Health Consultation

Evaluation of Dioxins in Shellfish from the Oakland Bay Site
Shelton, Mason County, Washington

July 27, 2010

Prepared by

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

Washington State Department of Health

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Foreword

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

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

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

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

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

Table of Contents

Glossary

Agency for Toxic Substances and Disease Registry (ATSDR)	The principal federal public health agency involved with hazardous waste issues, responsible for preventing or reducing the harmful effects of exposure to hazardous substances on human health and quality of life. ATSDR is part of the U.S. Department of Health and Human Services.
Cancer Risk	A theoretical risk for developing cancer if exposed to a substance every day for 70 years (a lifetime exposure). The true risk might be lower.
Cancer Risk Evaluation Guide (CREG)	The concentration of a chemical in air, soil or water that is expected to cause no more than one excess cancer in a million persons exposed over a lifetime. The CREG is a *comparison value* used to select contaminants of potential health concern and is based on the *cancer slope factor* (CSF).
Cancer Slope Factor	A number assigned to a cancer causing chemical that is used to estimate its ability to cause cancer in humans.
Carcinogen	Any substance that causes cancer.
Comparison value	Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause harmful (adverse) health effects in exposed people. The CV is used as a screening level during the public health assessment process. Substances found in amounts greater than their CVs might be selected for further evaluation in the public health assessment process.
Contaminant	A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.
Dose (for chemicals that are not radioactive)	The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An “exposure dose” is how much of a substance is encountered in the environment. An “absorbed dose” is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.

Environmental Media Evaluation Guide (EMEG)	A concentration in air, soil, or water below which adverse non-cancer health effects are not expected to occur. The EMEG is a *comparison value* used to select contaminants of potential health concern and is based on ATSDR's *minimal risk level* (MRL).
Environmental Protection Agency (EPA)	United States Environmental Protection Agency.
Exposure	Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [**acute exposure**], of intermediate duration, or long-term [**chronic exposure**].
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.
Media	Soil, water, air, plants, animals, or any other part of the environment that can contain contaminants.
Minimal Risk Level (MRL)	An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified time period (acute, intermediate, or chronic). MRLs should not be used as predictors of harmful (adverse) health effects [see **oral reference dose**].
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)/Parts per trillion (ppt)	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. 1 ounce of TCE in 1 trillion ounces of water is 1 ppt. If one drop of TCE is mixed in a competition size swimming pool, the water will contain about 1 ppb of TCE.
Reference Dose Media Evaluation Guide (RMEG)	A concentration in air, soil, or water below which adverse non-cancer health effects are not expected to occur. The RMEG is a *comparison value* used to select contaminants of potential health concern and is based on EPA's oral reference dose (RfD).
Route of exposure	The way people come into contact with a hazardous substance. Three routes of exposure are breathing [inhalation], eating or drinking [ingestion], or contact with the skin [dermal contact].
Tolerable Daily Intake (TDI)	It is the amount of intake per kg body weight per day of a chemical substance suspected of causing harmful health effects as a result of long-term incorporation by the body, that is judged not to give rise to manifestations of adverse health effects even if humans take in as much as that amount throughout their entire lifetimes.
Toxic Equivalent (TEQ)	Is defined as the sum of the products of the concentration of each compound (e.g., dioxin and furan compound) multiplied by its Toxic Equivalent Factor (TEF) value.
Toxic Equivalency Factors (TEFs)	It is an estimate of the toxicity of the compound relative to 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD). Each dioxin/furan is multiplied by a TEF to produce the dioxin TEQ. The TEQs for each chemical are then summed to give the overall 2,3,7,8-tetrachlorodibenzo-p-dioxin TEQ.

Summary

Introduction:

The Department of Health's (DOH) top priority for Oakland Bay area residents and others who work, harvest fish/shellfish, and/or recreate there (tribal members and the general population) is to ensure the community has the best information possible to safeguard its health. The Department of Ecology (Ecology), the Squaxin Island Tribe, and the Pacific Coast Shellfish Growers Association asked DOH to conduct this investigation. The purpose of this health consultation is to evaluate dioxin data for shellfish from the Oakland Bay site in Shelton, Mason County, Washington and to make recommendations for actions that ensure the public's health is protected. DOH reached three important conclusions in this health consultation:

Conclusion 1:
Eating shellfish that contains dioxins from the Oakland Bay site is not expected to harm health or produce harmful non-cancer health effects for the general population or subsistence fish/shellfish consumers (i.e., low, medium, and high-end).

Basis for decision:
Dioxin levels are below concentrations where we would expect to see health effects (i.e., the estimated doses are below the ATSDR minimal risk level (MRL) of 1 pg/kg/day and World Health Organization (WHO) daily intake of 4 pg Toxic Equivalent (TEQ)/kg/day.

Conclusion 2:
Eating shellfish that contains dioxins from the Oakland Bay site is not expected to harm health or produce harmful cancer health effects for subsistence fish/shellfish consumers, or the general population (low, medium, and high-end). This conclusion is based on the assumption of total dioxin exposure from childhood into adulthood (average lifetime exposure of 70 years).

Basis for decision:
Based on exposure calculations and lifetime daily intakes for the general population and subsistence fish/shellfish consumers, it is unlikely that people will be at appreciable risk of developing cancer health effects. It should be noted that these estimates do not exceed EPA's acceptable cancer risk for fish consumption. The range of cancer risks considered acceptable by EPA is 1 additional case of cancer per 10,000 people exposed to 1 additional case of cancer per 1,000,000 people exposed.

Next steps:

DOH will provide copies of this health consultation to Ecology, the Pacific Coast Shellfish Growers Association, the Squaxin Island Tribe, and other concerned parties when the report is approved.

For More Information:

Please feel free to contact Elmer Diaz at 360-236-3357 or toll free at 1-877-485-7316 if you have any questions about this health consultation.

Statement of Issues

The Washington State Department of Health (DOH) has prepared this health consultation at the request of the Washington State Department of Ecology (Ecology), the Squaxin Island Tribe, and the Oakland Bay Shellfish Growers Association. The purpose of this health consultation is to evaluate the dioxin exposures associated with consumption of shellfish harvested from the Oakland Bay site in Shelton, Mason County, Washington. DOH prepares health consultations under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR).

Background

The Oakland Bay site is located in South Puget Sound and is composed of Oakland Bay, Shelton Harbor, and Hammersley Inlet. Oakland Bay is one of the most productive commercial shellfish growing areas in the country and is known worldwide for its Manila clams (*Tapes philippinarum*). In addition, Pacific oysters (*Crassostrea gigas*), Kumamoto (Kumo) oysters (*Crassostrea sikamea*), and Mussels (*Mytilus edulis*) are grown in the area. Historical and current industrial uses of the Oakland Bay site have resulted in sediment contamination in Shelton Harbor and surrounding areas. Within Oakland Bay, there are currently three beaches open for recreational harvesting: Oakland Bay Recreation Tidelands located in the Bayshore area at the northern end of Oakland Bay, and North East Chapman Cove and Chapman Cove Spit, which are located near Chapman Cove (Figure 1). All of these areas are used for recreational shellfish harvesting during the year and harvest advisories (for fecal coliform bacteria) are occasionally established for these areas. DOH's Shellfish Program classifies recreational shellfish beaches as Approved, Advisory, Closed, and Unclassified. The northern end of Oakland Bay is restricted for shellfish harvesting[a]. Local residents also live in some of these areas, thus subsistence and residential use of shellfish in these areas is not limited to only public access areas.

Shellfish (bivalves) are marine invertebrates that have the capacity to accumulate contaminants found in their environment and therefore present a potential threat for consumers of shellfish. This study was conducted to assess the chemical threats associated with consumption of shellfish harvested from the Oakland Bay site. In September and October of 2008, Ecology conducted a sediment investigation of the Oakland Bay site by collecting surface and subsurface sediment samples in Shelton Harbor and the Oakland Bay area. Ecology quantified inorganic and organic compounds. Dioxins were the only chemicals detected above Ecology's sediment quality standards (which apply to protection of aquatic organisms) or at levels of concern to Ecology for possible human health impacts. The levels of dioxin in the surface sediment ranged from 4.4 to 54 parts per trillion (ppt) in Oakland Bay and 1 to 175 ppt in Shelton Harbor (Figure 1).

