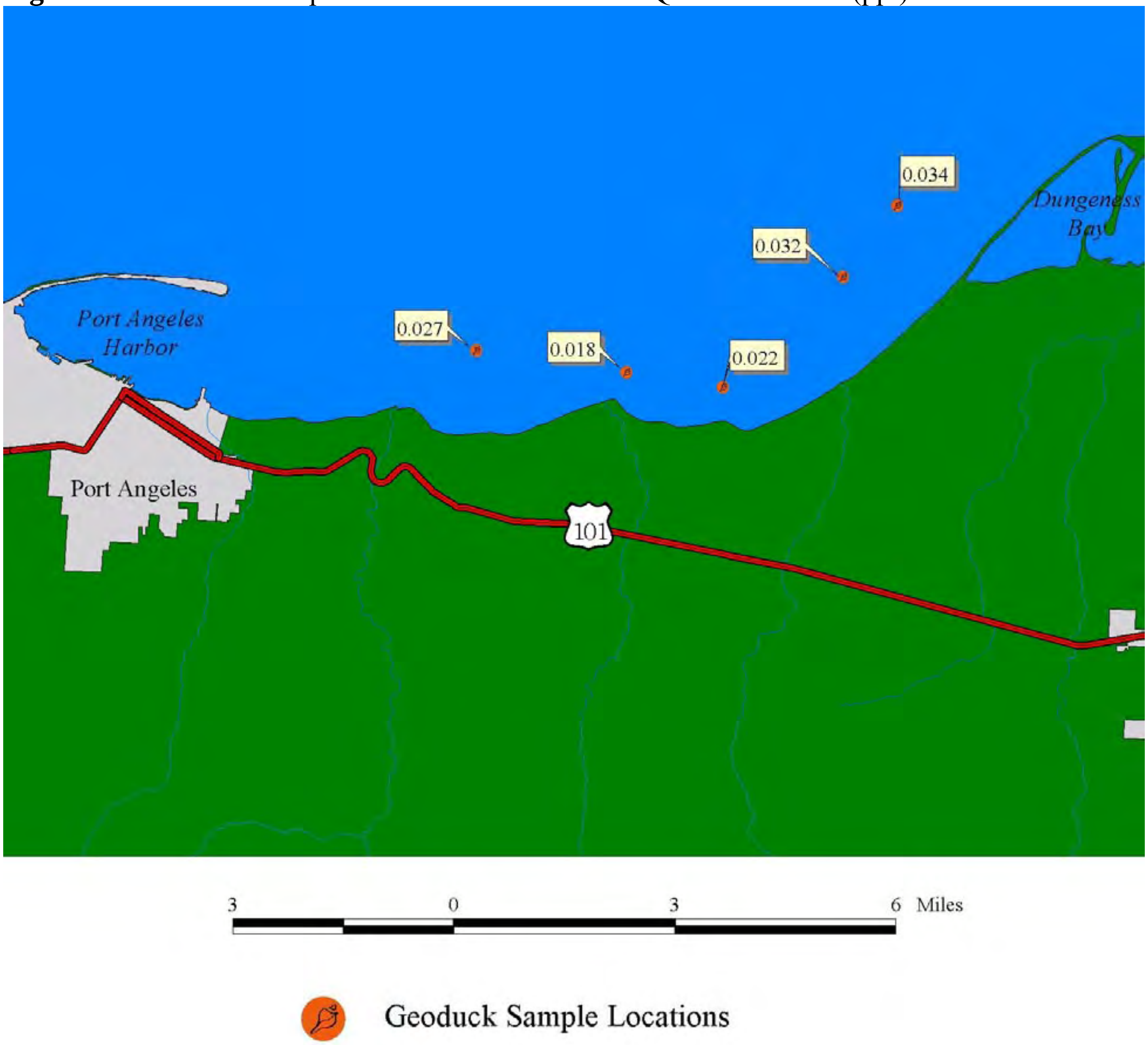


Figure A3. Red Rock Crab Sample Locations and Dioxin TEQ Concentration (ppt)

