Health Consultation

Lake Roosevelt Fish Non-Tribal Exposure
Northeast, Washington

February 28, 2013

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
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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 wastes. This report was supported by funds through a cooperative agreement with ATSDR. It was completed in accordance with approved methodologies and procedures existing at the time the health consultation was initiated. Editorial review was completed by DOH.

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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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 Center for Disease Control and Prevention Information Center at 1-800-CDC-INFO (1-800-232-4636) or visit the agency's Web site: www.atsdr.cdc.gov .

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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.
Aquifer	An underground formation composed of materials such as sand, soil, or gravel that can store and/or supply groundwater to wells and springs.
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 (CV)	Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause harmful (adverse) health effects in exposed people. The CV is used as a screening level during the public health assessment process. Substances found in amounts greater than their CVs might be selected for further evaluation in the public health assessment process.
Contaminant	A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.
Dermal Contact	Contact with (touching) the skin (see route of exposure).
Dose (for chemicals that are not radioactive)	The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An “exposure dose” is how much of a substance is encountered in the environment. An “absorbed dose” is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.

Environmental Media Evaluation Guide (EMEG)	A concentration in air, soil, or water below which adverse non-cancer health effects are not expected to occur. The EMEG is a *comparison value* used to select contaminants of potential health concern and is based on ATSDR's *minimal risk level* (MRL).
Environmental Protection Agency (EPA)	United States Environmental Protection Agency.
Exposure	Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [**acute exposure**], of intermediate duration, or long-term [**chronic exposure**].
Groundwater	Water beneath the earth's surface in the spaces between soil particles and between rock surfaces [compare with surface water].
Hazardous Substance	Any material that poses a threat to public health and/or the environment. Typical hazardous substances are materials that are toxic, corrosive, ignitable, explosive, or chemically reactive.
Ingestion	The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see route of exposure].
Ingestion Rate (IR)	The amount of an environmental medium that could be ingested typically on a daily basis. Units for IR are usually liter/day for water, and mg/day for soil.
Inhalation	The act of breathing. A hazardous substance can enter the body this way [see **route of exposure**].
Inorganic	Compounds composed of mineral materials, including elemental salts and metals such as iron, aluminum, mercury, and zinc.
Lowest Observed Adverse Effect Level (LOAEL)	The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.
Maximum Contaminant Level (MCL)	A drinking water regulation established by the federal Safe Drinking Water Act. It is the maximum permissible concentration of a contaminant in water that is delivered to the free flowing outlet of the ultimate user of a public water system. MCLs are enforceable standards.
Media	Soil, water, air, plants, animals, or any other part of the environment that can contain contaminants.

Minimal Risk Level (MRL)	An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified time period (acute, intermediate, or chronic). MRLs should not be used as predictors of harmful (adverse) health effects [see **oral reference dose**].
Model Toxics Control Act (MTCA)	The hazardous waste cleanup law for Washington State.
No Observed Adverse Effect Level (NOAEL)	The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.
Oral Reference Dose (RfD)	An amount of chemical ingested into the body (i.e., dose) below which health effects are not expected. RfDs are published by EPA.
Organic	Compounds composed of carbon, including materials such as solvents, oils, and pesticides that are not easily dissolved in water.
Parts Per Billion (ppb)/Parts Per Million (ppm)	Units commonly used to express low concentrations of contaminants. For example, 1 ounce of trichloroethylene (TCE) in 1 million ounces of water is 1 ppm. 1 ounce of TCE in 1 billion ounces of water is 1 ppb. If one drop of TCE is mixed in a competition size swimming pool, the water will contain about 1 ppb of TCE.
Plume	A volume of a substance that moves from its source to places farther away from the source. Plumes can be described by the volume of air or water they occupy and the direction they move. For example, a plume can be a column of smoke from a chimney or a substance moving with groundwater.
Reach	A division of an area (river or lake) based on physical characteristics and historical contaminant distribution. The site was divided into three reaches (upper, middle, and lower reach) and fish were collected from two distinct fish sample collection areas (FSCAs) located in each reach.
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].

Subsistence	Fishing carried out to feed families of the fishers (personal consumption) or for Native American traditional/ceremonial purposes (EPA's recommended subsistence value 142.4 g/day or more).
Surface Water	Water on the surface of the earth, such as in lakes, rivers, streams, ponds, and springs [compare with **groundwater**].
Volatile Organic Compound (VOC)	Organic compounds that evaporate readily into the air. VOCs include substances such as benzene, toluene, methylene chloride, and methyl chloroform.

Summary

Introduction

The northern reach of the Columbia River (Upper Columbia River) includes Franklin D. Roosevelt Lake (Lake Roosevelt). For the purpose of this health consultation, Lake Roosevelt and the Upper Columbia River are treated as a contiguous site called Lake Roosevelt. In the Lake Roosevelt community, Washington State Department of Health's (DOH) top priority is to ensure that the community has the best information possible to safeguard its health. DOH has prepared this health consultation at the request of the U.S. Environmental Protection Agency (EPA). The purpose of this health consultation is to evaluate whether contaminants found in fish from Lake Roosevelt pose a health hazard to people who consume them (Non-tribal exposures/populations are the focus of this evaluation). DOH prepares health consultations under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR).

Conclusions:
DOH reached two important conclusions in this health consultation about Lake Roosevelt fish in northeast Washington.

Conclusion 1:
DOH concludes that mercury levels in Lake Roosevelt fish could harm the health of young children and the developing fetus. Therefore, women who might become pregnant, are pregnant or nursing, and young children should follow the fish consumption advisory. The current fish advisory for Lake Roosevelt (eat no more than 2 meals per month of walleye) should remain in place due to methylmercury (mercury) exposure and be expanded to limit burbot and large-scale sucker meals to 4 per month.

Basis for decision:
The latest (2005) levels of mercury in walleye fish tissue have not changed much since the 1997 results. The 2005 fillet mercury results ranged from 0.11 to 0.44 parts per million (ppm), which are elevated concentrations of mercury. Thus, the current fish advisory should remain in place. This 2005 fish tissue data set shows elevated concentrations of mercury in burbot and large-scale sucker that require an additional fish advisory of no more than four meals per month for these species. Eating more than the calculated consumption limit may increase a person's risk of developing health problems.

Conclusion 2:
DOH cannot currently conclude whether dioxins, polychlorinated biphenyls (PCBs), arsenic, and/or lead associated with eating fish at Lake Roosevelt could harm people's health.

Basis for decision:
Dioxins - Theoretical cancer risks for a given reach are based on the average concentrations of contaminants in that reach. Therefore, while some calculated theoretical cancer risks because of dioxin contamination for some species of fish falls outside the EPA's acceptable cancer risk range, they are still within what is considered background risk levels. Dioxin concentrations may be overestimated due to several factors. Dioxin concentrations in some species were based on

whole fish rather than fillets, which people generally consume. Also, dioxins are similar to PCBs and are stored in the fatty tissue, and exposure to dioxins in fish can also be significantly reduced through simple preparation and cooking measures, as in the case of PCBs. Simply removing the skin and eating fillets instead of whole fish can reduce PCB levels by 26% [14]. In some cases, 20 to 100% of PCBs can be removed through preparation and cooking [15, 16]. Following these same simple steps will also reduce dioxin exposure when eating fish.

Polychlorinated biphenyls (PCBs), arsenic, and/or lead - Some calculated polychlorinated biphenyl (PCB) and arsenic theoretical cancer risks for some species of fish are higher than EPA's acceptable cancer risk range. Due to the high analytical detection limit and the failure to meet the data quality objectives (DQOs) for the PCB Aroclor data, there is too much uncertainty in the PCB data at this time for DOH to provide advice on fish consumption. Similarly, there are uncertainties with the arsenic speciation data for all fish species and lead concentrations in large-scale suckers data.

Next Steps

DOH recommends:

1. Additional sampling for PCB Aroclors in fish. The DQOs should be achieved for these samples. However, using PCB congener data instead of PCB Aroclors data can avoid the DQO problems seen in PCB Aroclors data.

2. If the DQOs for PCB Aroclors are not achievable, conduct 100% PCB congener analysis.

3. Speciate arsenic using method 1632, revision A. These samples should meet DQOs. http://www.epa.gov/waterscience/methods/method/files/1632.pdf.

4. Analyze large-scale suckers using fillets and whole gut-less samples to allow for an evaluation of human exposures.

DOH will:

1. Review and evaluate the fish data collected in 2009, which became available in the fall of 2010 (to be published in Fall of 2012).

2. Address other pathways, such as ingestion of water or plant materials, in future public health consultations when data are available.

3. Establish community repositories for the public health consultation and related fact sheets.

For More Information

Please feel free to contact Lenford O'Garro at 360-236-3376 or 1-877-485-7316 if you have any questions about this health consultation.

Background

The Columbia River flows from British Columbia, Canada, southwards through eastern Washington, and west to the Pacific Ocean. The construction of the Grand Coulee Dam and reservoir on the upper portion of the Columbia River created Lake Roosevelt which is about 135 miles long [1]. The Columbia River contributes about 90% of the water flowing into Lake Roosevelt [1].

Smelting and mining activities in British Columbia, northeast Washington, and Idaho have left a legacy of contaminated byproducts (slag) along the beaches and in Lake Roosevelt. In August 1999, the Confederated Tribes of the Colville Reservation (Colville Tribes) petitioned the U.S. Environmental Protection Agency (EPA) to assess human health and environmental risk of the Upper Columbia River (UCR) [2]. In 2001, EPA conducted an expanded site inspection. EPA determined a Remedial Investigation/Feasibility Study (RI/FS) was necessary to evaluate human health and environmental risks of the UCR due to widespread contamination in lake and river sediments from the U.S. - Canada border to Lake Roosevelt [3]. Over the years, a number of studies have been conducted on Lake Roosevelt's water, sediments, and fish. These studies showed various contaminants including heavy metals, dioxins/furans, and polychlorinated biphenyls (PCBs) [4, 5, 6, 7, 8, 9, 10].

In April and May 2005, CH2M HILL, an authorized contractor for the EPA, collected sediment samples from the Upper Columbia River Site as part of the RI/FS Phase 1 sampling (see Figure 1). Field crews from the EPA, the Colville Tribes, and the U.S. Fish and Wildlife Service collected Phase 1 fish tissue samples in September and October of 2005. The site was divided into Focus Areas 1 and 2 (upper reach), Focus Areas 3 and 4 (middle reach), and Focus Areas 5 and 6 (lower reach) based on historical contaminant distribution and physical characteristics of Lake Roosevelt (see Figure 2).

Figure 1. Upper Columbia River relief map (red dots – beaches with contamination of concern) showing the sediment sample areas from beaches along Lake Roosevelt in northeast Washington.

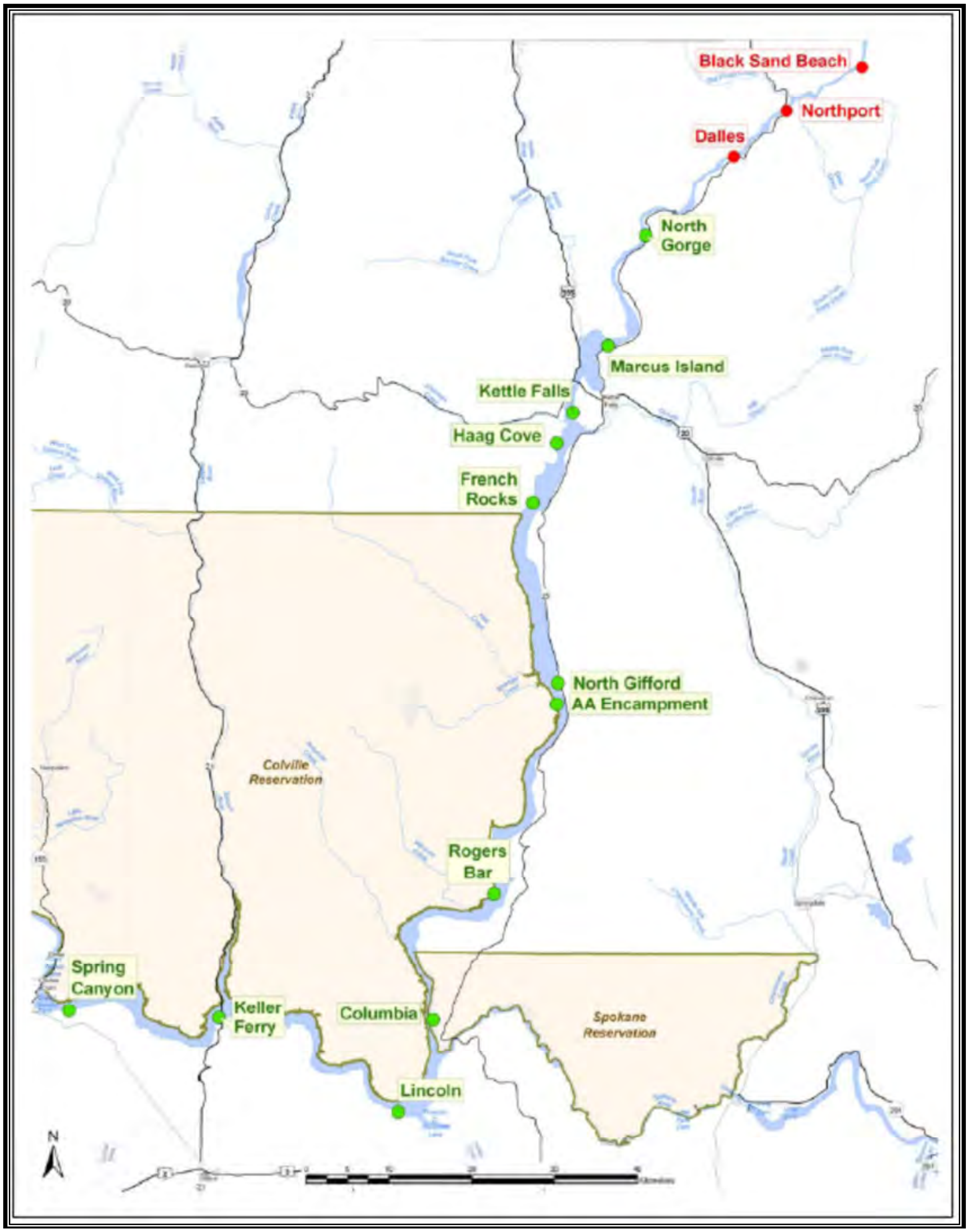
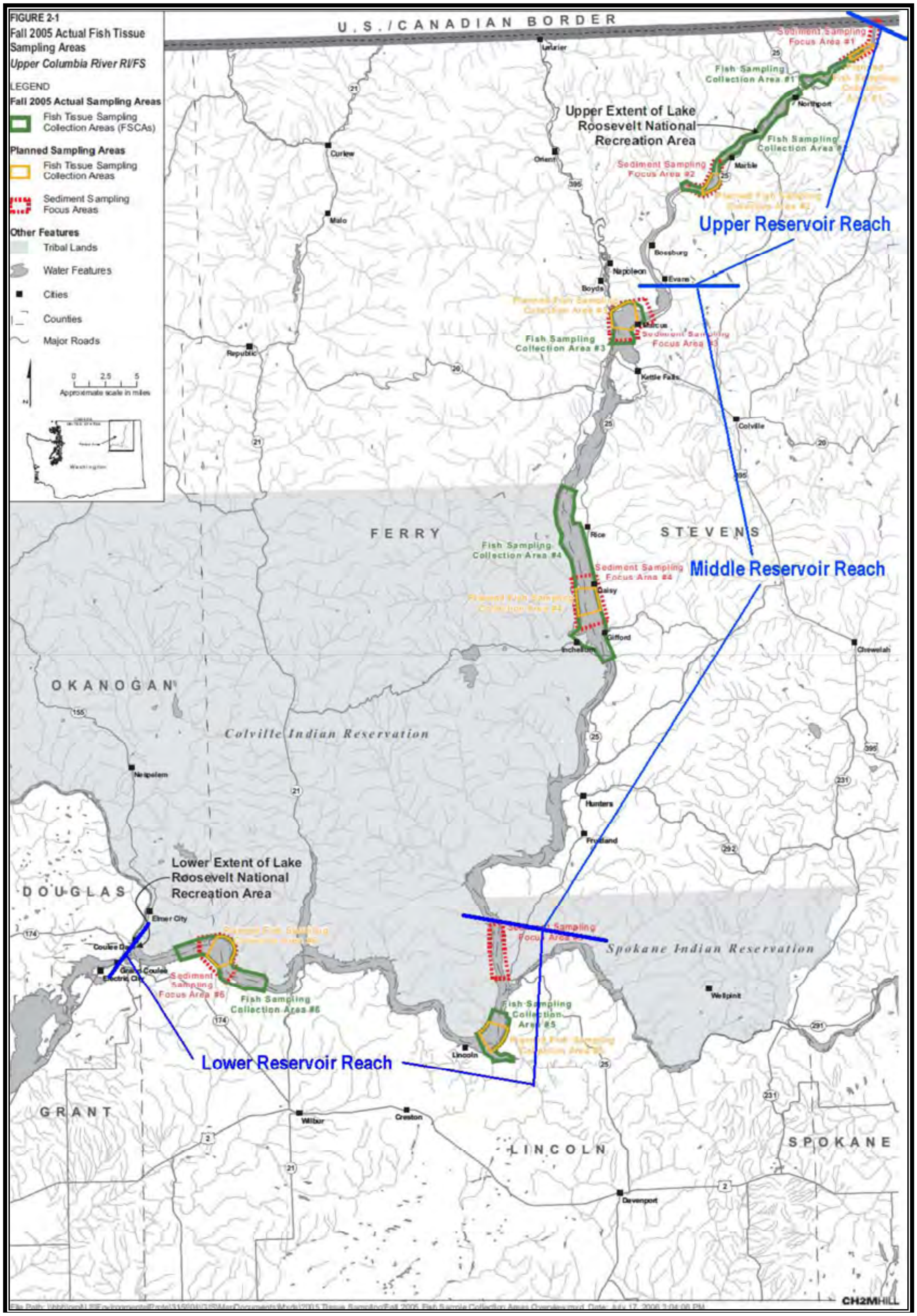