In August 2009 - June 2010, DOH conducted a health evaluation of contaminants in surface

[a] A **Restricted** classification is used for areas that do not meet water quality standards for an Approved classification, but the sanitary survey indicates only a limited degree of pollution from non-human sources. Shellfish harvested from Restricted growing areas cannot be marketed directly. They must be "relayed" to Approved growing area waters for a specified amount of time allowing shellfish to naturally cleanse themselves of contaminants before they are harvested for market.

sediments from the Oakland Bay site. Total dioxins and total polycyclic aromatic hydrocarbons (PAHs) detected in the surface sediment in Oakland Bay and Shelton Harbor were the only contaminants that exceeded health comparison values. DOH concluded that levels of these contaminants in surface sediment are not expected to produce harmful non-cancer or cancer health effects in the general population.[1] DOH recommended sampling and analysis of shellfish grown in the area to determine if shellfish consumers were impacted by chemical contamination. In this evaluation, DOH will estimate lifetime daily intake and assess the cancer and non-cancer risks associated with consumption of shellfish harvested from this area.

Sample collection and analysis

Shellfish sampling areas

Eight different regions were sampled at the Oakland Bay site. One additional sampling area across Walker County Park in Shelton Harbor served as a reference area (Figure 2). Manila clams, Pacific oysters, Kumamoto oysters, and mussels were the species targeted for this study. A composite of approximately 30 individual organisms was collected from each sampling area, representing a specific area within each sample location (i.e., 10 shellfish at 3 locations). Twenty-two animal tissue samples were collected from the study area.

Shellfish sampling and homogenate preparation

Sampling was performed during a low tidal cycle in the spring prior to shellfish spawning. Shellfish of legal harvest size were collected by hand. The shellfish were then placed in a plastic bag and subsequently transferred to a cooler filled with ice cubes. The shellfish were washed in water to remove sand. Samples were then stored in a freezer at -20^{o}C until transported by car to the laboratory. Samples were freeze dried and then homogenized by staff at the laboratory.

Selected contaminants

Dioxin and furans were the only contaminants chosen for this evaluation because of the following: a) they were present in the sediment across Oakland Bay and Shelton Harbor; b) they are likely to bioaccumulate in shellfish; and c) they have suspected or recognized harmful health effects.

Chemical analysis

Columbia Analytical Services Inc. (Houston, Texas) analyzed the tissue samples (homogenates). All analyses were performed according to the laboratory's quality assurance requirements. All samples were analyzed for polychlorinated dibenzodioxins (dioxins) and polychlorinated dibenzofurans (furans) by High Resolution Gas Chromatography/High Resolution Mass Spectrometry (HRGC/HRMS) using EPA method 1613B. Ten grams per sample were extracted for analysis. The laboratory met the desired detection limits as follows: 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and 1,2,3,7,8-pentachlorodibenzo-p-dioxin (PeCDD) at 0.06 parts per trillion (ppt) and all other congeners at 0.1 ppt or lower.

Concentrations calculated

The laboratory calculated total dioxin toxic equivalence quotients (TEQ)[b] according to the 2005 World Health Organization re-evaluation of Human and Mammalian Toxic Equivalency Factors (TEF)[c] for Dioxins and Dioxin-like compounds.[2] DOH confirmed the accuracy of these values and accepted them as valid calculations. Undetected congeners were assigned a concentration equal to half (1/2) the detection limit (DL). Not all congeners were detected; overall, the main ones were 1,2,3,6,7,8- hexachlorodibenzo-p-dioxin (1,2,3,7,8,9-HxCDD); Heptachlorodibenzo-*p*-dioxin (1,2,3,4,6,7,8-HpCDD); Octachlorodibenzo-*p*-dioxin (OCDD); Pentachlorodibenzofuran (2,3,4,7,8-PeCDF); Hexachlorodibenzofuran (2,3,4,6,7,8-HxCDF); Heptachlorodibenzofuran (1,2,3,4,6,7,8-HpCDF); and Octachlorodibenzofuran (OCDF). 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) was not detected in any samples. Data validation for the results, reported by Columbia Analytical Services, Inc., was considered acceptable for use as qualified.[3]

Results

Contaminant concentrations

Table 1 shows levels of dioxins found in shellfish species from the Oakland Bay site. Contaminant concentrations are expressed as wet weight (ww). Total dioxin concentrations in Manila clams ranged from 0.05 to 0.27 ppt and lipid (fat) content ranged from 0.03 to 0.34%. Similarly, total dioxin concentrations in Pacific oysters ranged from 0.13 to 0.37 ppt and lipid content ranged from 0.08 to 0.47%. In Kumamoto oysters, total dioxin concentrations ranged from 0.3 to 0.6 ppt while lipid content ranged from 0.47 to 0.64%. For the mussel sample, total dioxin concentration was 0.17 ppt and lipid content was 1.36%. Appendix A, Table A1 summarizes the concentrations of dioxin and furan congeners found in shellfish from the Oakland Bay site.

In general, organic compounds such as dioxins accumulate in lipid-rich tissues. The higher the lipid content, the higher the dioxin concentration. This trend (i.e., lipid content and average total dioxin concentrations) is seen in the Manila clams, Pacific oysters, and Kumamoto oysters. On the other hand, Mussels had the highest lipid content compared to other species but levels of dioxins were lower than Pacific oysters and Kumamoto oysters[d] (Table 1). The fact that Manila clams, Pacific oysters, and Kumamoto oysters are grown in the sediment, while mussels are grown in the water column likely accounts for this difference.

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[b] TEQ is defined as the sum of the products of the concentration of each dioxin and furan compound multiplied by its Toxic Equivalent Factor (TEF) value.

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

[d] Mussels – only a single composite location was sampled from the Oakland Bay site.

Table 1. Total dioxin concentrations detected in shellfish from the Oakland Bay site, Shelton, Mason County, Washington.

Species	Contaminant	N (number of samples)	Range of Concentration (wet weight) (ppt)	Lipid Range (percent %)	Mean Concentration (wet weight) (ppt)	EPA's Comparison Value (ppt)[b]
Manila clams	Total Dioxin TEQ[a]	14	0.05 – 0.27	0.03 – 0.34	**0.11**	**0.0315**
Pacific oysters		5	0.13 – 0.37	0.08 – 0.47	**0.26**	
Kumo oysters		2	0.3 – 0.6	0.47 – 0.64	**0.45**	
Mussels †		1	NA	1.36	**0.17**	

BOLD values exceed EPA's comparison value
Total Dioxin TEQ – sum of dioxin and furans toxic equivalent (TEQ)
[a] Toxic equivalent (TEQ) = Toxic equivalents (TEQs) were calculated using the mammalian dioxin and furan Toxic Equivalent Factors (TEFs) from Van den Berg et al. (2006) and one-half the reporting limit (RL) for undetected congeners.[2]
[b] Derived from EPA Guidance for Assessing Chemical Contaminant Data (subsistence fishers).[4] Based on fish consumption rate of 142 g/day, 70 kg body weight and, for carcinogens, 10^{-5} risk level and 70-year lifetime exposure.
† There is not a range concentration available; only a single composite location was sampled from the Oakland Bay site.
ppt – parts per trillion
NA – Not available
N – Each composite sample contained 30 individual organisms representing a specific area within each sampling location (i.e., 10 shellfish each in the lower, middle, and upper of each segment).

Background total dioxin concentrations in shellfish are unknown in the Puget Sound area (i.e., studies have not been conducted to quantify background levels). Thus, it is not possible to compare these values to a Puget Sound background value.