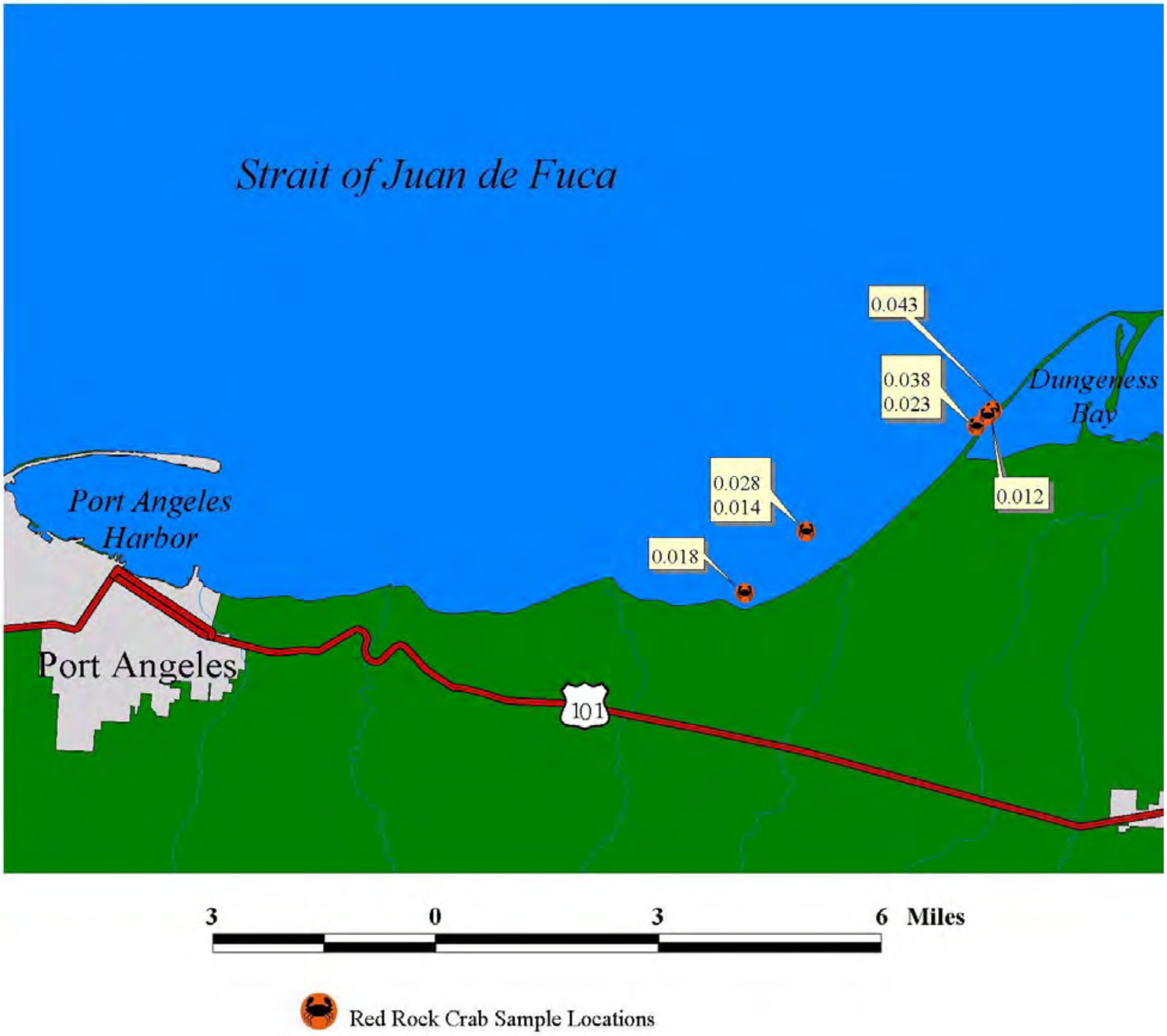