Figure 2. Upper Columbia River relief map (green - fish sample collection areas (FSCA) showing the fish sample collection areas along Lake Roosevelt in northeast Washington.



Discussion

Benefits of Fish Consumption

It is important to consider the benefits of eating fish. Fish is an excellent source of protein and is associated with reduced risk of coronary heart disease. The health benefits of eating fish are associated with low levels of saturated fats in people. Saturated fats are linked with increased cholesterol levels and risk of heart disease while unsaturated fats (e.g., omega-3 polyunsaturated fatty acid) are essential nutrients. Fish provide a good source of omega-3 polyunsaturated fatty acid, some vitamins, and minerals [11, 12]. The American Heart Association recommends two servings of fish per week as part of a healthy diet [13].

The health benefits of eating fish deserve particular consideration when one is dealing with subsistence consuming populations. Removal of fish from the diet of subsistence consumers can have serious health, social, and economic consequences that must be considered when issuing fish advisories. Consumption advisories for high-end consumers could significantly impact diet. Any advice given to fish consumers to reduce the amount of fish they eat based on chemical contamination should attempt to balance the health benefits with the health risks.
In general, people should eat fish low in contaminants and high in omega-3 fatty acid. Fish consumption advice should also take into account that eating alternative sources of protein also has risks. For instance, consumption of excessive beef or pork at the expense of eating fish can increase the risk of heart disease. In addition, some contaminants that are common in fish, such as dioxin, might also be present in other meats or other sources of animal proteins.

The level of contaminant exposure from fish consumption varies with the species of fish, the part consumed (e.g., fillet vs. whole fish), consumption rate, and preparation and cooking. Depending on the contaminant, levels can be reduced through simple preparation measures. Simply removing the skin of the fish can reduce PCB exposure [14]. Eating fillets instead of whole fish can reduce PCB levels by more than 20%. In some cases, 50% of PCBs were removed through preparation and cooking [15, 16].

Existing Fish Consumption Advisories

DOH has issued two statewide freshwater fish consumption advisories recommending the following:

1. Women who might become pregnant, are pregnant, nursing, or young children should not consume northern pikeminnow.

2. Women who might become pregnant, are pregnant, nursing, or young children should limit their consumption of freshwater large-mouth and small-mouth bass to no more than two meals per month. More information regarding these advisories is available at http://www.doh.wa.gov/CommunityandEnvironment/Food/Fish/Advisories.aspx or by calling toll-free 1-877-485-7316.

Additionally, women of childbearing age and children under six years of age should limit their consumption of canned tuna fish and should not eat swordfish, shark, tilefish, king mackerel, or fresh-caught or frozen tuna steak.

The current fish advisory for Lake Roosevelt is based on data from 1997. That DOH advisory recommends that women who might become pregnant, are pregnant, nursing, and young children should eat no more than two meals per month of walleye caught from Lake Roosevelt.

Sample Collection and Analysis

The EPA, the Colville Tribes, and the U.S. Fish and Wildlife Service collected Phase 1 fish tissue samples in September and October of 2005. Six fish sample collection areas (FSCAs) were sampled, two in each reach (see Figure 2) [17]. Target species collected were walleye *(Sander vitreus)*, rainbow trout *(Oncorhynchus mykiss)*, lake whitefish (*Coregonus clupeaformis*), large-scale sucker *(Catostomas macrocheilus),* and burbot (*Lota lota)*.

Individual samples were homogenized (ground) and species-specific from the same FSCA were composited (combined) and prepared in accordance with the study design in the Fish Tissue Sampling Quality Assurance Project Plan (Fish Tissue QAPP) [18]. Five composite samples of each species were analyzed from each FSCA. The analytes included EPA target analyte list for metals, organic arsenic species, PCB aroclors, PCB congeners, dioxins and furans, percent lipids, and percent moisture. Rainbow trout were identified as hatchery or wild, based on morphological characteristics, and were composited and analyzed separately. Mountain whitefish (*Prosopium williamsoni*) were collected at the upstream FSCA because lake whitefish were not available in this area due to habitat conditions [17]. Sediment (it was speculated that some of the sediment was slag) was noted in the guts of large-scale suckers collected from the upstream FSCA. Appendix A - Tables A1to A6 shows the analytes (contaminants) that were detected in each species.

Contaminants of Concern

Contaminants of concern (COCs) in fish were determined by employing a screening process. Screening values (SVs) were developed according to EPA guidance and are used to narrow the focus of evaluation to contaminants that are present at potential levels of public health concern (Appendix A) [19]. Maximum fish contamination levels for each contaminant were screened against SVs for non-cancer health effects (see Table 1 and Appendix A - Tables A1-A6).

With the exception of lead, SVs for chemicals that do not cause cancer represent levels that are not expected to cause any health problems. For lead, SVs are usually based on the goal of keeping blood lead levels in children below 10 micrograms per deciliter (µg/dl). However, the Centers for Disease Control and prevention (CDC) have recently updated its definition for elevated blood lead level (BLL) to greater than, or equal to, 5 µg/dl [20]. These types of SVs often form the basis for cleanup goals. In general, if a contaminant's maximum concentration is greater than its SV, then the contaminant is evaluated further. Chemicals detected at concentrations that exceed their respective SVs, do not necessarily represent a health threat. For chemicals that cause cancer, SVs represent levels that are calculated to increase the risk of cancer by about one additional cancer in one hundred thousand people exposed. However, for this health consultation all contaminants that are possible carcinogens were automatically evaluated further except cadmium and beryllium. The latter two contaminants were not considered because they are only known to cause cancer through inhalation and not ingestion.

Essential nutrients (e.g., calcium, magnesium, potassium, and sodium) are important minerals that maintain basic life functions; therefore, certain doses are recommended on a daily basis because these chemicals are necessary for life. Although these chemicals were analyzed, they are not relevant to this fish bioaccumulation assessment and therefore, will not be evaluated for human health impacts in this consultation.

The maximum level of each contaminant found in fish samples (whole fish: burbot, large-scale sucker, and whitefish; and fillet with skin: rainbow trout and walleye) from Lake Roosevelt are summarized in Table 1 and Appendix A. This health consultation covers only potential exposure to contaminants in Lake Roosevelt target species fish. However, there are other potential exposure pathways to contaminants through water contact recreation, drinking Lake Roosevelt water, and inhaling fugitive dust at Lake Roosevelt. These other pathways will be evaluated as additional data become available.

Use of Non-Detect Results for Screening COCs

Some uncertainty is associated with any approach dealing with non-detected chemicals. Non-detect results do not indicate whether the contaminant is present at a concentration just below the detection limit, present at a concentration just above zero, or absent from the sample. Therefore, contaminants that were evaluated as non-detects can lead to an overestimation of risk if the actual concentrations are just above zero or absent from the sample (See the PCB Uncertainty of Non-detected Results section). Conversely, if a sample concentration is at the detection limit or just above it and you screen out these chemicals you may be underestimating risks. Therefore, for this health consult, one-half the reported detection limit for non-detect samples (U) was included in the sampling data set, unless otherwise stated.

Use of Dioxins and Furans Results

Although several dioxin and furan congeners were analyzed in fish tissue, only a single value, called a dioxin Toxic Equivalent (TEQ) is used in this health consultation. Each dioxin/furan 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 2,3,7,8-tetrachlorodibenzo-p-dioxin TEQ. The TEQ approach is based on the premise that many dioxins/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 ten chlorinated dibenzofurans and seven chlorinated dibenzodioxins using the World Health Organization (WHO) methodology [21].

Table 1. Maximum concentration of contaminants detected in whole body or fillet fish sampled by EPA in 2005 from Lake Roosevelt in northeast Washington.

Chemicals	Maximum Concentration (ppm)	Screening Values (ppm)		EPA Cancer Class	(MRL or RfD) (mg/kg/day)	Contaminant of Concern
		General Population +	Non-Tribal High end consumer ++			
Aluminum	400.6	8000	983.15		2	No
Antimony	**0.584**	1.6	0.197	D	0.0004	**Yes**
Arsenic total	**0.958**	1.2	0.147	A	0.0003	**Yes**
Barium	38.8	800	98	D	0.2	No
Beryllium	0.022	8	0.98	B1	0.002	No
Cadmium	**0.544**	4	0.49	B1	0.001	**Yes**
Calcium	14000	n/a	n/a		n/a	No
Chromium	**8.2**	12	1.47	D	0.003	**Yes**
Cobalt	1.18	40	4.9		0.01	No
Copper	**48.49**	160	19.7	D	0.04	**Yes**
Iron	**1990**	2800	344		0.7**	**Yes**
Lead	**7.814**	n/a	n/a	B2	n/a	**Yes**
Magnesium	429.9	n/a	n/a		n/a	No
Manganese	**85.22**	560	68.8	D	0.14	**Yes**
Mercury	**0.417**	0.4	0.049	D	0.0001*	**Yes**
Nickel	5.2	80	9.8		0.02	No
Potassium	4870	n/a	n/a		n/a	No
Selenium	1.24	20	2.46	D	0.005	No
Silver	0.166	20	2.46	D	0.005	No
Sodium	1640	n/a	n/a		n/a	No
Thallium	**0.078**	0.32	0.039		0.00008	**Yes**
Uranium	0.098	12	1.47		0.003	No
Vanadium	0.802	12	1.47		0.003	No
Zinc	**359.35**	1200	147.5	D	0.3	**Yes**
Total PCBs	**0.615**	0.08	0.0098	B2	0.00002	**Yes**
Total Dioxin TEQ	**2.4E-5**	4.0E-6	4.9E-7		1.00E-9***	**Yes**

U- data qualifier: (half of the concentration was used in subsequent evaluation).
A - EPA: Human carcinogen
B1 - EPA: Probable human carcinogen (limited human, sufficient animal studies)
B2 - EPA: Probable human carcinogen (inadequate human, sufficient animal studies)
D - EPA: Not classifiable as to health carcinogenicity
* Minimal Risk Level (MRL) for methlymercury
** Provisional RfD for Iron
*** ATSDR Minimal Risk Level (MRL) for Dioxin TEQ
n/a – not available
ppm -parts per million
RfD - EPA oral reference dose
MRL- ATSDR's Minimal Risk Level
mg/kg/day - milligrams per kilogram body-weight per day
PCBs – polychlorinated biphenyls

TEQ – Toxic Equivalent
Bold – chemical is a contaminant of concern and the value exceeds screening values (Appendix A) [19]

+ Derived from EPA Guidance for Assessing Chemical Contaminant Data (recreational fishers). Based on fish consumption rate of 17.5 g/day, 70 kg body weight for noncarcinogens exposure [19].

++ Derived from EPA Guidance for Assessing Chemical Contaminant Data (subsistence fishers). Based on fish consumption rate of 142 g/day, 70 kg body weight for noncarcinogens exposure [19].

Review of Data Quality and Uncertainty for Calculating Risks

This public health consultation relies upon data and information collected from the 2005 EPA Lake Roosevelt fish sampling effort. The objective of the fish tissue collection and analyses was to generate data of known quality appropriate for project needs in terms of end decisions. Many factors are considered during review of the analytical data for public health assessments such as, sampling procedures, sample handling, laboratory procedures and reporting limits, and data validation. The data quality objectives (DQOs) for the 2005 fish tissue sampling are found in Fish Tissue QAPP [18]. The following are the data uncertainties found during a review of the final fish tissue data. During that review, we found 3 chemicals that did not meet the quality objectives and include arsenic, lead, and PCBs.