Discussion

Contaminants of Concern (COC)

DOH used a conservative approach to evaluate whether contaminants in shellfish from the Oakland Bay site pose a possible health concern (Appendix B). Contaminants of concern in shellfish were determined by employing a screening process. In general, health-based comparison or screening values include ATSDR cancer risk evaluation guide (CREG), environmental media evaluation guide (EMEG), and reference dose media evaluation guide (RMEG) [see the glossary for descriptions]. Comparison values such as the CREG and EMEG offer a high degree of protection and assurance that people are unlikely to be harmed by contaminants in the environment. For chemicals that cause cancer, the comparison values represent levels that are calculated to increase the theoretical risk of cancer by about one additional cancer in a million people exposed.

DOH uses ATSDR comparison values whenever available to make health based decisions. In the absence ATSDR comparison or screening values, DOH may also use EPA's health guideline values or other available values. In this health evaluation, mean total dioxin levels were screened against EPA's comparison values for non-cancer and cancer health effects (Table 1). EPA's comparison value is derived from EPA Guidance for Assessing Chemical Contaminant Data (subsistence fishers)[4] which is based on a fish consumption rate of 142 g/day, 70 kg body weight, and for carcinogens, a 1 additional cancer in 100,000 people exposed (10^{-5}) risk level and 70-year lifetime exposure. In general, if a contaminant's mean and/or maximum concentration is greater than its comparison value, then the contaminant is evaluated further. Based on the screening results summarized in Table 1, total dioxins in shellfish will be carried out for further evaluation.

Exposure Pathways

In order for any contaminant to be a health concern, the contaminant must be present at a high enough concentration to cause potential harm and there must be a completed route of exposure [e] to people.

In general, people can be exposed to dioxins through incidental ingestion of soils or sediments that are contaminated, eating contaminated foods and drinking water, inhaling, and skin contact. Human use patterns and site-specific conditions were considered in the evaluation of exposure to total TEQ dioxins from eating shellfish from the Oakland Bay site. Exposure to dioxins in shellfish at the Oakland Bay site for the general population and for a subsistence fish/shellfish consumer can occur through the following completed pathway and route of exposure:

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

Ingestion exposure (swallowing)

For chemicals (like dioxins) that are persistent and build up over time, contaminants in food are the primary source of exposure. Meat, dairy products, and fish contribute more than 90% of the dioxin intake for the public. Therefore, everyone has some dioxin in their body. Yet for most, it is not life threatening; the health threat depends on the amount and length of time a person is exposed to a contaminant.

Consumption scenarios

DOH established four consumption scenarios for shellfish harvesters. These scenarios were based on the general population and subsistence fish/shellfish consumption rates. The first scenario is based on the general population. The remaining scenarios were based on a low, medium, and high-end consumption rate for total seafood (adult).[5] The consumption rate used for the general population scenario is based on the average quantity of total seafood consumed at each meal for an adult or 17.5 g (ww) per day. The other scenarios target subsistence fish/shellfish consumers who eat shellfish at a low, medium, and high rate. Manila clams from the Oakland Bay site are consumed more often than oysters and mussels.[5] The subsistence fish/shellfish (total seafood) low, medium, and high-end consumption rates are 60 g/day, 175 g/day, and 260 g/day, respectively. These consumption rates for an adult subsistence fish/shellfish consumer were used to calculate non-cancer and cancer risks (Appendix B, Tables B2 and Table B3). A fish consumption survey of the Tulalip and Squaxin Island tribes indicates that Squaxin Island Tribal members (adult) eat shellfish at a median consumption rate of 0.07 g/kg/day (5.7 g/day for an 81.8 kg adult).[6] An exposure scenario was assumed for the general population and a subsistence fish/shellfish tribal consumer that consume shellfish from the Oakland Bay site. This scenario assumed that Manila clams from the Oakland Bay site are consumed 50% of the time from total seafood, and oysters and mussels from the Oakland Bay site are consumed 1% of the time from total seafood. The following provides reasons why oysters and mussels are consumed at a lower rate than Manila clams:

- Oysters and mussels are mainly grown for commercial purposes and are very limited in public access areas, while Manila clams are more accessible in these areas. These are not the main species harvested in these areas.
- According to the Squaxin Island Tribe fish consumption survey, finfish are consumed the most (primarily anadromous fish followed by shellfish). Bottom fish and pelagic fish are consumed at a lower rate.[6] Oysters and mussels are consumed at a lower rate than Manila clams.

DOH considers this approach very conservative for shellfish consumers that may eat shellfish from the Oakland Bay site.

Estimation of contaminant intakes

DOH estimated lifetime average daily intake of total dioxins in picograms per kilogram per day (pg/kg/day) by multiplying the mean of the contaminant concentration by the daily shellfish consumption rates. As mentioned above, consumption rates were derived assuming subsistence fish/shellfish consumption rates of low (0.06 kg/day), medium (0.175 kg/day), and high-end (0.26 kg/day), and the general population consumption rates (0.0175 kg/day). The result was then divided by the weight of an average U.S. adult (72 kg) and an adult subsistence fish/shellfish consumer (81.8 kg) [6] to obtain a dose expressed as pg/kg/day (Table 2). The general population and subsistence fish/shellfish consumer lifetime exposure is based on 30 and 70-year exposure durations, respectively. Contaminant intakes are described in more detail in the consumption scenarios below.

In general, DOH considers that the health evaluations are based on valid scenarios for the general population and a subsistence fish/shellfish consumer. The general population consumption scenario of 17.5 g/day appears to reflect the average U.S. fish consumer. This value is an estimate of the average consumption of uncooked fish and shellfish from estuarine and fresh waters by recreation fishers.[4] The low and medium shellfish consumption scenarios that reflect a subsistence fish/shellfish consumer equivalent to 60 and 175 g/day, respectively, are realistically comparable with the Tulalip Tribe's 194 g/day total consumption rate of fish and shellfish harvested from Puget Sound.[7] The scenario of a person whose daily shellfish consumption is 260 g/day can be comparable to the 95th percentile consumption rate of 270.6 g/day for adult tribal members of the Squaxin Island Tribe who consume total fish and shellfish from the Puget Sound.[7] This high-end scenario addresses those consumers who may eat this amount on a daily basis for 70 years.

Chemical Specific Toxicity

Below are general summaries of dioxin health effects. The public health implications of exposure to dioxins from shellfish are discussed in the next section.

Dioxins and furans

Dioxins and furans (dioxins) consist of about 210 structural variations of dioxin congeners, which differ by the number and location of chlorine atoms on the chemical structure. The primary sources of dioxin releases to the environment are the combustion of fossil fuels and wood; the incineration of municipal, medical, and hazardous wastes; and certain pulp and paper processes.[8] Dioxins also occur at very low levels from naturally occurring sources and can be found in food, water, air, and cigarette smoke.

The most toxic of the dioxin congeners, 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) can cause chloracne (a condition of acne like lesions on the face and neck). Exposure to high levels of dioxins can cause liver damage, developmental effects, and impaired immune function.[8]

Long-term exposure to dioxins could increase the likelihood of developing cancer. Studies in rats and mice exposed to TCDD resulted in thyroid and liver cancer.[9] EPA considers TCDD to be a probable human carcinogen and developed a cancer slope factor of $1.5x\ 10^{5}$ per mg/kg/day.[10,11]

Dioxins and Furans, TEQ concentrations

There are many forms of dioxins and "dioxin-like compounds" (DLCs) that share most, if not all, of the toxic potential of TCDD, although nearly all are considerably less potent. Included in the list of DLCs are chlorinated forms of dibenzofurans and certain polychlorinated biphenyls (PCBs). Although several dioxin and furan congeners were analyzed in shellfish tissue, only a single value, called a dioxin toxic equivalent (TEQ), was used to determine non-cancer health threats and cancer risks. Each dioxin/furan congener is multiplied by a Toxic Equivalency Factor (TEF) to produce the dioxin TEQ. The TEQs for each chemical are then summed to give the overall TCDD TEQ. The TEQ approach is based on the premise that many dioxins/furans and in general, dioxin-like PCB congeners are structurally and toxicologically similar to TCDD. TEFs are used to account for the different potency of dioxins and furans relative to TCDD and are available for ten chlorinated dibenzofurans and seven chlorinated dibenzodioxins using the WHO methodology.[2]

Evaluating non-cancer hazards

Exposure assumptions for estimating contaminant doses from ingestion of dioxins in shellfish are found in Appendix B, Table B1. In order to evaluate the potential for non-cancer adverse health effects that may result from exposure to contaminated media (i.e., air, water, soil, and sediment), a dose is estimated for each COC. These doses are calculated for situations (scenarios) in which a person might be exposed to the contaminated media. The estimated dose for each contaminant under each scenario is then compared to ATSDR Minimal Risk Levels (MRLs). MRLs are an estimate of the daily human exposure to a substance that is likely to be without appreciable risk of adverse health effects during a specified duration of exposure. MRLs are based only on non-carcinogenic effects. In the absence of MRLs, DOH uses the EPA's oral reference dose (RfD). RfDs are doses below which no non-cancer adverse health effects are expected to occur (considered "safe" doses). MRLs and/or RfDs are derived from toxic effect levels obtained from human population and laboratory animal studies.