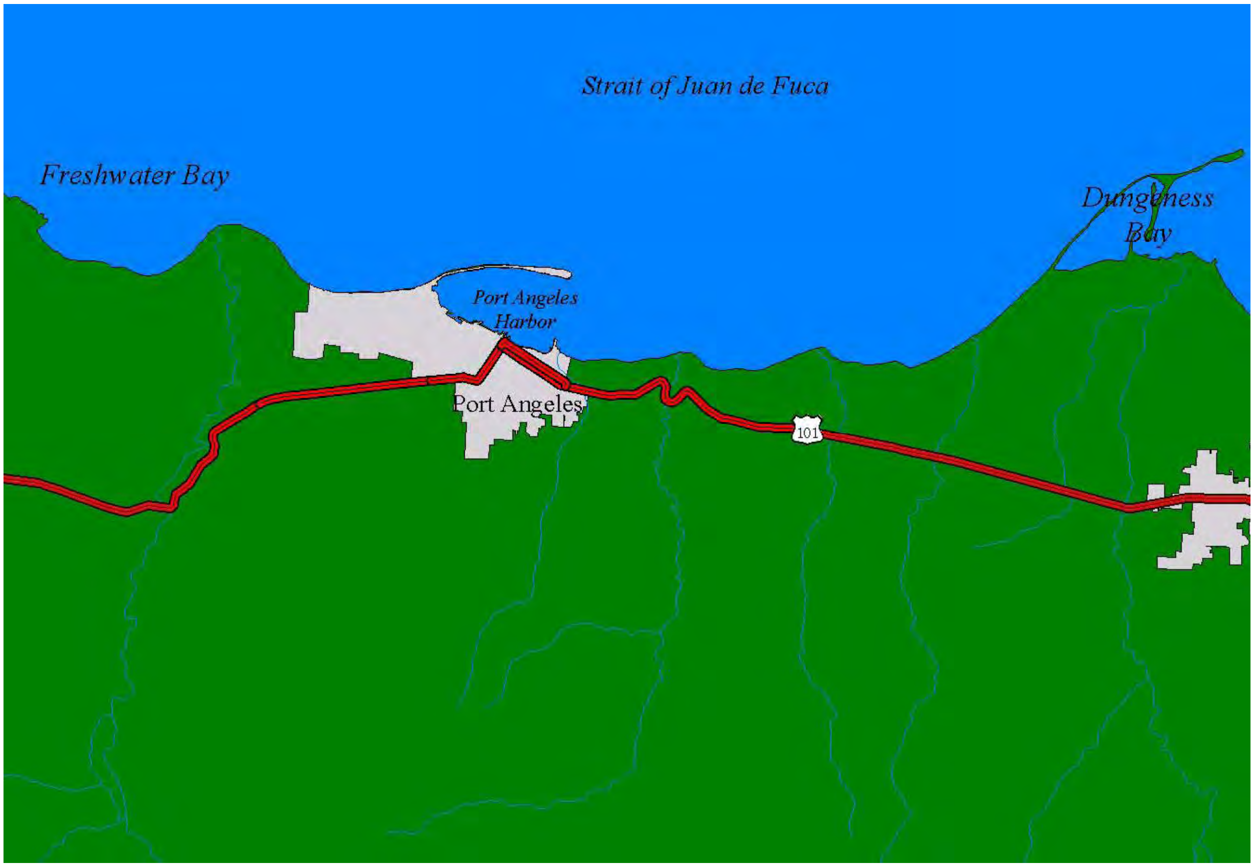