Additionally, some uncertainty is associated with any approach in dealing with non-detected chemicals. Non-detect results do not indicate whether the contaminant is present at a concentration just below the detection limit, present at a concentration just above zero, or absent from the sample. Therefore, contaminants that were evaluated as non-detects can lead to an overestimation of risk if the actual concentrations are just above zero or absent from the sample. Generally, using one-half the reported detection limit for non-detect samples (U) is a commonly accepted practice in both human health and ecological risk assessments in calculating sample concentration. This assumes that the average value for non-detects could be as high as half the detection limit. On the other hand, using half the detection limit may create high biased results if the non-detects are more than 50% of the analytical results for a chemical. Another argument could be made that if 90% or more of the samples are below the detection level, then the surrounding or actual concentrations are probably closer to zero than one-half the detection level. Therefore, the percentage of non-detects for a contaminant is an important consideration in the analysis of data sets.

Arsenic and Lead Data Quality and Uncertainty

Since metals are a primary contaminant of concern at this site, the analysis of arsenic and lead in fish was evaluated. Inorganic arsenic is much more harmful to human health than organic arsenic; therefore, DOH bases any health evaluation on the levels of inorganic arsenic present in fish samples. Generally, inorganic arsenic in fish and shellfish ranges from about one to 20% of the total arsenic [22, 23, 24, 25]. The U.S. Food and Drug Administration (FDA) proposed a default value of 10% of the total arsenic estimated as inorganic arsenic [25]. A small percentage of the Lake Roosevelt samples have arsenic speciation (samples content of organic vs. inorganic arsenic) data. However, arsenic was not detected in the majority of those samples and there were some data quality issues with the arsenic speciation data set for Lake Roosevelt samples. The above factors have created uncertainty in evaluating arsenic and the fish data set.

Lead concentration uncertainty is an issue for large-scale suckers, a bottom feeding species. During sample preparation, more sediment was observed in their digestive tracts than in other fish species. Sediment in the digestive tracts can affect the concentration of metals (in particular lead) during whole fish analyses. For purposes of assessing future public health issues related to fish consumption, the analysis of large-scale suckers should only include gutted whole fish or fillets.

PCBs Data Quality Objectives

Data quality objectives (DQOs) are sampling, sample handling, and laboratory processes designed to determine the type, quantity, and quality of data needed to support a decision. For that reason, DQOs are based on the degree to which uncertainty in a data set must be controlled to achieve an acceptable level of confidence in a decision based on the data [26, 27, 28, 29]. With this in mind, the majority of PCB Aroclor samples failed to achieve the DQOs for detection limits in the data sets. It is believed that increased lipids and oils in fish samples likely affected Aroclor detection and/or reporting limits.

PCBs Uncertainty of Non-detected Results

Non-detected PCB Aroclor data pose a risk of overestimation if Aroclor concentrations when they are simply summed. Even the assumption that all non-detect Aroclors are present at one-half the detection limit may not be justified when Aroclor data are used to estimate the total PCB concentration in cases where all potential Aroclors (1016, 1221, 1232, 1242, 1248, 1254, 1260, 1262, and 1268) are analyzed with high reporting limits. Aroclor identification is based on the presence or absence of a particular Aroclor fingerprint identified in the sample chromatogram. The absence of a fingerprint, while subjective, can be a very good indication that the Aroclor is not present. Therefore, the percentage of non-detects for an Aroclor is an important consideration in the analysis of the data set.

Analytical data quality for a fish advisory should have low enough detection limits compared to health guidelines. Therefore, congener analysis is preferred over Aroclor analysis because of the very low detection limits and high analytical sensitivity. For Lake Roosevelt, congener analysis was only done on a small subset of samples. In this case, total PCB concentration was not drastically affected by non-detected congeners because of the very low and sensitive detection limits. The relative contribution of non-detected congeners to the total PCBs concentration is insignificant, assuming half the detection limits for non-detected.

Non-detected Aroclors contributed 30 to 95% of the total PCB concentration and risk, depending on the species of fish. To adjust for bias due to so many non-detect values, DOH determined that if 90% or more of a specific Aroclor were non-detected data points for each species of fish sampled, the Aroclor data for that species would be assigned a value of zero instead of half the detection limit. The following list of Aroclors were not detected 100% of the time: 1016[a], 1221, 1232, 1242, 1248, 1262, 1268.

Exposure Quantification

The Lake Roosevelt exposure quantification is based on exposure doses, theoretical cancer risks, and assumptions (Table 3). The following exposure scenarios were developed to model exposures that might occur at Lake Roosevelt. These scenarios were devised to represent exposures to a general population (GEN) child, Non-Tribal High End Consumer (SUB) child (0-6 years of age), GEN adult, and SUB adult. The following exposure parameters and dose equations were used to estimate exposure from eating fish that contain chemicals of concern.

Table 3. Exposure assumptions used to determine exposure to contaminants in fish samples from Lake Roosevelt in northeast Washington (2005).

Ingestion Route

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

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

Parameter	Value	Unit	Comments
Concentration (C)	Variable	ug/kg	Average detected value
Conversion Factor (CF_1)	0.001	mg/ug	Converts contaminant concentration from micrograms (ug) to milligrams (mg)
Conversion Factor (CF_2)	0.001	kg/g	Converts mass of fish from grams (g) to kilograms (kg)
Ingestion Rate (IR)	7	g/day	Average general population child
Ingestion Rate (IR)	60		Non-tribal high-end consumer (SUB) child used at Portland Harbor, Oregon
Ingestion Rate (IR)	17.5		Average general population adult
Ingestion Rate (IR)	142.4		EPA subsistence fisher (SUB) adult
Exposure Frequency (EF)	365	days/year	Assumes daily exposure
Exposure Duration (ED)	6	years	Number of years (child)
Exposure Duration (ED)	30		Number of years (adult)
Body weight (BW)	15	kg	Mean body weight child
Body weight (BW)	70		Mean body weight adult
Averaging Time$_{\text{non-cancer}}$ (AT)	Variable	days	Equal to Exposure Duration
Averaging Time$_{\text{cancer}}$ (AT)	25550	days	70 years
Cancer Potency Factor (CPF)	Variable	mg/kg-day^{-1}	Source: EPA – Chemical specific

The average child ingestion rate of 7 g/day is about 2 ounces per week or 6 pounds of fish per year.
The average adult ingestion rate of 17.5 g/day is 4.4 ounces per week or about 14 pounds of fish per year.
The high-end child ingestion rate of 60 g/day is 15 ounces per week or about 48 pounds of fish per year.

[a] Aroclor 1016 showed up in two whitefish samples at the detection limit a potential data quality error (missing a data flag U). Additionally, one of the two samples had a field duplicate and triplicate that were U flagged. Therefore, DOH assigned a 100% non-detected flag/note to whitefish.

The high-end adult ingestion rate of 142.4 g/day is about 2.25 pounds per week or 115 pounds of fish per year.

Evaluating Non-cancer Hazards

The non-cancer evaluation of PCB data was done using zero for non-detects. Exposure assumptions for estimating contaminant doses from fish exposure 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 contaminant of concern. These doses are calculated for situations (scenarios) in which area residents or vacationers might be exposed to 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. In the absence of MRLs, DOH uses the EPA's oral reference dose (RfD). RfDs are doses below which non-cancer adverse health effects are not expected to occur. MRLs and/or RfDs are derived from observed effect levels obtained from human population and laboratory animal studies. They are 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 known adverse health effects.

Because of uncertainty in these data, the toxic effect level is divided by "uncertainty factors" to produce the lower and more protective MRL or RfD. If a dose exceeds the MRL or RfD, it does not mean that adverse health effects will occur. When the MRL or RfD is exceeded, further toxicological evaluation is needed. The further evaluation includes comparing the site-specific estimated dose to doses from animal and human studies that showed either an effect level or a no effect level. This comparison, combined with other toxicological information, such as sensitive populations and/or chemical metabolism, is used to determine the risk of specific harmful effects. A MRL or RfD is exceeded whenever the Hazard Quotient (HQ) is greater than one. The equation for the HQ is shown below:

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

The sum of the HQ is called the hazard index (HI). If an HI approach is used, the RfD for each contaminant should be for the same health effect. To calculate hazard indices, the endpoint-specific (e.g., developmental endpoint, immunological endpoint, etc.) hazard quotient for each contaminant must be calculated as shown above.

Next, hazard quotients are summed to determine the hazard index for a specific endpoint, as shown below:

$$HI_{\text{(Developmental)}} = HQ_{\text{PCBs (Developmental)}} + HQ_{\text{Mercury (Developmental)}}.$$

If the HI is greater than 1.0, then further evaluation is necessary. For chemical mixtures with an HI greater than 1.0, the estimated doses of the individual chemicals are compared with their NOAELs or LOAELs.

Estimated exposure doses, exposure assumptions, and hazard quotients are presented in Appendix B for COCs found in fish for the following chemicals: antimony, cadmium, chromium, copper, dioxins, iron, manganese, mercury, thallium, zinc, and total PCBs. *Several estimated doses from exposure to contaminants in target fish species in Lake Roosevelt resulted in hazard quotients in excess of one* (see Appendix B - Tables B3 – B6).

Note: the evaluation of PCB fish data was done using zero for the non-detects. Risk from maximum levels in Table B3 were not used because Lake Roosevelt is 150 miles long and it is highly unlikely that a person would be exposed to maximum levels everyday over a lifetime of exposure to contaminants in fish. Therefore, the average concentration for each of the three reaches was used in each reach evaluation. The following discussions focus on individual chemicals and not chemical mixtures. Exposure to multiple chemicals is discussed later in the report (Multiple Chemical Exposures).

These risk estimate results are likely biased low or high due to the following data limitations: data quality objectives (DQOs) were not met for PCBs, uncertainty in the arsenic speciation data, and uncertainty in the large-scale suckers lead concentrations (See Review of Data Quality Section). Using these numbers to estimate an allowable meal limit would likely result in erroneous fish consumption advice and therefore was not used in meal limit calculations.

For antimony, consuming fish from Lake Roosevelt would result in average exposure doses ranging from 3.38×10^{-4} to 2.32×10^{-5} mg/kg/day for children (subsistence to general consumers) and 1.72×10^{-4} to 1.24×10^{-5} mg/kg/day for adults (subsistence to general consumers) (see Tables B4 – B6). EPA's oral RfD for antimony is 4.00×10^{-4} mg/kg/day. Health effects of decreased non-fasting blood glucose levels in male rats and cholesterol levels were altered in both sexes exposed to 3.5×10^{-1} mg/kg/day of antimony [30]. Therefore, DOH does not expect that exposures to antimony in fish could cause harmful non-cancer health effects.

For cadmium, consuming fish from Lake Roosevelt would result in average exposure doses ranging from 1.32×10^{-3} to 1.16×10^{-4} mg/kg/day for children (subsistence to general consumers) and 6.70×10^{-4} to 6.20×10^{-5} mg/kg/day for adults (subsistence to general consumers) (see Tables B4 – B6). A NOAEL of 1.0×10^{-2} mg/kg/day was established for exposure to cadmium. Therefore, DOH does not expect that exposures to cadmium in fish could cause harmful non-cancer health effects.

For chromium, consuming fish from Lake Roosevelt would result in average exposure doses ranging from 4.71×10^{-3} to 1.65×10^{-4} mg/kg/day for children (subsistence to general consumers) and 2.40×10^{-3} to 8.86×10^{-5} mg/kg/day for adults (subsistence to general consumers) (see Tables B4 – B6). A NOAEL of 2.5 mg/kg/day was established for rats chronically exposed to chromium (VI). Some exposure scenarios resulted in doses that exceed the RfD but fall below the NOAEL. Since, DOH was very conservative in its evaluation and assumed all chromium in the fish was chromium VI and 100% of the chromium was absorbed. DOH does not expect that exposures to chromium in fish could cause harmful non-cancer health effects to the population.

For copper, consuming fish from Lake Roosevelt would result in average exposure doses ranging from 8.27×10^{-3} to 3.21×10^{-4} mg/kg/day for children (subsistence to general consumers) and 4.21×10^{-3} to 1.72×10^{-4} mg/kg/day for adults (subsistence to general consumers) (see Tables B4 – B6). Health effects of abdominal pain, vomiting, and diarrhea were observed in humans chronically exposed to 5.6×10^{-2} mg/kg/day of copper [31]. The Health Effects Assessment Summary Tables (HEAST) established RfD for copper is 4.00×10^{-2} mg/kg/day [32]. Therefore, DOH does not expect that exposures to copper in fish could cause harmful non-cancer health effects.

For dioxin, consuming fish from Lake Roosevelt would result in average exposure doses ranging from 5.88×10^{-9} to 8.91×10^{-11} mg/kg/day for children (subsistence to general consumers) and 2.99×10^{-9} to 4.78×10^{-11} mg/kg/day for adults (subsistence to general consumers) (see Tables B4 – B6). Health effects of altered social behavior have been observed in monkeys exposed to 1.2×10^{-7} mg/kg/day of dioxin [33]. Some exposure scenarios resulted in doses that exceed the chronic MRL of 1.0×10^{-9} mg/kg/day but fall below documented toxic effect levels. Also, dioxin concentrations in some species were based on whole fish rather than fillets which people generally consume. Similar to PCBs, dioxins are stored in the fatty tissue, and exposure to dioxins in fish can also be significantly reduced through simple preparation and cooking measures, as in the case of PCBs. Simply removing the skin of the fish can reduce PCB exposure [14]. Eating fillets instead of whole fish can reduce PCB levels by more than 20%. In some cases, 50% of PCBs were removed through preparation and cooking [15, 16]. Therefore, DOH does not expect that exposures to dioxin in fish could cause harmful non-cancer health effects to the population especially if the skin is removed prior to cooking.

For iron, consuming fish from Lake Roosevelt would result in average exposure doses ranging from 5.64×10^{-1} to 2.53×10^{-2} mg/kg/day for children (subsistence to general consumers) and 2.87×10^{-1} to 1.35×10^{-2} mg/kg/day for adults (subsistence to general consumers) (see Tables B4–B6). The EPA-established provisional RfD for iron is 7.0×10^{-1} mg/kg/day [34]. Therefore, DOH does not expect that exposures to iron in fish could cause harmful non-cancer health effects.

For manganese, consuming fish from Lake Roosevelt would result in average exposure doses ranging from 4.72×10^{-2} to 2.79×10^{-3} mg/kg/day for children (subsistence to general consumers) and 2.40×10^{-2} to 1.49×10^{-3} mg/kg/day for adults (subsistence to general consumers) (see Tables B4 – B6). The EPA established RfD for manganese in food is 1.4×10^{-1} mg/kg/day [35]. Therefore, DOH does not expect that exposures to manganese in fish could cause harmful non-cancer health effects.

For mercury, consuming fish from Lake Roosevelt would result in average exposure doses ranging from 1.33×10^{-3} to 2.59×10^{-5} mg/kg/day for children (subsistence to general consumers) and 6.79×10^{-4} to 1.39×10^{-5} mg/kg/day for adults (subsistence to general consumers) (see Tables B4 – B6). ATSDR has derived a NOAEL of 1.3×10^{-3} mg/kg/day for mercury. Some exposure scenarios resulted in doses that exceed the RfD and the actual toxic effect levels. DOH does expect that some exposures to mercury in fish could cause harmful non-cancer health effects to the population. Therefore, mercury will be assessed later (Fish Meal Limits Section and in Appendix D).