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

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

Dioxin intakes associated with shellfish consumption scenarios

Table 2 shows contaminant intakes associated with the various consumption scenarios listed in Appendix B. Average daily intakes were compared to the ATSDR minimal risk level (MRL) of 1 pg/kg/day and the WHO (World Health Organization) lifetime average daily intake value of 4 pg/kg/day. The maximum tolerable daily intake (TDI) established by the WHO is 1.0 to 4.0 pg TEQ/kg/day. This level is the amount of contaminants that can be ingested over a lifetime without detectable health effects. WHO and ATSDR levels are based on no observed adverse effect levels (NOAEL) and/or lowest observed adverse effect levels (LOAEL) considered to be the most sensitive in experimental animals, namely endometriosis, developmental and reproductive neurobehavioral effects and immunotoxicity.[12,13] A subsistence fish/shellfish consumer high-end exposure scenario did not exceed the ATSDR MRL of 1 pg/kg/day or the WHO daily intake of 4 pg/kg/day.

Table 2. Total dioxin (TEQ) intakes (pg/kg/day) associated with each of the shellfish consumption scenarios, Oakland Bay site, Shelton, Mason County, Washington.

Total seafood consumption rates (g/day)						
Species	General population 17.5 (g/day)	Subsistence fish/shellfish consumer (low) 60 g/day	Subsistence fish/shellfish consumer (medium) 175 g/day	Subsistence fish/shellfish consumer (high) 260 g/day	ATSDR MRL (pg/kg/day)[a]	WHO Lifetime Average daily intake (pg/kg/day)[a]
	Lifetime Average daily intake (pg/kg/day)					
Manila clams	0.006	0.04	0.118	0.175	1	4
Pacific oysters	< 0.001	0.002	0.006	0.008	1	4
Kumo oysters	< 0.001	0.003	0.01	0.014	1	4
Mussels	< 0.001	0.001	0.004	0.005	1	4

a – Total food intake
Agency for Toxic Substances and Disease Registry (ATSDR), MRL –Minimal risk level. This is the dose below which non-cancer adverse health effects are not expected to occur ("safe" doses).
World Health Organization (WHO) – This level is the amount of contaminants that can be ingested over a lifetime without detectable health effects. 4 pg Toxic Equivalent (TEQ)/kg/day is considered the upper range and/or the maximum tolerable daily intake.
< - less than
pg/kg/day – picograms/kilograms/day

Estimated exposure doses, exposure assumptions, and hazard quotients are presented in Appendix B for dioxins found in shellfish tissue. Based on exposure estimates quantified in Appendix B, Table B2, the general population is not likely to experience adverse non-cancer health effects from exposure to dioxins in Oakland Bay site shellfish since the exposure dose did not exceed the ATSDR dioxins MRL of 0.000000001 mg/kg/day. Thus, even at a medium and high-end consumption rate scenario, it is unlikely that shellfish consumers would experience adverse non-cancer health effects from exposure to dioxins.

Results of this study suggest that the consumption of shellfish harvested from the Oakland Bay site does not represent a significant risk of non-cancer effects to a consumer's health. DOH considers that the exposure assumptions used in the evaluation of dioxins in shellfish samples taken from the Oakland Bay site are very conservative for consumers (i.e., for the general population and a subsistence fish/shellfish consumer) who may eat shellfish from this site. These assumptions were based on total seafood intake for a subsistence consumer and the general population. The ingestion rates/ intakes used in this evaluation are much higher than the median (or mean) consumption rates of 0.07 g/kg/day for a subsistence fish/shellfish consumer who eats shellfish at this rate.[6] The high-end consumption rate (i.e., 260 g/day) for a subsistence fish/shellfish consumer results in a dioxin exposure dose below the ATSDR MRL. DOH did not estimate threats for children because of lack of ingestion rates for the general population and subsistence fish/shellfish for children (see Children's Health Concerns section).

Evaluating Cancer Risk

Some chemicals have the ability to cause cancer. Theoretical 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 assumes there is no "safe dose" of a carcinogen. Any dose of a carcinogen will result in some additional 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 cancer threat because any level of a carcinogenic contaminant carries an associated risk. The validity of the "no safe dose" assumption for all cancer-causing chemicals is not clear. Some evidence suggests that certain chemicals

Theoretical Cancer Risk

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

Term		# of Excess Cancers
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

considered to be carcinogenic must exceed a threshold of tolerance before initiating cancer. For such chemicals, risk estimates are not appropriate. Recent guidelines on cancer risk from EPA reflect the potential that thresholds for some carcinogenesis exist. However, EPA still assumes no threshold unless sufficient data indicate otherwise.[14]

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

Cancer is a common illness and its occurrence in a population increases with the age of the population. There are many different forms of cancer resulting from a variety of causes; not all are fatal. Approximately one fourth (1/4) to one third (1/3) of people living in the United States will develop cancer at some point in their lives.[15]

Theoretical cancer risks were evaluated for dioxins. The theoretical cancer risks associated with the four consumption scenarios are presented in Appendix B, Table B3. Theoretical cancer risk estimates for exposure to Manila clams by the general population and a subsistence fish/shellfish consumer (high-end) ranged from slight (2 additional cancers estimated per 1,000,000 people exposed) to very low (3 additional cancers estimated per 100,000 people exposed), respectively. Theoretical cancer risk estimates for other shellfish species (i.e., Pacific oysters, Kumamoto oysters, and Mussels) are also very low.

It should be noted that the U.S. EPA generally considers an excess upper-bound lifetime cancer risk to an individual of between 10^{-4} and 10^{-6} as an acceptable range. That means regular exposure to a substance would lead to one additional case of cancer per ten thousand to one additional case of cancer per one million people exposed. The results of this study reveal a low theoretical cancer risk associated with shellfish consumption in the area studied.

Limitations

DOH used very conservative assumptions to calculate exposures. However, data limitations and uncertainties must be considered before drawing conclusions about the relative safety of shellfish consumption. One limitation is sample size since not all harvesting areas were sampled and the sample size was small for each selected area. Manila clams were sampled at most locations, while Pacific oysters and Kumamoto oysters were sampled at a few locations. Mussels were only collected at a single location (samples were collected in the water column). Since it is cost-prohibitive and technically infeasible to sample for dioxins at all locations throughout the

Oakland Bay site, DOH used composite samples to maximize the opportunity to assess the presence of dioxins in shellfish. For more information, please refer to the sampling plan.[16]

Children's Health Concerns

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

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

These unique vulnerabilities of infants and children demand special attention in communities that have contamination of their water, food, soil, or air. DOH did not estimate risks for children because of lack of children's ingestion rates for the general population and subsistence fish/shellfish scenarios. However, very conservative/protective values were used for the adult general population and for a subsistence fish/shellfish consumer eating shellfish at a low, medium, and high-end rate. Although children are smaller and receive higher doses of contaminant exposures per body weight, it is likely that children may be more susceptible to disease than adults if they eat shellfish at these rates.