Figure A4. Freshwater Bay and Dungeness Bay reference areas relative to Port Angeles, Washington



Appendix B: Exposure dose calculations and assumptions

Average and upper-bound exposure scenarios were evaluated for consumption of geoduck and crab from the study area. Exposure assumptions given in Table B1 below were used with the following equations estimate contaminant doses associated with shellfish consumption.

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

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

Table B1. Exposure Assumptions

Parameter	Value	Unit	Comments
Concentration (C) – High-end	Variable	ng/kg	Maximum detected value.
Conversion Factor$_1$ (CF_1)	0.000001	mg/ng	Converts contaminant concentration from micrograms (ng) to milligrams (mg)
Geoduck Ingestion Rate (IR) – Average Child	0.053	g/kg/day	Median Suquamish Children - Consumers Only
Geoduck Ingestion Rate (IR) - High-end Child	0.554		90th percentile Suquamish Children – Consumers Only
Geoduck Ingestion Rate (IR) – Average Adult	0.052		Median Suquamish Adults - Consumers Only
Geoduck Ingestion Rate (IR) - High-end Adult	0.441		90th percentile Suquamish Adults – Consumers Only
Dungeness Crab Ingestion Rate (IR) – Average Child	0.082		Median Suquamish Children - Consumers Only
Dungeness Crab Ingestion Rate (IR) - High-end Child	2.348		90th percentile Suquamish Children – Consumers Only
Dungeness Crab Ingestion Rate (IR) – Average Adult	0.071		Median Suquamish Adults - Consumers Only
Dungeness Crab Ingestion Rate (IR) – High-end Adult	0.425		90th percentile Suquamish Adults – Consumers Only
Red Rock Crab Ingestion Rate (IR) – Average Child	0.028		Median Suquamish Children - Consumers Only
Red Rock Crab Ingestion Rate (IR) – Average Child	0.028		90th percentile Suquamish Children – Consumers Only
Red Rock Crab Ingestion Rate (IR) – AverageAdult	0.012		Median Suquamish Adults - Consumers Only
Red Rock Crab Ingestion Rate (IR) – Average Adult	0.117		90th percentile Suquamish Adults – Consumers Only
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) – Child	5	years	Number of years eating shellfish while still a child
Exposure Duration (ED) – Average Adult	30		Number of years eating shellfish.
Exposure Duration (ED) – High end Adult	55		Number of years eating shellfish
Averaging Time$_{non-cancer}$ (AT)	10950	days	30 years
Averaging Time$_{non-cancer}$ (AT)	20075		55 years
Averaging Time$_{cancer}$ (AT)	25550		70 years
Minimal Risk Level (MRL)	$1x10^{-9}$	mg/kg/day	Source: ATSDR
Cancer Slope Factor (CSF)	153000	mg/kg-day^{-1}	Source: EPA HEAST 97

a– child to adult cancer risk scenario assumes 5 year exposure duration at child consumption rate plus an additional 25 years (average scenario) or 50 years (higher-end scenario) exposure duration at adult consumption rate.

Table B2. Health risk calculations from exposure to contaminants of concern in shellfish sampled from the LEKT fishing area - Clallam County, Washington.

Species	Dioxin TEQ Max Concentration (ppt)	MRL (mg/kg/day)	Hazard Quotient Adult		Hazard Quotient Child		Cancer Slope Factor (kg-day/mg)	Cancer Risk Adult		Cancer Risk Exposure starting at childhood [a]	
			Average	High-end	Average	High-end		Average	High-end	Average	High-end
Geoduck	0.034	$1x10^{-9}$	0.002	0.015	0.002	0.019	156,000	$1x10^{-7}$	$2x10^{-6}$	$1x10^{-7}$	$2x10^{-6}$
Dungeness Crab	0.32		0.023	0.136	0.026	0.751		$2x10^{-6}$	$2x10^{-5}$	$2x10^{-6}$	$2x10^{-5}$
Red Rock Crab	0.043		0.0005	0.005	0.002	0.003		$3x10^{-8}$	$6x10^{-7}$	$5x10^{-8}$	$6x10^{-7}$

a – assumes 5 years of exposure occurring as a child

Appendix C – Toxic Equivalency Factors (TEFs)

Table C1. Toxic Equivalency Factors (TEF) relative to 2,3,7,8 tetrachlorodibenzo(p)dioxin (TCDD).

COMPOUND	TEF
2,3,7,8-TCDD	1
1,2,3,7,8-PeCDD	1
1,2,3,4,7,8-HxCDD	0.1
1,2,3,6,7,8-HxCDD	0.1
1,2,3,7,8,9-HxCDD	0.1
1,2,3,4,6,7,8-HpCDD	0.01
OCDD	0.0001
2,3,7,8-TCDF	0.1
1,2,3,7,8-PeCDF	0.05
2,3,4,7,8-PeCDF	0.5
1,2,3,4,7,8-HxCDF	0.1
1,2,3,6,7,8-HxCDF	0.1
1,2,3,7,8,9-HxCDF	0.1
2,3,4,6,7,8-HxCDF	0.1
1,2,3,4,6,7,8-HpCDF	0.01
1,2,3,4,7,8,9-HpCDF	0.01
OCDF	0.0001

Certification

This Health Consultation was prepared by the Washington State Department of Health under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with approved methodology and procedures existing at the time the health consultation was begun.

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The Division of Health Assessment and Consultation, ATSDR, has reviewed this public health consultation and concurs with the findings.

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