For PCBs, consuming fish from Lake Roosevelt would result in average exposure doses ranging from 4.33×10^{-4} to 1.62×10^{-6} mg/kg/day for children (subsistence to general consumers) and 2.20×10^{-4} to 8.70×10^{-7} mg/kg/day for adults (subsistence to general consumers), depending on the PCB mixture (see Tables B4 – B6). Health effects of decreased antibody response and eyelid and toe/finger nail changes have been observed in female Rhesus monkeys chronically exposed to 5.0×10^{-3} mg/kg/day of Aroclor 1254 [36]. Some exposure scenarios resulted in doses that exceed the RfD but fall below documented toxic effect levels. Therefore, DOH does not expect that exposures to PCBs in fish could cause harmful non-cancer health effects to the population. However, there is too much uncertainty in the PCB data; therefore, DOH will not provide consumption advice on PCBs in fish.

For thallium, consuming fish from Lake Roosevelt would result in average exposure doses ranging from 2.60×10^{-4} to 1.22×10^{-5} mg/kg/day for children (subsistence to general consumers) and 1.32×10^{-4} to 6.55×10^{-6} mg/kg/day for adults (subsistence to general consumers) (see Tables B4 – B6). Health effects of increased levels of serum glutamic oxaloacetic transaminase and lactate dehydrogenase have been observed in rats exposed to more than 2.5×10^{-1} mg/kg/day of thallium [37]. Some exposure scenarios resulted in doses that exceed the RfD but fall below documented toxic effect levels. Therefore, DOH does not expect that exposures to thallium in fish could cause harmful non-cancer health effects to the population.

For zinc, consuming fish from Lake Roosevelt would result in average exposure doses ranging from 1.57×10^{-1} to 8.82×10^{-3} mg/kg/day for children (subsistence to general consumers) and 7.97×10^{-2} to 4.73×10^{-3} mg/kg/day for adults (subsistence to general consumers) (see Tables B4 – B6). Health effects of a decrease in blood enzyme have been observed in female rats exposed to 1.0×10^{-0} mg/kg/day of zinc for ten weeks [38]. EPA's established RfD for zinc is 0.3 mg/kg/day. Therefore, DOH does not expect that exposures to zinc in fish could cause harmful non-cancer health effects to the population.

Evaluating Exposure to Lead

The biokinetics of lead are different from most toxicants because lead is stored in bone and remains in the body long after it is ingested. Children's exposure to lead is evaluated through the use of the Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK) developed by the EPA. The IEUBK predicts blood lead levels in a distribution of exposed children based on the amount of lead that is in environmental media (e.g., fish) [39]. It is important to note that the IEUBK model is not expected to accurately predict the blood lead level of a child (or a small group of children) at a specific point in time. In part, this is because a child (or group of children) may behave differently, and therefore have different amounts of exposure to contaminated soil and dust than the average group of children used by the model to calculate blood lead levels. For example, the model does not take into account reductions in exposure that could result from community education programs. Despite this limitation, the IEUBK model is a useful tool to help prevent lead poisoning because of the information it can provide about the hazards of environmental lead exposure. For children who are regularly exposed to lead-contaminated fish, the IEUBK model can estimate the percentage of young children who are likely to have blood lead concentrations that exceed a level that may be associated with health problems (usually 10 μg/dl). However, CDC has recently updated its definition for elevated BLL to greater than, or equal to, 5 μg/dl [20].

Average Fish Lead Concentrations and Estimated Blood Lead Levels

The EPA IEUBK model was used to estimate the percentage of children that could have elevated blood lead levels if they frequently eat lead contaminated fish. Only the fish portion of the IEUBK model was used; the soil ingestion portion was left out. Default parameters are used for all model inputs unless stated [39]. Exposure based on a general population scenario of children eating 7 g/day or a non-tribal high-end consumer scenario of children eating 60 g/day of fish containing the average concentration of lead in each reach was used (see Appendix C).

The adult lead model was used to estimate the percentage of fetus that could have elevated blood lead levels (BLL) if pregnant women frequently eat lead contaminated fish. Only the fish portion of the adult lead model was used; the soil ingestion portion was left out. Exposure was based on a general population scenario of adults eating 17.5 g/day or a non-tribal high-end consumer scenario of adults eating 142.4 g/day of fish containing the average concentration of lead in each reach (see Appendix C).

The CDC has recently updated its definition for elevated BLL to greater than, or equal to, 5 μg/dl [20]. Studies have not revealed a safe level of exposure to lead in children that is without potential health effects. Previously, the cutoff level for elevated BLL was at greater than, or equal to, 10 μg/dl. With the exception of large-scale suckers, consuming fish from Lake Roosevelt would result in less than 5% estimated BLL above 5 μg/dL for a child (see Appendix C, Table C1). Fetus blood lead exceedences in percent above 5 μg/dL using the adult lead model included whitefish, walleye, large-scale suckers, and burbot but not for all reaches in the Lake Roosevelt (see Appendix C, Table C2).

Evaluating Theoretical Cancer Risk

The following theoretical cancer risk evaluation of PCB data was done using zero for non-detects. Some chemicals have the ability to cause cancer. Cancer risk is estimated by calculating a dose similar to that described for non-cancer evaluation and multiplying it by a cancer potency factor, also known as the cancer slope factor (CSF). 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 there is no “safe dose” of a carcinogen and that a very small dose of a carcinogen will result in a very small cancer risk. Theoretical cancer risk estimates are, therefore, not yes/no answers but measures of chance (probability). Such measures, however uncertain, are useful in determining the magnitude of a 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 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 potential that thresholds for some carcinogenesis exist. However, EPA still assumes no threshold unless sufficient data indicate otherwise [40].

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 1 excess cancer case per 10,000 persons exposed over a lifetime. A very low estimate might result in one excess cancer case per several tens of thousands exposed over a lifetime and a slight estimate would require an exposed population of several hundreds of thousands to result in a single case. DOH considers cancer risk insignificant when the estimate results in less than 1 cancer per 1,000,000 exposed over a lifetime. 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 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 1 in 3 to 1in 2 people living in the United States will develop cancer at some point in their lives [41].

Theoretical Cancer Risk

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

Term		# of Excess Cancers
low	is approximately equal to	1 in 10,000
very low	is approximately equal to	1 in 100,000
slight	is approximately equal to	1 in 1,000,000
insignificant	is less than	1 in 1,000,000

Theoretical cancer risk from exposure to Lake Roosevelt fish was calculated for arsenic, dioxin, and PCBs as carcinogenic COCs in fish (see Appendix B - Tables B7 – B10). No theoretical cancer risk was calculated for cadmium because cancer caused via the oral route by cadmium is disputed. In addition, the CSF for cadmium is for cadmium via the inhalation route. Theoretical cancer risks and non-cancer health hazards were not quantified for subpopulations (Colville Tribes and Spokane Tribes) that may be highly exposed.

Risk from maximum levels in fish were not used because Lake Roosevelt is 150 miles long and it is highly unlikely that a person would be exposed to the maximum levels everyday over a lifetime of exposure to contaminants in fish (Table B7). Instead, the average concentration in each of the three reaches was used in this evaluation. Theoretical cancer risk based on the reach's average concentration of contaminants and general population adult consumer's ingestion ranged from 7 cancers per 100,000 to 9 cancers per 1,000,000. These theoretical cancer risks fall within the acceptable cancer risk range of 1 cancer per 10,000 to 1 cancer per 1,000,000. Theoretical cancer risk based on the reach's average concentration of contaminants and non-tribal high-end adult consumer's ingestion ranged from 1 cancer per 10,000 to 6 cancers per 10,000. Some of these theoretical cancer risks fall outside the acceptable cancer risk range of 1 cancer per 10,000 to 1 cancer per 1,000,000 (see Appendix B - Tables B8 – B10).

These risk estimate results are likely biased low or high due to the following data limitations: data quality objectives (DQOs) were not met for PCBs, uncertainty in the arsenic speciation data, and uncertainty in the large-scale suckers lead concentrations (see Data quality objectives, PCBs uncertainty of non-detected results, and Arsenic and Lead Uncertainty sections). Using these numbers to estimate an allowable meal limit could result in erroneous fish consumption advice.

Multiple Chemical Exposures

A person can be exposed to more than one chemical through more than one pathway. Exposure to a chemical through multiple pathways occurs if a contaminant is present in more than one medium (i.e., air, soil, surface water, groundwater, and sediment). For example, the dose of a contaminant received from drinking water might be combined with the dose received from contact with the same contaminant in fish.

For many chemicals, much information is available on how the individual chemical produces effects. However, it is much more difficult to assess exposure to multiple chemicals. Due to the large number of chemicals in the environment, it is not yet possible to measure all of the possible interactions between these chemicals. The potential exists for these chemicals to interact in the body and increase or decrease the potential for adverse health effects. Individual theoretical cancer risk estimates can be added since they are measures of probability. In general, when estimating non-cancer risk, similarities must exist between the individual chemicals or their target organs if the doses are to be added. However, if the relative toxicities are known and accounted for you cannot just add the doses of individual chemicals. As mentioned previously, in the dioxin TEQ section, dioxins are assessed as one combined group. Also, PCBs or polycyclic aromatic hydrocarbons (PAHs) are other groups of compounds that can be assessed as one combined dose based on similarities in chemical structure and metabolites. Groups of chemicals that have similar toxic effects can be added such as volatile organic compounds (VOCs) which cause liver toxicity.

The ATSDR Interaction Profile for persistent chemicals found in fish evaluates the possibility of interactive effects from exposure to a chemical mixture of contaminants including mercury, PCBs, and dioxins [42]. Non-cancer risk of mixtures was taken into consideration when evaluating the data. For chemical mixtures with an HI greater than 1.0, the estimated doses of individual chemicals are compared with their NOAELs or LOAELs. If the estimated dose of one or more of the individual chemicals is within one order of magnitude of its respective NOAEL (0.1 x NOAEL), then the potential exists for additive or interactive effects. The lifetime excess cancer risks (LECR's) for each species of fish were evaluated (see Appendix B - Tables B7 – B10). However, the LECR's were not considered suitable because of DQOs were not met for PCBs and uncertainty in the arsenic speciation data.

Whitefish (whole fish)

The hazard index for general population children who consume Lake Roosevelt whitefish ranged from 1.6 to 2.0, and 0.8 to 1.1 for the general adult population based on the reach's average concentration of contaminants in whole whitefish (see Appendix B - Tables B4 – B6). For general population consumer children and adults none of the estimated contaminant doses are within one order of magnitude of its respective NOAEL or LOAEL. Therefore, additive or interactive effects are unlikely. For non-tribal high-end consumers, the hazard index ranged from 13.0 to 17.0 for children and 7.0 to 9.0 for adults (see Appendix B - Tables B4 – B6). Children and adults estimated doses for mercury are within one order of magnitude of their NOAEL therefore, additive or interactive effects with other contaminants in Whitefish are possible.

The sum of additional excess theoretical cancer risk based on the reaches average concentration of contaminants and adults ingesting whole whitefish in Lake Roosevelt ranged from 3 to 5 cancers per 100,000 for general population consumers, and 3 to 4 cancers per 10,000 for non-tribal high-end adult consumers (see Appendix B - Tables B8 – B10).

Walleye (fillet with skin)

The hazard index for the general population consumer children ranged from 1.4 to 2.6 and 0.8 to 1.1 for the general population consumer adults based on the reaches average concentration of contaminants in walleye (see Appendix B - Tables B4 – B6). For general population consumer children the estimated dose in the lower reservoir reach is within one order of magnitude of its LOAEL and for adults none of the estimated dose is within one order of magnitude of its LOAEL. Therefore, additive or interactive effects for other contaminants in Walleye and other species may be possible for children in the lower reservoir reach but are unlikely for adults. For non-tribal high-end consumers, the hazard index ranged from 11.5 to 17.6 for children and 6.5 to 9.9 for adults (see Appendix B - Tables B4 – B6). Children and adults estimated doses for mercury are within one order of magnitude of their NOAEL therefore, additive or interactive effects with other contaminants in walleye are possible.

The sum of additional excess theoretical cancer risk based on the reaches average concentration of contaminants and adults ingesting walleye in Lake Roosevelt ranged from 1 cancer per 100,000 to 9 cancers per 1,000,000 for general population consumers. For non-tribal high-end adult consumers the theoretical cancer risks ranged from 1 cancer per 10,000 to 7 cancers per 100,000 (see Appendix B - Tables B8 – B10).

Large-scale sucker (whole fish)

The hazard index for the general population consumer children ranged from 4.0 to 2.5 and 2.1 to 2.3 for the general population consumer adults based on the reaches average concentration of contaminants in large-scale sucker (see Appendix B - Tables B4 – B6). For general population consumer children and adults none of the estimated dose is within one order of magnitude of its respective NOAEL or LOAEL. Therefore, additive or interactive effects are unlikely. For non-tribal high-end consumers, the hazard index ranged from 11.5 to 17.6 for children and 6.5 to 9.9 for adults (see Appendix B - Tables B4 – B6). Estimated doses for zinc and copper in children and mercury and cadmium in children and adults are within one order of magnitude of their NOAEL or LOAEL therefore, additive or interactive effects are possible.

The sum of additional excess theoretical cancer risk based on the reaches average concentration of contaminants and adults ingesting whole large-scale sucker in Lake Roosevelt ranged from 4 cancers per 100,000 to 5 cancers per 100,000 for general population consumers. For non-tribal high-end adult consumers the theoretical cancer risks is 4 cancers per 10,000 (see Appendix B - Tables B8 – B10).

Rainbow trout wild (fillet with skin)

The hazard index for the general population consumer children ranged from 0.8 to 1.2 and 0.4 to 0.6 for the general population consumer adults based on the reaches average concentration of contaminants in wild rainbow trout fillets (see Appendix B - Tables B4 – B6). For general population consumer children and adults none of the estimated dose is within one order of magnitude of its respective NOAEL or LOAEL. Therefore, additive or interactive effects are unlikely. For non-tribal high-end consumers, the hazard index ranged from 7.0 to 11.0 for children and 3.1 to 4.7 for adults (see Appendix B - Tables B4 – B6). Children and adults estimated doses for mercury are within one order of magnitude of their NOAEL therefore, additive or interactive effects for contaminants in wild Rainbow trout are possible.

The sum of additional excess theoretical cancer risk based on the reaches average concentration of contaminants and adults ingesting wild rainbow trout fillets in Lake Roosevelt ranged from 1 to 2 cancers per 100,000 for general population consumers. For non-tribal high-end adult consumers the theoretical cancer risks ranged from 1 cancer per 10,000 to 8 cancers per 100,000 (see Appendix B - Tables B8 – B10).