Conclusions

In general, there are uncertainties in evaluating low-level environmental exposures to dioxins in shellfish; thus, the true risk to the public is difficult to assess accurately. True risk depends on a number of factors such as the chemical sensitivity, concentration of chemicals, consumption rates, frequency and duration of exposure, and the genetic susceptibility of an individual. For some Native American subsistence fishers, and/or the general population the use of an acceptable risk level of 1 excess cancer in 10,000 people exposed and 1 excess cancer in 1,000,000 people exposed (10^{-4} and 10^{-6}) may not be acceptable.

Based on the information provided, DOH concludes the following:

- Eating shellfish that contains dioxins from the Oakland Bay site is not expected to harm health or produce harmful non-cancer health effects for the general population or subsistence fish/shellfish consumers (i.e., low, medium, and high-end). Dioxin levels are below concentrations where we would expect to see health effects (i.e., the estimated doses are below the ATSDR minimal risk level (MRL) of 1 pg/kg/day and World Health Organization (WHO) daily intake of 4 pg Toxic Equivalent (TEQ)/kg/day.

- Eating shellfish that contains dioxins from the Oakland Bay site is not expected to harm health or produce harmful cancer health effects for subsistence fish/shellfish consumers, or the general population (low, medium, and high-end). This conclusion is based on the assumption of total dioxin exposure from childhood into adulthood (average lifetime exposure of 70 years). Based on exposure calculations and lifetime daily intakes for the general population and subsistence fish/shellfish consumers, it is unlikely that people will be at appreciable risk of developing cancer health effects. It should be noted that these estimates do not exceed EPA's acceptable cancer risk for fish consumption. The range of cancer risks considered acceptable by EPA is 1 additional case of cancer per 10,000 people exposed to 1 additional case of cancer per 1,000,000 people exposed.

Recommendations

DOH has no recommendations at this time.

Public Health Action Plan

Actions Planned

1. DOH will provide copies of this health consultation to Ecology, the Pacific Coast Shellfish Growers Association, the Squaxin Island Tribe, and other concerned parties when the report is approved.

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Figures

Figure 1: Oakland Bay and Shelton Harbor Overview shellfish growing areas, Oakland Bay site - Shelton, Mason County, Washington.

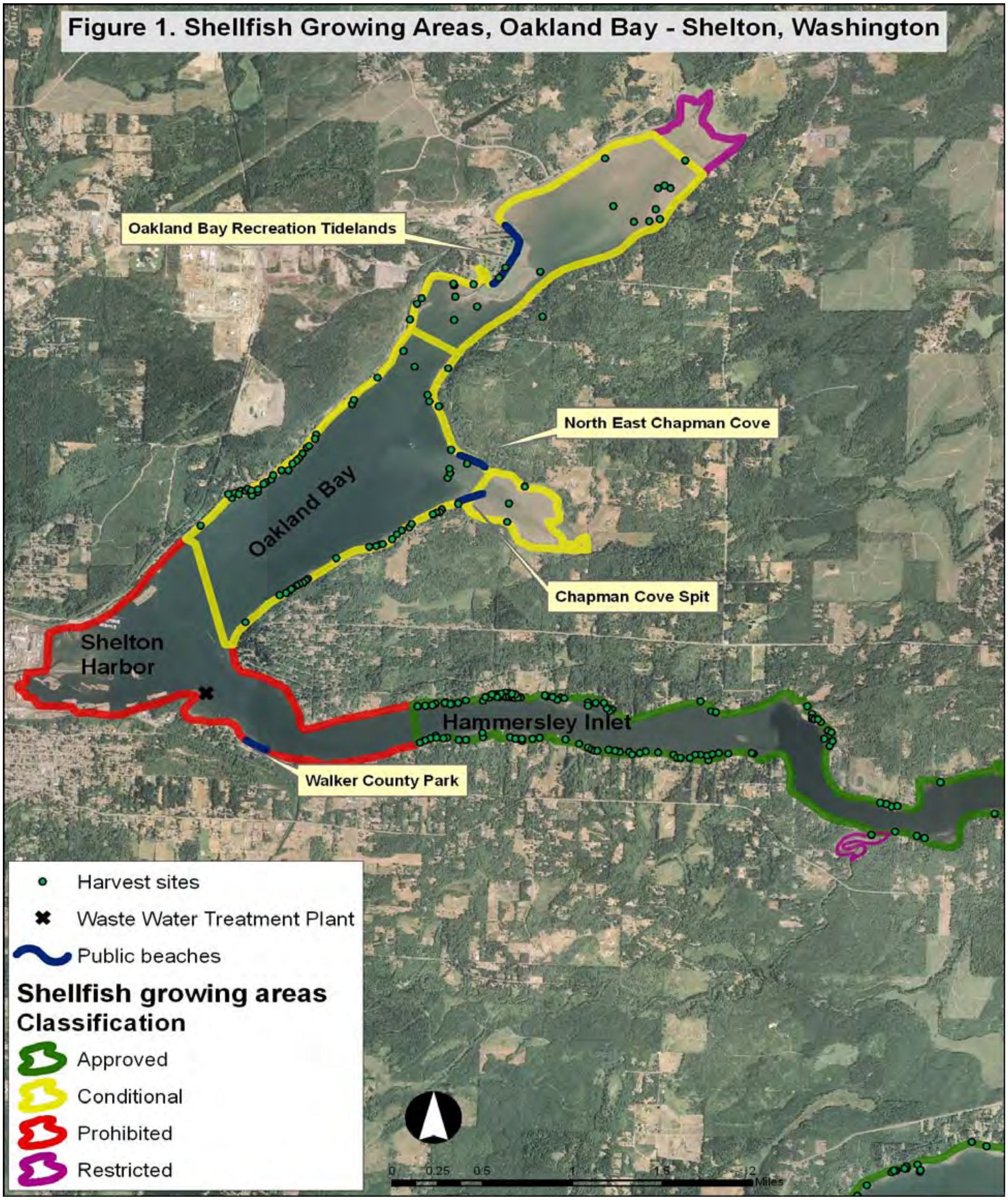


Figure 2: Oakland Bay and Shelton Harbor shellfish sampling locations, Oakland Bay site - Shelton, Mason County, Washington.