Rainbow trout hatchery (fillet with skin)

The hazard index for the general population consumer children ranged from 0.8 to 1.1 and 0.5 to 0.6 for the general population consumer adults based on the reaches average concentration of contaminants in hatchery rainbow trout fillets (see Appendix B - Tables B4 – B6). For general population consumer children and adults none of the estimated dose is within one order of magnitude of its respective NOAEL or LOAEL. Therefore, additive or interactive effects are unlikely. For non-tribal high-end consumers, the hazard index ranged from 6.0 to 9.0 for children and 2.7 to 4.8 for adults (see Appendix B - Tables B4 – B6). Children and adults estimated doses for mercury are within one order of magnitude of their NOAEL therefore, additive or interactive effects for contaminants in hatchery Rainbow trout are possible.

The sum of additional excess theoretical cancer risk based on the reaches average concentration of contaminants and adults ingesting hatchery rainbow trout fillets in Lake Roosevelt ranged from 1 to 2 cancers per 100,000 for general population consumers. For non-tribal high-end adult consumers the theoretical cancer risks is 1 cancer per 10,000 (see Appendix B - Tables B8 – B10).

Burbot (whole fish)

The hazard index for the general population consumer children is 1.8 and for the general population consumer adults the HI ranged from 0.9 to 1.0 based on the reaches average concentration of contaminants in burbot (see Appendix B - Tables B4 – B6). For general population consumer children and adults none of the estimated dose is within one order of magnitude of its respective NOAEL or LOAEL. Therefore, additive or interactive effects are unlikely. For non-tribal high-end consumers, the hazard index ranged from 15.5 to 16.6 for children and 7.3 to 8.3 for adults (see Appendix B - Tables B4 – B6). Children and adults estimated doses for mercury are within one order of magnitude of their NOAEL therefore, additive or interactive effects of other contaminants in Burbot are possible.

The sum of additional excess theoretical cancer risk based on the reaches average concentration of contaminants and adults ingesting whole whitefish in Lake Roosevelt ranged from 6 to 7 cancers per 100,000 for general population consumers, and 4 to 6 cancers per 10,000 for non-tribal high-end adult consumers (see Appendix B - Tables B8 – B10).

Each fish species were evaluated based on the assumption that 100% of the fish species is consumed rather than a fraction of the total fish diet since there are no species-specific consumption rates.

Fish Meal Limits

Several contaminants of concern are present in fish from Lake Roosevelt; however, only meal limits for mercury were calculated due to the high uncertainty for PCBs, arsenic, and lead in large-scale suckers. Meal limits were calculated based on developmental endpoints for mercury and a 132 lb (60 kg) woman. Meal limits were calculated using the RfD as the target risk value and the exposure parameters provided in Appendix D, Table D1.

Many factors must be considered when one is recommending limits on the consumption of fish including the very real health benefits of eating fish, the quality and comprehensiveness of environmental data, and the availability of alternate sources of nutrition. In addition, these limits do not consider that multiple species are consumed, a consideration that would require weighting the percent of each species consumed.

Children’s Health Considerations

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

- Children have proportionally larger livers and brains – fatty organs in which PCBs and other organic contaminants preferentially accumulate.
- Children have a longer remaining lifespan in which the expression of toxicity can occur.
- Children are smaller and receive higher doses of chemical exposure per body weight.

- Fetal and child exposure to contaminants can cause permanent damage during critical growth stages.

These unique vulnerabilities of infants and children demand special attention in communities that have contaminated water, food, soil, or air. Children's health was considered in the writing of this health consultation and the exposure scenarios treated children as the most sensitive population being exposed.

Conclusions

1. DOH concludes that mercury levels in Lake Roosevelt fish could harm the health of young children and the developing fetus. Therefore, women who might become pregnant, are pregnant or nursing, and young children should follow the fish consumption advisory. The current fish advisory for Lake Roosevelt (eat no more than 2 meals per month of walleye) should remain in place due to methylmercury (mercury) exposure and be expanded to limit burbot and large-scale sucker meals to 4 per month.

The latest (2005) levels of mercury in walleye fish tissue have not changed much since the 1997 results. The 2005 fillet mercury results ranged from 0.11 to 0.44 parts per million (ppm), which are elevated concentrations of mercury. Thus, the current fish advisory should remain in place. This 2005 fish tissue data set shows elevated concentrations of mercury in burbot and large-scale sucker that require an additional fish advisory of no more than four meals per month for these species. Eating more than the calculated consumption limit may increase a person's risk of developing health problems.

2. DOH cannot currently conclude whether dioxins, polychlorinated biphenyls (PCBs), arsenic, and/or lead associated with eating fish at Lake Roosevelt could harm people's health.

Dioxins - Theoretical cancer risks for a given reach are based on the average concentrations of contaminants in that reach. Therefore, while some calculated theoretical cancer risks because of dioxin contamination for some species of fish falls outside the EPA's acceptable cancer risk range, they are still within what is considered background risk levels. Dioxin concentrations may be overestimated due to several factors. Dioxin concentrations in some species were based on whole fish rather than fillets, which people generally consume. Also, dioxins are similar to PCBs and are stored in the fatty tissue, and exposure to dioxins in fish can also be significantly reduced through simple preparation and cooking measures, as in the case of PCBs. Simply removing the skin and eating fillets instead of whole fish can reduce PCB levels by 26% [14]. In some cases, 20 to 100% of PCBs can be removed through preparation and cooking [15, 16]. Following these same simple steps will also reduce dioxin exposure when eating fish.

Polychlorinated biphenyls (PCBs), arsenic, and/or lead - Some calculated polychlorinated biphenyl (PCB) and arsenic theoretical cancer risks for some species of fish are higher than EPA's acceptable cancer risk range. Due to the high analytical detection limit and the failure to meet the data quality objectives (DQOs) for the PCB Aroclor data, there is too much uncertainty in the PCB data at this time for DOH to provide advice on fish consumption. Similarly, there are uncertainties with the arsenic speciation data for all fish species and lead concentrations in large-scale suckers data.

Recommendations

1. DOH recommends additional sampling for PCB Aroclors in fish. If the DQOs for PCB Aroclors are not achievable, DOH recommends 100% PCB congener analysis. PCB congener data will address the DQOs problems seen in PCB Aroclors data.

2. DOH recommends arsenic speciation using Method 1632, Revision A. These samples should meet DQOs. http://www.epa.gov/waterscience/methods/method/files/1632.pdf.

3. DOH recommends large-scale suckers be analyzed using fillets and whole gut-less samples in order to assess public health issues associated with fish consumption.

General Advice

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

- Eat a variety of fish that are low in contaminants according to the guidance provided on our website at http://www.doh.wa.gov/fish.
- Follow advice provided by DOH and local health agencies for water bodies where you fish.
- Eat proportionally smaller meal sizes (young children and small adults).
- Grill, bake, or broil fish so that fat drips off while cooking.
- Eat fillets without the skin. Mercury and other metals are stored in the fillet or bones of the fish and will not be reduced by preparing fish this way.

Public Health Action Plan

Action Completed

- DOH updated the information on fish advisories for Lake Roosevelt in the 2008/2009 "Fishing in Washington" sport fishing rules pamphlet produced by the Washington Department of Fish and Wildlife.

- DOH provided fact sheets to communities indicating ways to reduce exposure to some contaminants in fish in the spring of 2012.

Actions Planned

1. DOH toxicology section is currently developing a report for the new data set from the 2009 fish sampling effort (to be published in Fall of 2012).

2. DOH will address other pathways, such as oral ingestion of water or plant materials in future public health consultations when data are available.

3. DOH has established a community repositories for public health consultation and related fact sheets at the following:

   - Northport: Northport Town Hall, 315 Summit Street, 509-732-4450
   - Colville: Colville Public Library, 195 S. Oak Street, 509-684-6620
   - Inchelium: Inchelium Tribal Resource Center, 12 Community Loop, 509-634-2791
   - Nespelem: Office of Environmental Trust, Building #2, Colville Confederated Tribes, 1 Colville, 509-634-2413
   - Grand Coulee: Grand Coulee Library, 225 Federal Street, 509-633-0972
   - Wellpinit: Spokane Tribe Department of Natural Resources, 6290 B Ford-Wellpinit Road, 509-258-7709 ext. 13
   - Spokane: Spokane Library, 906 W. Main Avenue, 509-444-5336

Responses to Public Comments Received

The Public Comment Draft was available to individual citizens and groups for review. The public comment period was open from April 30, 2008 to May 30, 2008. During the public comment period, DOH received comments only from the Citizens for Clean Columbia (CCC). The CCC community group has had a long history of active involvement with the Lake Roosevelt site in northeast Washington. The CCC group has worked with state, federal, and other public health agencies. CCC prepared and submitted five attachments/comments (A, B, C, D, and E). DOH addresses the CCC comments in this section.

Question:

Attachment A:

Mr. Lenford O'Garro:

We appreciate the opportunity to comment on the D*raft* Health Consultation Upper Columbia River Site Lake Roosevelt Non-Tribal Fish exposure Northeast Washington, April 30, 2008 (hereinafter referred to as HC2). Our comments focus on data and analysis generated upstream by EPA and their contractors. This material contains fatal flaws which render any subsequent computations or use of their results invalid, especially for a health assessment.

Our comments are contained in a series of e-mail attachments which are listed below.

- Attach A: introduction and comments on HC2.
- Attach B: EPA e-mail of October 25, 2007 from the UCR site manager, Kevin Rochlin, acknowledging that EPA will correct the sediment particle sizes. Abandon the use of ½ the detection limit as a substitution for nondetects and use methods given in EPA (2006, 2007). Correctly calculate statistical coverage, goodness-of-fit tests, and fit the log normal distribution according to the above EPA documents. On the whole, EPA intends to implement the corrections given in my comments of July 19, 2007. A copy of these comments is included in Attach C as Appendix A.
- Attach C: contains prior comments which were sent to DOH on an earlier draft of this Health Consultation (HC). These comments apply to HC2.
- Attach D: comments sent to DOH on HC2 by the board of CCC on May 27, 2008.
- Attach E: comments on composite sampling.

Unfortunately, EPA's intentions are greater than their accomplishments. The data and analysis in the UCR documents have not been corrected. The comments in our attachments amply show that any use of the data in EPA Final Phase I Fish Tissue Sampling Data Evaluation Upper Columbia River Site CERCLA RI/FS of October 30, 2007 or use of preceding drafts will render downstream calculations invalid. HC2 is a case of *"garbage in garbage out."*

In the past and for some time in the future, the public have experienced restrictions on their use of the resources of the UCR. It is time to restrict the polluters and begin to cleanup the contamination.

Although we reject this report, we do not view this as an ending but the opening of a beginning. Where the state and federal agencies, whose fundamental mandate is to serve the public, will freely and openly meet with and discuss the public's concerns.
We ask your agency to join with the citizens to obtain immediate correction of the EPA documents and to prevent any more effort being wasted.

REFERENCES

EPA 2006. On the Computation of a 95% Upper Confidence Limit of the Unknown Population Mean Based Upon Data Sets with Below Detection Limit Observations. EPS/600/R-06/022.

EPA 2007. ProUCL Version 4.0 User Guide. EPA/600/R-07/038.

Answer:

Please refer to the response below to Attachment E, the letter dated July 24, 2008, from Professor John R. Skalski of the University of Washington on composite sampling prepared for the EPA.

As DOH explored the PCB and arsenic fish data as to possible ways to evaluate the data set, it became clear that the best approach was to ask EPA to resample and reanalyze the fish data. Similarly, DOH came to the same conclusion during the evaluation of lead data for the large-scale suckers. These conclusions were due to laboratory analysis of the samples not meeting data quality objectives in the case of PCB testing. Arsenic speciation created uncertainty as to what percent of the total arsenic was inorganic arsenic. Sediments in the digestive tracts of large-scale suckers also created uncertainty as to the levels of lead in this species of fish. However, the other organic and inorganic analyses were acceptable.

Question:
Attachment B:

In this work we use statistical analysis on environmental monitoring data in making environmental impact decisions on how the data can be compared to regulatory standards and naturally occurring background concentrations. The statistics must be comprehensive, accurate, and employ valid modern statistical methods. In our review of the work accomplished and ongoing we identify the data accuracy and statistical analysis of the following items of concern and suggest changes and improvements that can be implemented to better define and identify the distribution of hazardous waste contaminants and their effects.

(1) Errors in computing the particle size percentages
(2) Statistical analysis of data with below detection limit values
(3) Statistical coverage of 95% upper confidence limits of the mean
(4) Goodness-of-Fit statistical tests
(5) Use of the lognormal distribution

The following EPA documents, statistical monographs, and articles are used in our investigation of this data. We provide brief comments on these references.

The EPA docs SML-06, ProUCL 4.0, and monographs and articles by Helsel, Conover, Birnham & Anderson, Gibbons & Coleman, Brooks, Lambert, Schmoyer . For listing see the references.

The EPA documents (EPA-docs) SML-06 and ProUCL 4.0 provide detailed and comprehensive statistical investigations of data sets with below detection limit (DL) observations, statistical coverage, outlier contamination of data, use of maximum value, normal (N), lognormal (LN), and gamma (GA) distributions. ProUCL 4.0 User Guide provides software and computer instructions for a complete analysis of below DL data sets. These documents and computer programs are available on the web. We endorse and recommend the procedures given in SML-06 and ProUCL 4.0.

Helsel's statistical monograph provides methods for analyzing censored environmental data. The accompanying Practical Stats web page has current statistical information and tutorials on statistical analysis of censored environmental data. The text by Gibbons and Coleman (2001) is recommended as an excellent source on environmental statistics, with examples that apply here. The article by Brooks (1982) contains an analysis of loss of information due to censoring. The paper by Lambert et al. (1991) investigates how detection limits are defined and relevant for statistical analysis of environmental data. The paper by Schmoyer et al. (1996) reinforces the statements made in SML-06 and discusses several mathematical statistics problems with the use of the LN distribution.

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(2) Statistical analysis of data with below detection limit values

EPA/R-10 has proposed using one-half the detection limit (DL/2) as a rule for values below the detection limit. The EPA SML-06, ProUCL 4.0 and other EPA documents and references given in these comments have conclusively proven that this is the worst method which can be used to analyze data with below detection limit values. Both SML-06 and ProUCL 4.0 provide recommendations for statistically reliable methods, tutorials, examples, and computer software. The documents and computer software are freely available on the web. Some material in these documents may require consultation with a statistician. The field work, time, and expense expended on this effort demand that the data analysis be valid. Helsel (2005a) when writing of using DL/2 for values below the detection limit stated; "The result is inaccurate statistics, poor and misleading regression models, and incorrect decisions about whether to remediate. There are better ways."