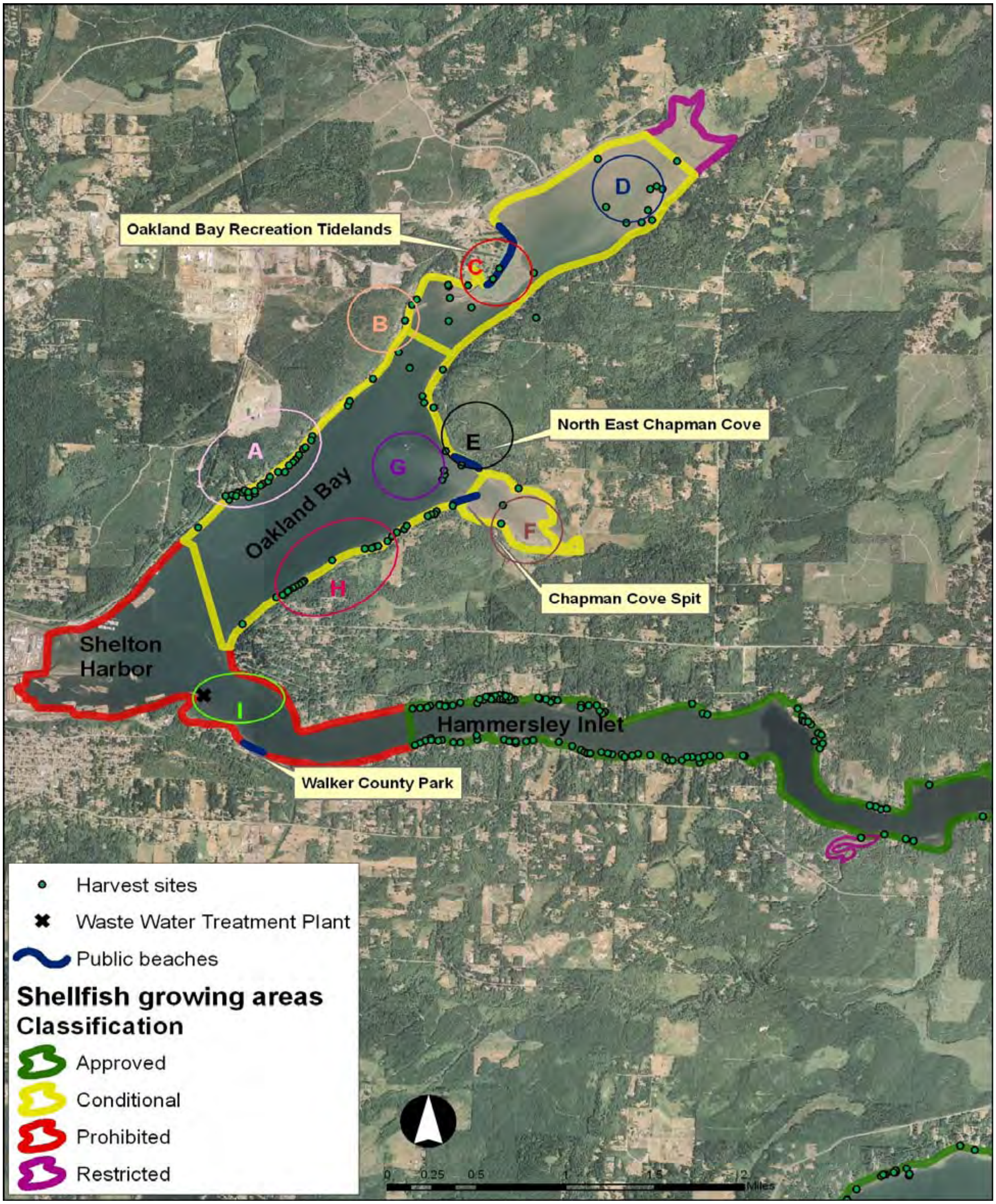
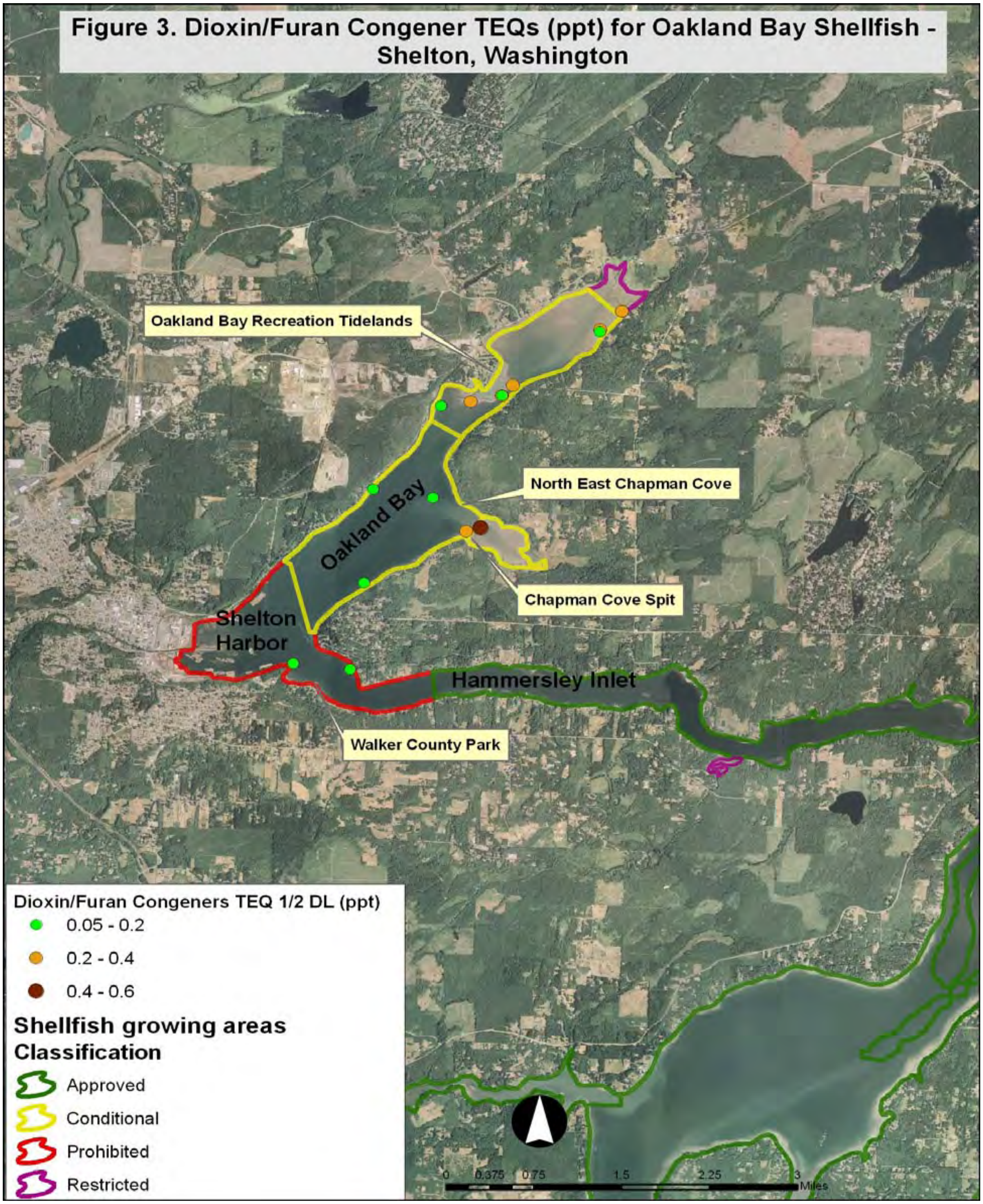


Figure 3: Shellfish dioxin/furan congeners in parts per trillion (ppt) at Oakland Bay and Shelton Harbor, Oakland Bay site - Shelton, Mason County, Washington.



Appendix A

Abbreviations for dioxins and furans

1,2,3,4,6,7,8-HPCDD	Heptachlorodibenzo-*p*-dioxin
1,2,3,4,6,7,8-HPCDF	Heptachlorodibenzofuran
1,2,3,4,7,8,9-HPCDF	Heptachlorodibenzofuran
1,2,3,4,7,8-HXCDD	Hexachlorodibenzo-*p*-dioxin
1,2,3,4,7,8-HXCDF	Hexachlorodibenzofuran
1,2,3,6,7,8-HXCDD	Hexachlorodibenzo-*p*-dioxin
1,2,3,6,7,8-HXCDF	Hexachlorodibenzofuran
1,2,3,7,8,9-HXCDD	Hexachlorodibenzo-*p*-dioxin
1,2,3,7,8,9-HXCDF	Hexachlorodibenzofuran
1,2,3,7,8-PECDD	Pentachlorodibenzo-*p*-dioxin
1,2,3,7,8-PECDF	Pentachlorodibenzofuran
2,3,4,6,7,8-HXCDF	Hexachlorodibenzofuran
2,3,4,7,8-PECDF	Pentachlorodibenzofuran
2,3,7,8-TCDD	2,3,7,8-tetrachlorodibenzo-*p*-dioxin
2,3,7,8-TCDF	2,3,7,8-tetrachlorodibenzo-*p*-furan
OCDD	Octachlorodibenzo-*p*-dioxin
OCDF	Octachlorodibenzofuran

Table A1. Shellfish dioxin/furan congeners (wet weight basis) at Oakland Bay and Shelton Harbor, Oakland Bay site - Shelton, Mason County, Washington.