Some additional concerns are loss of information due to censoring, and establishment of the detection limit. Brooks (1982) analyzed the loss of information due to censoring and calculated relative estimates of the percent loss compared to no censoring for various combinations of sample size and censoring. As an example for 5% censoring the percent information loss can vary between 5% to 8% and for 25% censoring it can be between 27% to 36%. No guidance is provided for problems of statistical inference for samples with widely varying levels of censoring; and consequently, different levels of information content. This is analogous to comparing samples that have different variances (the much discussed Behrens-Fisher problem in statistics). The caveat here is to avoid statistical comparisons between samples of widely varying levels of censoring.

The article by Lambert, et al. (1991) introduces the concepts of the probability of acceptance and the probability of detection for field data with values below the detection limit. These concepts are used to investigate how detection limits are formulated and to confirm that detection limits are valid for statistical analysis. Examples of these concepts are shown using data from the Love Canal study.

It is generally believed that using DL/2 provides a conservative margin of safety for an exposed population. In fact, this belief is dead wrong. The SML-06 analysis shows that DL/2 coverage (for coverage see item (3)) was usually worse than any other method. For LN models with sample sizes around 15 the UCL95 coverage was less than 55% and was less than 70% for sample sizes of 100. This means in many cases more than 40% of the population would be over exposed to the contamination, and cleanup actions that should have been taken were not.

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(3) Statistical coverage of 95% UCLs of the mean.

Coverage refers to the percentage of the sampled population that is contained in the confidence limit. A 95% upper confidence limit (UCL95) should be a value in which 95% of the samples are equal to or less than this value. The data set should be a representative sample from a single study area or population. If the estimated UCL95 does not contain 95% of the population then cleanup or safety actions would not be taken that should be taken. If the estimated UCL95 contains more than 95% of the population then unnecessary actions are taken.

In this study the UCL95s are used, most notably, in the estimation of the exposure point concentration (EPC). For this purpose it is required to collect the necessary field samples to statistically compute valid UCL95s and to evaluate whether the necessary coverage is provided for the estimated population mean values.

It is intuitive, that associated with the problem of adequate coverage are estimates of sample size, use of surrogate values (such as maximum sample size) to estimate the EPC, outlier contamination of the data set, and use of the incorrect probability model (for instance inappropriate use of the LN model (see item 5)).

The plan adopted by EPA for the UCR and L. Roosevelt beach sampling was essentially taken from work performed by URS Greiner on the Coeur d'Alene basin. In that study the number of samples taken at each beach location was referred to as the "Max of N" method. It yielded a sample size of 7. The "Max of N" method was only designed to estimate a sample size necessary to obtain a value that is greater than the median. The "Max of N' method seriously underestimates the sample size required to obtain a reliable beach sample for even a normally distributed complete sample population, let alone for a population which is skewed and censored. A sample size of 7 to 15 would be inadequate to calculate a reliable UCL95 of the mean. The SML-06 document and appendices contain calculations and graphs that give coverage for several models, methods, and for various sample sizes. These results show that samples of size 7 to 20 do not provide the specified 95% coverage of the population mean. This is especially true for use of the maximum observation to estimate the EPC when the sample size is equal to or less than 20. Another drawback to using the maximum observation is, it may be an outlier that would result in an overestimate of the EPC. There are other methods that provide reliable estimates. The adjusted gamma model provides coverage close to 95% of the population mean for sample sizes about 10 and at least 95% coverage for samples ~20 and greater.

There is an important statistical principle to understand when considering coverage for a parameter value that will be used as a basis for action or inaction on human and/or ecological health, and environmental cleanup. We are specifying that we wish to include 95% of the population at a high level of confidence, but we also require that the interval will cover 96% or more of the population with a low probability. This is the standard criterion; we want to be safe but we do not want to over react. The use of "Max of N", and the maximum observation will not provide any guarantee of coverage.

In this study none of the beach, sediment, water, fish samples and bioassay tests provide adequate or reliable statistical coverage for the critical parameters needed to protect and evaluate human and ecological health.

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(4) Goodness-of Fit statistical tests.

There exist no satisfactory goodness-of-fit (GoF) tests for left censored, skewed data. Conover (1980, p367) makes the statement "We would be remiss if we did not point out that almost any goodness-of-fit test will result in rejection of the null hypothesis if the number of observations is very large." Conover could also have added that any statistical test of a hypothesis can lead to rejection if the sample size is large enough. GoF tests are conducted in the belief that the model chosen is best among the models considered and will be close enough to give reasonably accurate results. However, the power of a good statistical test should increase rapidly as the sample size increases, this is not the case for most GoF tests. It is an exception for a GoF test to approach a power of 0.50 and this has led statisticians to find improved alternatives to GoF tests. This has resulted in the development and use of model selection procedures. Their text on "Model Selection and Inference" Birnham and Anderson (1998, p32) states, "Full reality cannot be included in a model, thus we seek a good model to approximate the effects or factors supported by the empirical data." Christakos and Hristopulos (1998, p16) state that the question to be answered is "which model performs best among the various ones available?"

Among a candidate set of likely models (viz., normal, gamma, lognormal, Weibull, Cauchy, binomial, etc.) model selection procedures determine which model has the maximum likelihood of representing the data set considered. Although, the information theoretic approach of model selection lies deep in the theory of mathematical statistics, its application is simpler and less ambiguous than GoF hypothesis testing methods. Model selection applications and theory have been developed by Akiaki, Birnham and Anderson, Geisser, Kappenman, Kullback and Lieber, and many other statisticians. The writer while working with Kappenman (1985) developed computer programs which select from among seventeen symmetric and skewed distributions which model most closely represents the data.

It is important to investigate the consequences of misspecification of the correct model. In this study, we are working on percentiles or probabilities in the tails of a distribution and results can depend heavily on the model. For example the UCL95 would be much larger for the lognormal model than for either the normal or gamma model. SML-06 compared the tail properties of each of these models and concluded that the gamma model is more likely to represent skewed, left censored environmental data, also it is more accurate to use the normal model than the lognormal in all cases. The SML-06 investigation only considered the two parameter gamma model; however, the generalized gamma model has additional properties which make its use more flexible in modeling environmental data. In the analysis of the data collected here an investigation of model adequacy is lacking. The consequences would be comparable to that discussed in item (3) on statistical coverage.

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(5) Use of the lognormal distribution.

Environmental data are usually non-symmetric with positive skew and often contain trace levels of contaminants below the detection limit. The lognormal distribution has found popular usage for this data because a simple log transformation converts it to a normal distribution. There are problems with this simplicity that plague the use of the lognormal distribution. The heaviness of the right tail often results in estimates of the mean and upper confidence limits which may not be applicable in practice. This is especially true for small sample sizes with a few nondetects. Another problem arises when inferences are required in the original measurement scale instead of logarithmic scale. The back transformation from the log metric to the arithmetic metric is very tricky to handle and for small sample sizes, nondetects, and high skew cannot be achieved without serious bias. For example, unbiased estimators in one scale will become biased under non-linear transformation to another scale. Coverage probabilities in one scale may be below the nominal level in the other scale. Item (4) mentions problems with correctly selecting the lognormal model. Notable among these are the moments of the lognormal are not unique. Thus estimating a lognormal mean is ill-posed, and a lognormal distribution cannot be easily distinguished from some closely related heavy tailed distributions. For example, the log-t distribution cannot be distinguished from the lognormal by any GoF test even for sample sizes exceeding 5000. The first moment of the log-t distribution diverges and the mean does not exist Schmoyer (1996). The normal and gamma distributions have means and variances and lighter right tails than the lognormal. EPA documents SML-06 and ProUCL 4.0 and others provide detailed discussions and examples comparing the lognormal to the normal and gamma distributions for several combinations of estimation methods, skewness, sample sizes, and number of nondetects. They conclude that it is better to use either the normal or gamma distributions in all cases. Perhaps the lognormal distribution should bear a warning label “use only after consulting a statistician.”

Actually we should be considering models that are censored from both the right and left (from the left because of nondetects and from the right because only so much of a contaminant will fit into a unit volume). The river and the lake cannot be all mercury, lead, cadmium, dioxin, PCBs - .

Despite our enthusiasm for results there are situations where we must be honest with ourselves by emphasizing instead the limitations of the available information and determine how improved data and information can be obtained.

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4. Conover, W.J. 1980. *Practical Nonparametric Statistics.* John Wiley, N.Y.
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The following EPA documents

1. Singh, A.K., Singh, A., and Engelhardt, M. 1999. *Some Practical Aspects of Sample Size and Power Computations for Estimating the Mean of Positively Skewed Distributions in Environmental Applications. EPA/600/s-99/006.*
2. Singh, A., and Nocerino, J. 2001. *Robust Estimation of Mean and Variance Using Environmental Data Sets with Below Detection Limit Observations.* Technology Support Center Issue, Las Vegas, NV.

3. Singh, A., Singh, A.K., and Iaci, R.J. 2002. *Estimation of the Exposure Point Concentration Term Using a Gamma Distribution.* EPA/600/R-02/084.
4. Singh, A., Maichle, R., and Lee, S.E. 2006. *On the Computation of a 95% Upper Confidence Limit of the Unknown Population Mean Based Upon Data Sets with Below Detection Limit Observations.* EPA/600/R-06/022. Referred to in the text as **SML-06.**
5. Singh, A., Maichle, R., Singh, A.K., Lee, S.E. 2007. *ProUCL Version 4.0 User Guide.* EPA/600/R-07/038. Referred to in the text as **ProUCL 4.0.**
6. USEPA. 2006a. *Data Quality Assessment: A Reviewer's Guide.* EPA/240/B-06/002, QA/G-9R.
7. USEPA. 2006b. *Data Quality Assessment: Statistical Methods for Practitioners.* EPA/240/B-06/003, QA/G-9S.

Answer:

See EPA document cited below:

EPA 2006. On the Computation of a 95% Upper Confidence Limit of the Unknown Population Mean Based Upon Data Sets with Below Detection Limit Observations. EPS/600/R-06/022. http://www.epa.gov/esd/tsc/images/EPA%20600%20R-06%20022.pdf

Page 131:
"The maximum censoring level considered in the present simulation study is 70%. For data sets having a larger percentage of non-detects (e.g., 80%, 90%, or 99% non-detects), statistical estimates may not be reliable. Decisions about the use of an appropriate method (e.g., using proportion of NDs) should be made by the risk assessors and regulatory personnel on a site-specific basis."

Therefore, it is appropriate for DOH to explore the best way to evaluate the data including using half the detection limit or zero on a site-specific basis. However, as DOH explored the PCB and arsenic data as to possible ways to evaluate the data set, it became clear that the best approach was to ask EPA to resample and reanalyze the fish data. Similarly, DOH came to the same conclusion during the evaluation of lead data for the large-scale suckers. These conclusions were due to laboratory analysis of the samples not meeting data quality objectives in the case of PCB testing. Arsenic speciation created uncertainty as to what percent of the total arsenic was inorganic arsenic. Sediments in the digestive tracts of large-scale suckers also created uncertainty as to the levels of lead in this species of fish. However, the other organic and inorganic analyses were acceptable.

Question:

Attachment C:

Mr. Lenford O'Garro:

We appreciate the opportunity for public comment on the Health Consultation (HC) documents. We understand that we must delay our comments until the agencies comments are answered. However, we feel that it is important to bring our concerns on censored data to your attention now.

In Appendix D DOH states they will rely on the "commonly accepted practice" of using one-half the detection limit (DL) for data values below the DL. Rather than accepting this arbitrary rule DOH should look to what performs best among the choices available. No single procedure may be "correct" or "false" but among the choices available there may be one or more that are clearly better than others according to the criterion that must be satisfied. The object here is to extract information from data with below DL values. This problem is currently under investigation by statisticians, chemists, and environmental scientist. The activity has clearly demonstrated procedures that are superior to others. A limited literature review was provided in a list of data analysis concerns and sent to all Participating Parties including DOH on July 19, 2007. This report is appended to these comments as Appendices A and B. In comments made to EPA over a year ago the Citizens for a Clean Columbia criticized the ½ DL rule that EPA proposed to follow.

In particular, of all the methods for handling nondetect values the ½ DL rule has been shown to be the worst. EPA documents provide clear guidance on the use of better methods. For a bibliography of this material see Appendix A.

It would appear obvious to any responsible person that clearly demonstrated superior methods that are readily available, which fulfill the objective of extracting useful and reliable information from nondetect data, be applied to this data.

Throughout this document and the other DOH-HC on sediment health effects plus all EPA documents concerning the UCR and LR studies, and including the documents cited in Appendix A the method of censoring is considered Type I which is defined as the censoring point being fixed in advance. This means the censored values are random variables and the censoring is considered non-informative with respect to the contaminant being measured. However, in Appendix D for the PCB contaminant DOH proposes to use informative censoring. This radically alters all statistical analysis with this data. The use of standard formulas for likelihood and least squares estimation procedures will no longer be valid. It renders all statistical calculations on the PCB data such as averages, variances, confidence limits, percentiles, meal limits, etc. incorrect.
The PCB data must be recalculated using a valid method of censoring. Since this is needed for the PCB data all other data should be recalculated using the best method given in EPA documents EPA/600/R-06/022 and EPA/600/R-07/038, see Appendix A of these comments for citations.

The general user of statistics would not be expected to be cognizant of this distinction. Helsel (2005b) briefly discusses this point but he does not dwell on the mathematical statistics details. It is highly recommended that the DOH obtain statistical reviews of their documents.

The above EPA documents provide examples and graphs that clearly show the ½ DL rule does not provide reliable confidence limits and statistical coverage. See Appendix A for additional comments on DL's.

We are concerned about additional statements and results given in this HC that deserve full comment. A list of our concerns are:

- Statistical analysis of segmented composite sampling of fish
- Statistical coverage for confidence limits
- Data quality
- Sampling adequacy
- Point estimates are given, the uncertainty in all estimates should be given
- Assumptions and reliability of results should be discussed
- There are healthful and beneficial alternatives to eating fish, these should be discussed (for example, nuts)
- DOH should read Appendix A and B.

We consider it pointless to discuss these concerns in detail until the detection limit flaws are corrected. The use of the ½ DL rule renders the results in this HC fatally flawed and will require major corrections on the use of all data and calculations. The HC needs to be rewritten and submitted again for review.

Also, included was attachment B and paragraph below.

The work on the Upper Columbia River and Lake Roosevelt is concerned with real problems of pollution that impacts public health and environmental quality. We are realistically evaluating how the data collected can provide the information needed to make the decisions required to protect public health and remedy the environment.

We are convinced that the items we list and describe in this e-mail attachment (PP-StatAnal.doc) have an important impact on the actions taken in this work. We advocate an open meeting, with public involvement, of all Participating Parties.

Answer:
<u>Fish Health Consultation</u>

See EPA document cited below:

EPA 2006. On the Computation of a 95% Upper Confidence Limit of the Unknown Population Mean Based Upon Data Sets with Below Detection Limit Observations. EPS/600/R-06/022. http://www.epa.gov/esd/tsc/images/EPA%20600%20R-06%20022.pdf

Page 131:
"The maximum censoring level considered in the present simulation study is 70%. For data sets having a larger percentage of non-detects (e.g., 80%, 90%, or 99% non-detects), statistical estimates may not be reliable. Decisions about the use of an appropriate method (e.g., using proportion of NDs) should be made by the risk assessors and regulatory personnel on a site-specific basis."

Therefore, it is appropriate for DOH to explore the best way to evaluate the data including using half the detection limit or zero on a site-specific basis. However, as DOH explored the PCB and arsenic data as to possible ways to evaluate the data set, it became clear that the best approach was to ask EPA to resample and reanalyze the fish data. Similarly, DOH came to the same conclusion during the evaluation of lead data for the large-scale suckers. These conclusions were due to laboratory analysis of the samples not meeting data quality objectives in the case of PCB testing. Arsenic speciation created uncertainty as to what percent of the total arsenic was inorganic arsenic. Sediments in the digestive tracts of large-scale suckers also created uncertainty as to the levels of lead in this species of fish. However, the other organic and inorganic analyses were acceptable.

Question:
Attachment D:

May 27, 2008

RE: Revised Fish Consultation DOH April 08

To Whom it May Concern:

We are writing as members of the Board of Citizens for a Clean Columbia, a citizen action group dedicated to the clean-up and restoration to health of the Columbia River. Based on review by our mathematician member, Frank Ossiander, and our own review of the DOH/ATSDR Health Consultation, we continue to have concerns about the data and the statistical analysis. We were also dismayed to find that it was not until May 6th that a copy of the report was made available on the web site. This does not allow much time for those interested to comment on this long and somewhat convoluted report.

Frank notes that DOH made no changes to rectify the prior errors made by EPA (per comments sent on 7-19-07) and he noted additional errors as well. These included use of ½ the DL for non-detects, incorrect analysis of composite samples, "insider (or informative)" censoring of the PCB data, and invalid use of Haber's Rule. He has submitted his own comments and we, as a board, fully support him and would like to see a response to his concerns.

We would also like to know who was the responsible party for what appears to be a mostly failed study and what steps are being taken so that the next phase of study is not subject to these same errors. We understand that the cancer risk is small, but we have concerns about other potential health effects that have not yet been studied (for example, kidney damage (Cd, Cr, Cu), ulcers (Cr), liver disease (Cu), skin lesions (dioxin), and cognitive impairment/learning disability (Pb)). With respect to the report itself, the sections on the fish advisory, contaminants of concern, toxicity, and fish meal limits were clear. We found the information on the non-detects, PCB uncertainty, and what happened in this study confusing. A simplified table of results, as shown below, might have been easier to understand.

We appreciate the opportunity to comment on the report and look forward to continued dialogue on this most important process of discovery and clean-up.

Sincerely,

Matthew Wolohan (President and Treasurer); Clifford Ward (Vice president); Mindy Smith, MD (Secretary); and Board members: Carol Vrba, Hilary Ohm, Bob Jackman, Eleanor Mattice, Steve Schott, Mariah Pazerakas, and Russ Larson.

Table 1. Maximum concentration of concerning contaminants detected in whole body or fillet fish sampled at Lake Roosevelt in Northeast Washington (Phase 1; April – May 2005).

Substance	**Maximum Concentration (ppm)**	**Screening Values (ppm)***	**EPA Cancer Class****	**RfD+ (mg/kg/day)**	**Contaminant of Concern**
Arsenic	1.2	0.147	A	0.0003	Yes
Cadmium	4	0.49	B1	0.001	Yes
Chromium	12	1.47	D	0.003	Yes
Copper	160	19.7	D	0.04	Yes
Iron	2800	344		0.7	Yes
Lead	n/a	n/a	B2	n/a	Yes
Manganese	560	68.8	D	0.14	Yes
Mercury	0.4	0.049	D	0.0001	Yes
Thallium	0.32	0.039		0.00008	Yes
Zinc	1200	147.5	D	0.3	Yes
PCBs	0.08	0.0098	B2	0.00002	Yes
Dioxin	4.0E-6	4.9E-7		1.00E-9	Yes

*SV=RfD x mean body weight (kg)/mean daily consumption rate (kg/d) (if max concentration > SV, further study is required)
**A - EPA: Human carcinogen
B1 - EPA: Probable human carcinogen (limited human, sufficient animal studies)
B2 - EPA: Probable human carcinogen (inadequate human, sufficient animal studies)

D - EPA: Not classifiable as to health carcinogenicity
+Reference Dose (set by EPA) - A concentration in air, soil, or water below which adverse non-cancer health effects are not expected to occur.

Answer:

The 2006 and 2007 drafts of both health consultations were for agencies' comments only as was stated on the drafts. This point was made clear to Mr. Ossiander that the draft documents were for agencies comments only. At a later date, during the public comment period Mr. Ossiander, community groups, and other individuals can comment on the documents. However, while DOH did look at Mr. Ossiander comments at the time, no changes were made to the documents because it was not necessary due to the answers to Attachment C and Attachment E.

The Haber's rule forms the basis of inhalation toxicology (concentration x time = constant) and can be seen as a starting point for many of the formulas used in risk assessments. However, the formulas in the health consultations are used in standard and acceptable ways for human health and risk assessments.

Concerns about other potential health effects have not yet been studied (for example, kidney damage (Cd, Cr, Cu), ulcers (Cr), liver disease (Cu), skin lesions (dioxin), and cognitive impairment/learning disability (Pb)). These are issues that fall under non-cancer evaluation. Estimated dose for each contaminant was compared to EPA's oral reference dose (RfD). RfDs are doses below which non-cancer adverse health effects are not expected to occur (considered "safe" doses). They are derived from toxic effect levels obtained from human population and laboratory animal studies. 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 did not result in any adverse health effects.

Because of uncertainty in these data, the toxic effect level is divided by "safety factors" to produce the lower and more protective RfD. If a dose exceeds the RfD, 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 RfD, then that dose will fall well below the observed toxic effect level.

Question:

Attachment E: Composite Sampling

The EPA document: Final Phase I Fish Tissue Sampling Data Evaluation Upper Columbia River Site CERCLA RI/FS dated October 30, 2007, describes the sampling and data analysis for the sampled fish and fish tissue. The sampling plan specified a total of 180 composite samples (CS). CS were used for all fish sampled from the six fish sample locations along the lake and river.

A fish population is composed of individual members; it is a segmented population. The design and analysis of a CS program for fish will have to satisfy the acceptable statistical theory and procedures for sampling a segmented population. On the contrary, the procedures used by the EPA contractor, CH2M Hill, did not follow the correct segmented composite sampling statistical practices. Their methods of mixing the CS and estimating the variance were incorrect. As a result their estimates of the mean values for contaminants will be biased, and their estimates of variance will not even have any mathematical relationship to the actual segmented CS variance. As an example, they could have used a random number for their estimate of variance, it would be just as accurate. The research study by Fabrizio *et al.* (1995) on composite sampling of fish populations shows that the calculations used by the EPA contractor would underestimate the actual variance of fish contaminants by over an order of magnitude (over 10 times). The variance is used to estimate critical levels and upper confidence levels. All these values will be wildly in error and will have no factual support.

It is important to note that segmented CS will not provide a closed form, or analytical, estimate for variance. Elder *et al.* (1980) proved that the second moment diverges and a solution for variance is not possible. Fabrizio *et al.* assumed that some of the segmented CS variance terms were zero and used a double mixing design which assured that other variance terms were close to zero. With computer simulation, using a sample of measurements on 195 individual fish developed empirical curves for estimates of variance and sample size.

The EPA contractor summed the CS to obtain an overall average value for the contaminant concentration. Each CS is a sufficient statistic for estimating the average, and any of the samples would be a valid estimate of the average concentration. The operation of averaging the CS to obtain a mean value dilutes this mean value and will result in an underestimate. A better practice, to be protective of public health, would be to select the largest CS for an estimate of contaminant concentration.

The calculation errors in the EPA document render their results invalid; and also, render any downstream use of their results invalid.

References

Elder RS, Thompson WG, Myers RH. 1980. *Properties of Composite Sampling Procedures.* Technometrics 22:179-186.

Fabrizio MC, Frank AM, Savino JF. 1995. *Procedures for Formation of Composite Samples from Segmented Populations.* Environmental Science and Technology. 29:1137-1144.

Answer:

This attachment was best answered by EPA; therefore, it was forwarded to EPA. The EPA provided an answer in the form of a letter dated July 24, 2008, from Professor John R. Skalski of the University of Washington (Please refer to letter below). All follow-up questions or comments on this issue must be addressed to and by EPA.

SCHOOL OF AQUATIC & FISHERY SCIENCES
COLUMBIA BASIN RESEARCH

UNIVERSITY OF WASHINGTON

24 July 2008

Mr. Frank S. Dillon
NER Ecological Risk Assessment/
Natural Resources Damage Practice Leader
Environmental Services Group
CH2M Hill
2127 University Park Drive, Suite 360
Okemos, MI 48864

Dear Frank,
I didn't keep a copy of the Upper Columbia River (UCR) report since I wasn't an author, so my memory may be imperfect. The review comment refers to both the way the samples were analyzed in the lab and how the data were analyzed. My recollection was that for filet samples, equal mass from each fish was used in the compositing.

The analytical methods used in the UCR study, therefore, followed the compositing procedures in Fabrizio et al. (1995). For tissue analyses, the analysis was based on the "individual method" recommended by Fabrizio et al. (1995). The methods for the variance calculations were based on Eq. (4) of Fabrizio et al. (1995), where the number of aliquots within a fish was $k = 1$ and the number of fish per composite was $b = 5$. It was assumed the variance among aliquots within a fish, σ_ε^2, was negligible, such that for the average composite concentration,

$$\bar{y} = \frac{1}{c}\sum_{j=1}^{c} y_j$$

has an expected variance of

$$\mathrm{Var}(\bar{y}) = \frac{\sigma_S^2}{cb}.$$

based on Eq. (7) of Fabrizio et al. (1995) and where σ_S^2 is the between-fish variance and *c*, the number of composite samples. The assumption that σ_ε^2 was negligible is the same assumption Fabrizio et al. (1995) used in their simulation studies. Consistent with the methods in that referenced paper, σ_S^2 was then estimated by

$$\hat{\sigma}_S^2 = b \cdot s_y^2$$

where s_y^2 is the observed between-composite variance.

The inflammatory statement, "They could have used a random number for their estimate of variance, it would be just as accurate," is, according to their own reference, just not true. We *used* the recommended "individual method" in their reference.

What is inconsistent is the reviewer's recommendation to use the largest observed concentration among the composite samples. Nowhere in Fabrizio et al. (1995) do they suggest such a practice.

With regard to whole fish samples, I do not recall the exact laboratory protocol. You should compare that protocol to the "batch method" and the "individual method" in Fabrizio et al. (1995). In analyzing whole fish samples, the resulting concentration is, by definition, a weighted average of the various tissue masses and their individual concentrations. Averaging across fish, it is not obvious whether you would then want an arithmetic average (i.e., via the individual method) or a weighted average over fish sizes (i.e., via the batch method). Both methods have their strengths and weaknesses when interpreting the results.

Literature Cited
Fabrizio, M. C., A. M. Frank, and J. F. Savino. 1995. *Environmental Science & Technology* 29(5):1137-1143.

Sincerely,

John R. Skalski
Professor of Biological Statistics

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Report Preparation

This Health Consultation for the Upper Columbia River/Lake Roosevelt Site 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 is in accordance with the approved agency methods, policies, procedures existing at the date of publication. Editorial review was completed by the cooperative agreement partner. ATSDR has reviewed this document and concurs with its findings based on the information presented. ATSDR's approval of this document has been captured in an electronic database, and the approving agency reviewers are listed below.

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Appendix A - Screening Value Calculations

For Non-cancer Health Effects

SV = [(MRL or RfD)*BW]/CR [19]

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

BW (adult) = 70 kg
General population CR = 17.5 g/day
Non-Tribal High End Consumer CR = 142.4 g/day

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

For Cancer Health Effects
All contaminants that are possible carcinogens were automatically evaluated further except cadmium, which is based on inhalation and not ingestion.

Table A1. Maximum concentration of contaminants detected in whole body whitefish collected by EPA in 2005 from Lake Roosevelt in northeast Washington.

Chemicals	Maximum Concentration (ppm)	Screening Values (ppm)		EPA Cancer Class	(MRL or RfD) (mg/kg/day)	Contaminant of Concern
		General Population +	Non-Tribal High End Consumer ++			
Antimony	0.147U (0.074)	1.6	0.197	D	0.0004	No
Arsenic total	**0.312**	1.2	0.147	A	0.0003	**Yes**
Arsenic, inorganic 10% of total	0.0312	1.2	0.147	A	0.0003	No
Cadmium	0.135	4	0.49	B1 (inhalation)	0.001	No
Chromium	1.19	12	1.47	D	0.003	No
Copper	2.62	160	19.7	D	0.04	No
Iron	187.9	2800	344		0.7**	No
Lead	**0.449**	n/a	n/a	B2	n/a	**Yes**
Manganese	4.9	560	68.8	D	0.14	No
Mercury	**0.095**	0.4	0.049	D	0.0001*	**Yes**
Thallium	**0.092U (0.046)**	0.32	0.039		0.00008	**Yes**
Zinc	40.1	1200	147.5	D	0.3	No
Total PCBs	**0.066**	0.08	0.0098	B2	0.00002	**Yes**
Total Dioxin TEQ	**2.1E-5**	4.0E-6	4.9E-7		1.00E-9***	**Yes**

U- data qualifier indicating non-detect: (half of the concentration was used in subsequent evaluation).
A - EPA: Human carcinogen
B1 - EPA: Probable human carcinogen (limited human, sufficient animal studies)
B2 - EPA: Probable human carcinogen (inadequate human, sufficient animal studies)
D - EPA: Not classifiable as to health carcinogenicity
RfD - EPA oral reference dose
MRL- ATSDR's Minimal Risk Level
* Minimal Risk Level (MRL) for methlymercury
** Provisional RfD for Iron
*** ATSDR Minimal Risk Level (MRL) for Dioxin TEQ
n/a – not available
ppm – parts per million
mg/kg/day - milligrams per kilogram body-weight per day
PCBs – polychlorinated biphenyls
TEQ – Toxic Equivalent
% - percent
Bold – chemical is a contaminant of concern and the value exceed screening values (Appendix A) [19]

+ Derived from EPA Guidance for Assessing Chemical Contaminant Data (recreational fishers). Based on fish consumption rate of 17.5 g/day, 70 kg body weight for noncarcinogens exposure [19].

++ Derived from EPA Guidance for Assessing Chemical Contaminant Data (subsistence fishers). Based on fish consumption rate of 142 g/day, 70 kg body weight for noncarcinogens exposure [19].

Table A2. Maximum concentration of contaminants detected in fillet walleye collected by EPA in 2005 from Lake Roosevelt in northeast Washington.