Congener	ATDM 001 (Manila clams) pg/g	BTDM 002 (Manila clams) pg/g	BTDM 003 (Manila clams) pg/g	BTDP 004 (Pacific oysters) pg/g	CDRM 005 (Manila clams) pg/g	CDRM 006 (Manila clams) pg/g
2,3,7,8-TCDD	0.008	0.025	0.008	0.081	0.067	0.006
1,2,3,7,8-PeCDD	0.031	0.032	0.023	0.064	0.052	0.031
1,2,3,4,7,8-HxCDD	0.003	0.003	0.001	0.005	0.004	0.002
1,2,3,6,7,8-HxCDD	0.003	0.004	0.001	0.057 JK	0.005	0.003
1,2,3,7,8,9-HxCDD	0.003	0.003	0.001	0.006	0.004	0.002
1,2,3,4,6,7,8-HpCDD	0.003 BJK	0.004 BJK	0.003 BJ	0.023 BJ	0.015 BJK	0.009 BJ
OCDD	0.000 BJ	0.001 BJ	0.001 BJ	0.003 BJ	0.003 BJ	0.001 BJ
2,3,7,8-TCDF	0.003	0.003	0.002	0.011	0.005	0.002
1,2,3,7,8-PeCDF	0.001	0.001	0.001	0.002	0.001	0.001
2,3,4,7,8-PeCDF	0.008	0.009	0.006	0.016	0.013	0.005
1,2,3,4,7,8-HxCDF	0.002	0.002	0.002	0.009	0.008	0.003
1,2,3,6,7,8-HxCDF	0.002	0.003	0.002	0.010	0.008	0.003
1,2,3,7,8,9-HxCDF	0.003	0.003	0.002	0.011	0.009	0.003
2,3,4,6,7,8-HxCDF	0.002	0.002	0.002	0.007	0.007	0.003
1,2,3,4,6,7,8-HpCDF	0.001 BJ	0.000	0.001 BJK	0.004 JK	0.005 J	0.003 BJ
1,2,3,4,7,8,9-HpCDF	0.000	0.000	0.000	0.001	0.001	0.000
OCDF	0.000	0.000 BJK	0.000 BJK	0.000 J	0.000 J	0.000 BJ
Total TEQ ND ½ DL	**0.07257**	**0.09569**	**0.05428**	**0.3087**	**0.20688**	**0.0766**

B Indicates the associated analyte is found in the method blank, as well as in the sample.
J Indicates an estimated value – used when the analyte concentration is below the method-reporting limit (MRL) and above the estimated detection limit (EDL).
K EMPC (estimated maximum possible concentration) - When the ion abundance ratios associated with a particular compound are outside the QC limits, samples are flagged with a 'K' flag. A 'K' flag indicates an estimated maximum possible concentration for the associated compound.
Results with qualifiers were detected. All other results were non-detected and calculated based on half the detection limit.
DL = detection limit
pg/g – picograms per grams

Congener	CDRP 007 (Pacific oysters) pg/g	CDRP 008 (Pacific oysters) pg/g	ESDM 009 (Manila clams) pg/g	ESDM 010 (Manila clams) pg/g	GSHM 011 (Mussels) pg/g	HTCM 012 (Manila clams) pg/g
2,3,7,8-TCDD	0.032	0.019	0.009	0.036	0.035	0.026
1,2,3,7,8-PeCDD	0.044	0.021	0.018	0.029	0.038	0.025
1,2,3,4,7,8-HxCDD	0.003	0.007 J	0.001	0.003	0.003	0.002
1,2,3,6,7,8-HxCDD	0.085 J	0.030 J	0.002	0.004	0.004	0.003
1,2,3,7,8,9-HxCDD	0.031 J	0.008 JK	0.001	0.003	0.003	0.002
1,2,3,4,6,7,8-HpCDD	0.034 BJ	0.011 BJK	0.003 BJ	0.004 BJ	0.036 BJ	0.003 BJK
OCDD	0.004 BJ	0.002 BJ	0.001 BJ	0.001 BJ	0.006 B	0.001 BJ
2,3,7,8-TCDF	0.009	0.003	0.002	0.005	0.003	0.002
1,2,3,7,8-PeCDF	0.001	0.001	0.001	0.001	0.001	0.000
2,3,4,7,8-PeCDF	0.071 JK	0.008	0.006	0.006	0.008	0.004
1,2,3,4,7,8-HxCDF	0.008	0.003	0.002	0.002	0.005	0.004
1,2,3,6,7,8-HxCDF	0.009	0.003	0.002	0.002	0.006	0.001
1,2,3,7,8,9-HxCDF	0.022 J	0.003	0.002	0.003	0.006	0.002
2,3,4,6,7,8-HxCDF	0.008	0.003	0.002	0.002	0.005	0.001
1,2,3,4,6,7,8-HpCDF	0.007 J	0.003 BJ	0.001 BJK	0.002 BJ	0.011 J	0.001 BJK
1,2,3,4,7,8,9-HpCDF	0.000	0.000	0.000	0.000	0.000	0.000
OCDF	0.000 JK	0.000 BJ	0.000 BJK	0.000 BJ	0.001 JK	0.000 BJ
Total TEQ ND ½ DL	**0.36986**	**0.12526**	**0.05323**	**0.10455**	**0.1709**	**0.07875**

B Indicates the associated analyte is found in the method blank, as well as in the sample.
J Indicates an estimated value – used when the analyte concentration is below the method-reporting limit (MRL) and above the estimated detection limit (EDL).
K EMPC (estimated maximum possible concentration) - When the ion abundance ratios associated with a particular compound are outside the QC limits, samples are flagged with a ‘K’ flag. A ‘K’ flag indicates an estimated maximum possible concentration for the associated compound.
Results with qualifiers were detected. All other results were non-detected and calculated based on half the detection limit.
DL = detection limit
pg/g – picograms per grams

Congener	IDPM 013 (Manila clams) pg/g	DTBM 014 (Manila clams) pg/g	DTBM 015 (Manila clams) pg/g	DTBM 016 field duplicate (Manila clams) pg/g	DTBP 017 (Pacific oysters) pg/g	DTBP 018 (Pacific oysters) pg/g
2,3,7,8-TCDD	0.016	0.019	0.022	0.045	0.014	0.017
1,2,3,7,8-PeCDD	0.016	0.027	0.025	0.040	0.150 JK	0.088 JK
1,2,3,4,7,8-HxCDD	0.001	0.002	0.003	0.002	0.003	0.003
1,2,3,6,7,8-HxCDD	0.002	0.008 J	0.023 J	0.003	0.044 J	0.014 JK
1,2,3,7,8,9-HxCDD	0.002	0.002	0.017 J	0.002	0.013 JK	0.003
1,2,3,4,6,7,8-HpCDD	0.004 BJ	0.009 BJ	0.043 BJ	0.075 BJ	0.023 BJ	0.011 BJ
OCDD	0.001 BJ	0.002 BJ	0.009 B	0.015 B	0.003 BJ	0.001 BJ
2,3,7,8-TCDF	0.001	0.002	0.002	0.004	0.018 J	0.003
1,2,3,7,8-PeCDF	0.000	0.000	0.000	0.001	0.001	0.001
2,3,4,7,8-PeCDF	0.003	0.003	0.003	0.011	0.038 J	0.010
1,2,3,4,7,8-HxCDF	0.001	0.006 J	0.020 J	0.024 JK	0.005 J	0.002
1,2,3,6,7,8-HxCDF	0.001	0.001	0.002	0.008	0.007 J	0.002
1,2,3,7,8,9-HxCDF	0.002	0.002	0.002	0.009	0.002	0.003
2,3,4,6,7,8-HxCDF	0.001	0.001	0.011 JK	0.008	0.013 J	0.002
1,2,3,4,6,7,8-HpCDF	0.001 BJ	0.004 BJ	0.017 BJ	0.024 J	0.006 BJ	0.003 BJ
1,2,3,4,7,8,9-HpCDF	0.000	0.000	0.001 BJK	0.001	0.000	0.000
OCDF	0.000 BJ	0.000 BJ	0.001 BJ	0.002 J	0.000 BJ	0.000 BJ
Total TEQ ND ½ DL	**0.05297**	**0.09018**	**0.20136**	**0.27487**	**0.34000**	**0.16384**

B Indicates the associated analyte is found in the method blank, as well as in the sample.
J Indicates an estimated value – used when the analyte concentration is below the method-reporting limit (MRL) and above the estimated detection limit (EDL).
K EMPC (estimated maximum possible concentration)- When the ion abundance ratios associated with a particular compound are outside the QC limits, samples are flagged with a 'K' flag. A 'K' flag indicates an estimated maximum possible concentration for the associated compound.
Results with qualifiers were detected. All other results were non-detected and calculated based on half the detection limit.
DL = detection limit
pg/g – picograms per grams

Congener	FTTM 019 (Manila clams) pg/g	FTTM 020 (Manila clams) pg/g	FTTK 021 (Kumo oysters) pg/g	FTTK 022 (Kumo oysters) pg/g
2,3,7,8-TCDD	0.015	0.015	0.045	0.015
1,2,3,7,8-PeCDD	0.020	0.020	0.045	0.280 J
1,2,3,4,7,8-HxCDD	0.002	0.001	0.007	0.017 J
1,2,3,6,7,8-HxCDD	0.003	0.002	0.088 J	0.069 J
1,2,3,7,8,9-HxCDD	0.002	0.001	0.007	0.030 J
1,2,3,4,6,7,8-HpCDD	0.003 BJ	0.009 BJ	0.022 BJ	0.039 BJ
OCDD	0.000 BJ	0.002 BJ	0.002 BJ	0.006 B
2,3,7,8-TCDF	0.002	0.001	0.015	0.037 JK
1,2,3,7,8-PeCDF	0.000	0.000	0.002	0.001
2,3,4,7,8-PeCDF	0.003	0.003	0.020	0.062 JK
1,2,3,4,7,8-HxCDF	0.001	0.001	0.009	0.004
1,2,3,6,7,8-HxCDF	0.002	0.001	0.010	0.011 J
1,2,3,7,8,9-HxCDF	0.002	0.002	0.011	0.005
2,3,4,6,7,8-HxCDF	0.002	0.001	0.009	0.017 J
1,2,3,4,6,7,8-HpCDF	0.001 BJ	0.003 BJ	0.004 J	0.007 J
1,2,3,4,7,8,9-HpCDF	0.000	0.000	0.000	0.000
OCDF	0.000 BJ	0.000 BJ	0.000 J	0.000 J
Total TEQ ND ½ DL	**0.05913**	**0.06544**	**0.29609**	**0.59838**

B Indicates the associated analyte is found in the method blank, as well as in the sample.
J Indicates an estimated value – used when the analyte concentration is below the method-reporting limit (MRL) and above the estimated detection limit (EDL).
K EMPC (estimated maximum possible concentration) - When the ion abundance ratios associated with a particular compound are outside the QC limits, samples are flagged with a 'K' flag. A 'K' flag indicates an estimated maximum possible concentration for the associated compound.
Results with qualifiers were detected. All other results were non-detected and calculated based on half the detection limit.
DL = detection limit
pg/g – picograms per grams

Appendix B

This section provides calculated exposure doses and exposure assumptions used for dioxins in shellfish samples taken from the Oakland Bay site. These exposure scenarios were developed to model exposures that might occur. They were devised to represent exposures for the general population and for a subsistence fish/shellfish consumer. The following exposure parameters and dose equations were used to estimate exposure doses from ingestion of contaminants in shellfish.

Ingestion Route

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

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

Table B1. Exposure assumptions used in exposure evaluation of dioxins in shellfish samples taken from the Oakland Bay site in Shelton, Mason County, Washington.

Parameter	Value	Unit	Comments
Concentration (C)	Variable	ng/kg	Average detected value
Conversion Factor (CF_1)	0.000001	mg/ng	Converts contaminant concentration from nanograms (ng) to milligrams (mg)
Conversion Factor (CF_2)	0.001	kg/g	Converts mass of bottom fish and shellfish from grams (g) to kilograms (kg)
Ingestion Rate (IR)*	17.5	g/day	General population adult - (total seafood) [4]
	60		Subsistence fish/shellfish consumer adult, low (total seafood)
	175		Subsistence fish/shellfish consumer adult, medium (total seafood)
	260		Subsistence fish/shellfish consumer adult, high (total seafood)
Exposure Frequency (EF)	365	days/year	Assumes daily exposure
Exposure Duration (ED)	70	years	Number of years eating shellfish (adult)
Body weight (BW)	72	kg	Mean body weight U.S. general population
Body weight (BW)	81.8		Average mean body weight tribal adult member [6]
Averaging $Time_{\text{non-cancer}}$ (AT)	25550	days	70 years
Averaging $Time_{\text{cancer}}$ (AT)	25550	days	70 years

Cancer Potency Factor (CPF)	1.5E+05	mg/kg-day^{-1}	Source: EPA – Chemical specific

* Ingestion rates – This scenario assumed that manila clams from Oakland Bay are consumed 50% of the time from total seafood, and oysters and mussels from Oakland Bay are consumed 1% of the time from total seafood. For example, a shellfish consumption rate of 60 g/day for manila clams assuming they are consumed 50% of the time equals 30g/day and 0.6 g/day for oysters and mussels, which are consumed 1% of the time. This approach applies to all other consumption rates (17.5, 175 and 260 g/day).

Hazard Quotient formula:

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

Table B2. Lifetime non-cancer risks associated with each consumption scenario, Oakland Bay site - Shelton, Mason County, Washington.

Species	Average dioxin concentration (ppt)	N	Estimated dose (mg/kg/day) (Adult)				MRL (mg/kg/day)	Hazard quotient (Adult)			
			General population (fish)	Subsistence fish/shellfish consumer (low) (all seafood)	Subsistence fish/shellfish consumer (medium) (all seafood)	Subsistence fish/shellfish consumer (high-end) (all seafood)		General population (fish)	Subsistence fish/shellfish consumer (low) (all seafood)	Subsistence fish/shellfish consumer (medium) (all seafood)	Subsistence fish/shellfish consumer (high-end) (all seafood)
Manila clams	0.11	14	1.2E-11	4.2E-11	1.2E-10	1.8E-10	1.0E-9	<0.1	<0.1	0.1	0.2
Pacific oysters	0.26	5	5.6E-13	2.0E-12	5.6E-12	8.3E-12		<0.1	<0.1	<0.1	<0.1
Kumo oysters	0.45	2	9.6E-13	3.3E-12	9.6E-12	1.4E-11		<0.1	<0.1	<0.1	<0.1
Mussels	0.17	1	3.6E-13	1.2E-12	3.6E-12	5.4E-12		<0.1	<0.1	<0.1	<0.1

MRL – ATSDR chronic Oral Minimal risk level
N = number of samples. Each composite sample contained 30 individual organisms representing a specific area within each sampling location (i.e., 10 shellfish each in the lower, middle, and upper of each segment).
ppt – parts per trillion
mg/kg/day – milligrams per kilograms per day

Table B3. Theoretical lifetime cancer risks associated with each consumption scenario, Oakland Bay site, Shelton, Mason County, Washington.

Species	**N**	**Average (TEQ) dioxin concentration (ppt)**	**Cancer slope factor (per mg/kg/ day)** [17]	**Increased cancer risk (adult)**			
				General population (fish)	Subsistence fish/shellfish consumer (low) (all seafood)	Subsistence fish/shellfish consumer (medium) (all seafood)	Subsistence fish/shellfish consumer (high-end) (all seafood)
Manila clams [a]	14	0.11	1.5E+5	1.8E-6	6.1E-6	1.8E-5	2.6E-5
Pacific oysters [b]	5	0.26		8.3E-8	2.9E-7	8.3E-7	1.2E-6
Kumo oysters [b]	2	0.45		1.4E-7	5.0E-7	1.4E-6	2.2E-6
Mussels [b]	1	0.17		5.5E-8	1.9E-7	5.5E-7	8.1E-7

[a] – Used 50% of the consumption rates for Manila clams
[b] – Used 1% of the consumption rates for oysters and mussels
N = number of samples. Each composite sample contained 30 individual organisms representing a specific area within each sampling location (i.e., 10 shellfish each in the lower, middle, and upper of each segment).
ppt – parts per trillion
TEQ – Toxic equivalent

Certification

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

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

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