Compounds	Maximum Concentration (ppm)	Screening Values (ppm)		EPA Cancer Class	(MRL or RfD) (mg/kg/day)	Contaminant of Concern
		General Population +	Non-Tribal High End Consumer ++			
Antimony	0.114U (0.057)	1.6	0.197	D	0.0004	No
Arsenic	**0.179**	1.2	0.147	A	0.0003	**Yes**
Arsenic, inorganic 10% of total	0.0179	1.2	0.147	A	0.0003	No
Cadmium	0.042	4	0.49	B1 (inhalation)	0.001	No
Chromium	0.969	12	1.47	D	0.003	No
Copper	0.572	160	19.7	D	0.04	No
Iron	13.13	2800	344		0.7**	No
Lead	**0.223**	n/a	n/a	B2	n/a	**Yes**
Manganese	2.25	560	68.8	D	0.14	No
Mercury	**0.417**	0.4	0.049	D	0.0001*	**Yes**
Thallium	**0.074**	0.32	0.039		0.00008	**Yes**
Zinc	15.9	1200	147.5	D	0.3	No
Total PCBs	**0.014**	0.08	0.0098	B2	0.00002	**Yes**
Total Dioxin TEQ	**2.51E-7**	4.0E-6	4.9E-7		1.00E-9***	**Yes**

U- data qualifier indicating non-detect (half of the concentration was used in subsequent evaluation)
A - EPA: Human carcinogen
B1 - EPA: Probable human carcinogen (limited human, sufficient animal studies)
B2 - EPA: Probable human carcinogen (inadequate human, sufficient animal studies)
D - EPA: Not classifiable as to health carcinogenicity
RfD - EPA oral reference dose
MRL- ATSDR's Minimal Risk Level
* Minimal Risk Level (MRL) for methlymercury
** Provisional RfD for Iron
*** ATSDR Minimal Risk Level (MRL) for Dioxin TEQ
n/a – not available
ppm – parts per million
mg/kg/day - milligrams per kilogram body-weight per day
PCBs – polychlorinated biphenyls
TEQ – Toxic Equivalent
% - percent
Bold – chemical is a contaminant of concern and the value exceed screening values (Appendix A) [19]

\+ Derived from EPA Guidance for Assessing Chemical Contaminant Data (recreational fishers). Based on fish consumption rate of 17.5 g/day, 70 kg body weight for noncarcinogens exposure [19].

\++ Derived from EPA Guidance for Assessing Chemical Contaminant Data (subsistence fishers). Based on fish consumption rate of 142 g/day, 70 kg body weight for noncarcinogens exposure [19].

Table A3. Maximum concentration of contaminants detected in whole body large-scale sucker collected by EPA in 2005 from Lake Roosevelt in northeast Washington.

Compounds	Maximum Concentration (ppm)	Screening Values (ppm)		EPA Cancer Class	(MRL or RfD) (mg/kg/day)	Contaminant of Concern
		General Population +	Non-Tribal High End Consumer ++			
Antimony	**0.584**	1.6	0.197	D	0.0004	**Yes**
Arsenic	**0.334**	1.2	0.147	A	0.0003	**Yes**
Arsenic, inorganic 10% of total	0.0334	1.2	0.147	A	0.0003	No
Cadmium	**0.544**	4	0.49	B1 (inhalation)	0.001	**Yes**
Chromium	**8.2**	12	1.47	D	0.003	**Yes**
Copper	**48.49**	160	19.7	D	0.04	**Yes**
Iron	**1990**	2800	344		0.7**	**Yes**
Lead	**7.814**	n/a	n/a	B2	n/a	**Yes**
Manganese	**85.22**	560	68.8	D	0.14	**Yes**
Mercury	**0.300**	0.4	0.049	D	0.0001*	**Yes**
Thallium	**0.078U (0.039)**	0.32	0.039		0.00008	**Yes**
Zinc	**359.35**	1200	147.5	D	0.3	**Yes**
Total PCBs	**0.419**	0.08	0.0098	B2	0.00002	**Yes**
Total Dioxin TEQ	**2.4E-5**	4.0E-6	4.9E-7		1.00E-9***	**Yes**

U- data qualifier indicating non-detect (half of the concentration was used in subsequent evaluation)
A - EPA: Human carcinogen
B1 - EPA: Probable human carcinogen (limited human, sufficient animal studies)
B2 - EPA: Probable human carcinogen (inadequate human, sufficient animal studies)
D - EPA: Not classifiable as to health carcinogenicity
RfD - EPA oral reference dose
MRL- ATSDR's Minimal Risk Level
* Minimal Risk Level (MRL) for methlymercury
** Provisional RfD for Iron
*** ATSDR Minimal Risk Level (MRL) for Dioxin TEQ
n/a – not available
ppm – parts per million
mg/kg/day - milligrams per kilogram body-weight per day
PCBs – polychlorinated biphenyls
TEQ – Toxic Equivalent
% - percent
Bold – chemical is a contaminant of concern and the value exceed screening values (Appendix A) [19]

+ Derived from EPA Guidance for Assessing Chemical Contaminant Data (recreational fishers). Based on fish consumption rate of 17.5 g/day, 70 kg body weight for noncarcinogens exposure [19].

++ Derived from EPA Guidance for Assessing Chemical Contaminant Data (subsistence fishers). Based on fish consumption rate of 142 g/day, 70 kg body weight for noncarcinogens exposure [19].

Table A4. Maximum concentration of contaminants detected in fillet wild rainbow trout collected by EPA in 2005 from Lake Roosevelt in northeast Washington.

Compounds	Maximum Concentration (ppm)	Screening Values (ppm)		EPA Cancer Class	(MRL or RfD) (mg/kg/day)	Contaminant of Concern
		General Population +	Non-Tribal High End Consumer ++			
Antimony	0.128U (0.064)	1.6	0.197	D	0.0004	No
Arsenic	0.101	1.2	0.147	A	0.0003	No
Arsenic, inorganic 10% of total	0.0101	1.2	0.147	A	0.0003	No
Cadmium	0.066	4	0.49	B1 (inhalation)	0.001	No
Chromium	1.02	12	1.47	D	0.003	No
Copper	1.94	160	19.7	D	0.04	No
Iron	50.48	2800	344		0.7**	No
Lead	**0.253**	n/a	n/a	B2	n/a	**Yes**
Manganese	2.38	560	68.8	D	0.14	No
Mercury	**0.120**	0.4	0.049	D	0.0001*	**Yes**
Thallium	0.069U (0.035)	0.32	0.039		0.00008	No
Zinc	30	1200	147.5	D	0.3	No
Total PCBs	**0.037**	0.08	0.0098	B2	0.00002	**Yes**
Total Dioxin TEQ	**5.51E-7**	4.0E-6	4.9E-7		1.00E-9***	**Yes**

U- data qualifier indicating non-detect: (half of the concentration was used in subsequent evaluation)
A - EPA: Human carcinogen
B1 - EPA: Probable human carcinogen (limited human, sufficient animal studies)
B2 - EPA: Probable human carcinogen (inadequate human, sufficient animal studies)
D - EPA: Not classifiable as to health carcinogenicity
RfD - EPA oral reference dose
MRL- ATSDR's Minimal Risk Level
* Minimal Risk Level (MRL) for methlymercury
** Provisional RfD for Iron
*** ATSDR Minimal Risk Level (MRL) for Dioxin TEQ
n/a – not available
ppm – parts per million
mg/kg/day - milligrams per kilogram body-weight per day
PCBs – polychlorinated biphenyls
TEQ – Toxic Equivalent
% - percent
Bold – chemical is a contaminant of concern and the value exceed screening values (Appendix A) [19]

+ Derived from EPA Guidance for Assessing Chemical Contaminant Data (recreational fishers). Based on fish consumption rate of 17.5 g/day, 70 kg body weight for noncarcinogens exposure [19].

++ Derived from EPA Guidance for Assessing Chemical Contaminant Data (subsistence fishers). Based on fish consumption rate of 142 g/day, 70 kg body weight for noncarcinogens exposure [19].

Table A5. Maximum concentration of contaminants detected in fillet hatchery rainbow trout collected by EPA in 2005 from Lake Roosevelt in northeast Washington.

Compounds	Maximum Concentration (ppm)	Screening Values (ppm)		EPA Cancer Class	(MRL or RfD) (mg/kg/day)	Contaminant of Concern
		General Population +	Non-Tribal High End Consumer ++			
Antimony	0.124U (0.062)	1.6	0.197	D	0.0004	No
Arsenic	0.081	1.2	0.147	A	0.0003	No
Arsenic, inorganic 10% of total	0.0081	1.2	0.147	A	0.0003	No
Cadmium	0.068	4	0.49	B1 (inhalation)	0.001	No
Chromium	0.773	12	1.47	D	0.003	No
Copper	2.57	160	19.7	D	0.04	No
Iron	45.17	2800	344		0.7**	No
Lead	**0.211**	n/a	n/a	B2	n/a	**Yes**
Manganese	2.9	560	68.8	D	0.14	No
Mercury	**0.122**	0.4	0.049	D	0.0001*	**Yes**
Thallium	0.063U (0.032)	0.32	0.039		0.00008	No
Zinc	26.24	1200	147.5	D	0.3	No
Total PCBs	**0.010**	0.08	0.0098	B2	0.00002	**Yes**
Total Dioxin TEQ	**9.39E-7**	4.0E-6	4.9E-7		1.00E-9***	**Yes**

U- data qualifier indicating non-detect: (half of the concentration was used in subsequent evaluation).
A - EPA: Human carcinogen
B1 - EPA: Probable human carcinogen (limited human, sufficient animal studies)
B2 - EPA: Probable human carcinogen (inadequate human, sufficient animal studies)
D - EPA: Not classifiable as to health carcinogenicity
RfD - EPA oral reference dose
MRL- ATSDR's Minimal Risk Level
* Minimal Risk Level (MRL) for methlymercury
** Provisional RfD for Iron
*** ATSDR Minimal Risk Level (MRL) for Dioxin TEQ
n/a – not available
ppm – parts per million
mg/kg/day - milligrams per kilogram body-weight per day
PCBs – polychlorinated biphenyls
TEQ – Toxic Equivalent
% - percent
Bold – chemical is a contaminant of concern and the value exceed screening values (Appendix A) [19]

+ Derived from EPA Guidance for Assessing Chemical Contaminant Data (recreational fishers). Based on fish consumption rate of 17.5 g/day, 70 kg body weight for noncarcinogens exposure [19].

++ Derived from EPA Guidance for Assessing Chemical Contaminant Data (subsistence fishers). Based on fish consumption rate of 142 g/day, 70 kg body weight for noncarcinogens exposure [19].

Table A6. Maximum concentration of contaminants detected in whole body burbot collected by EPA in 2005 from Lake Roosevelt in northeast Washington.

Compounds	Maximum Concentration (ppm)	Screening Values (ppm)		EPA Cancer Class	(MRL or RfD) (mg/kg/day)	Contaminant of Concern
		General Population +	Non-Tribal High End Consumer ++			
Antimony	0.090U (0.045)	1.6	0.197	D	0.0004	No
Arsenic	**0.958**	1.2	0.147	A	0.0003	**Yes**
Arsenic, inorganic 10% of total	0.0958	1.2	0.147	A	0.0003	No
Cadmium	0.088	4	0.49	B1 (inhalation)	0.001	No
Chromium	**1.485**	12	1.47	D	0.003	**Yes**
Copper	1.51	160	19.7	D	0.04	No
Iron	37.98	2800	344		0.7**	No
Lead	**0.192**	n/a	n/a	B2	n/a	**Yes**
Manganese	3.42	560	68.8	D	0.14	No
Mercury	**0.242**	0.4	0.049	D	0.0001*	**Yes**
Thallium	0.057U (0.0285)	0.32	0.039		0.00008	No
Zinc	13.9	1200	147.5	D	0.3	No
Total PCBs	**0.058**	0.08	0.0098	B2	0.00002	**Yes**
Total Dioxin TEQ	**9.3E-7**	4.0E-6	4.9E-7		1.00E-9***	**Yes**

U- data qualifier indicating non-detect: (half of the concentration was used in subsequent evaluation).
A - EPA: Human carcinogen
B1 - EPA: Probable human carcinogen (limited human, sufficient animal studies)
B2 - EPA: Probable human carcinogen (inadequate human, sufficient animal studies)
D - EPA: Not classifiable as to health carcinogenicity
RfD - EPA oral reference dose
MRL- ATSDR's Minimal Risk Level
* Minimal Risk Level (MRL) for methlymercury
** Provisional RfD for Iron
*** ATSDR Minimal Risk Level (MRL) for Dioxin TEQ
n/a – not available
ppm – parts per million
mg/kg/day - milligrams per kilogram body-weight per day
PCBs – polychlorinated biphenyls
TEQ – Toxic Equivalent
% - percent
Bold – chemical is a contaminant of concern and the value exceed screening values (Appendix A) [19]

+ Derived from EPA Guidance for Assessing Chemical Contaminant Data (recreational fishers). Based on fish consumption rate of 17.5 g/day, 70 kg body weight for noncarcinogens exposure [19].

++ Derived from EPA Guidance for Assessing Chemical Contaminant Data (subsistence fishers). Based on fish consumption rate of 142 g/day, 70 kg body weight for noncarcinogens exposure [19].

Appendix B - Dose and Cancer Risk Calculations

This section provides calculated exposure doses and assumptions used for exposure to chemicals in fish in Lake Roosevelt (Table B1). These exposure scenarios were developed to model exposures that might occur. These scenarios were devised to represent exposures to a general population (Gen) child, Non-tribal high-end consumer (Sub) child (0-6 yrs), a Gen adult, and Non-tribal high-end consumer (Sub) adult. The following exposure parameters and dose equations were used to estimate exposure doses from ingestion of chemicals in fish.

Table B1. Exposure assumptions used to determine exposure to contaminants in fish samples from Lake Roosevelt in northeast Washington (2005).

Ingestion Route

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

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

Parameter	Value	Unit	Comments
Concentration (C)	Variable	ug/kg	Average detected value
Conversion Factor (CF_1)	0.001	mg/ug	Converts contaminant concentration from micrograms (ug) to milligrams (mg)
Conversion Factor (CF_2)	0.001	kg/g	Converts mass of fish from grams (g) to kilograms (kg)
Ingestion Rate (IR)	7	g/day	Average general population child
Ingestion Rate (IR)	60		Non-tribal high-end consumer (SUB) child used at Portland Harbor, Oregon
Ingestion Rate (IR)	17.5		Average general population adult
Ingestion Rate (IR)	142.4		EPA subsistence fisher (SUB) adult
Exposure Frequency (EF)	365	days/year	Assumes daily exposure
Exposure Duration (ED)	6	years	Number of years (child)
Exposure Duration (ED)	30		Number of years (adult)
Body weight (BW)	15	kg	Mean body weight child
Body weight (BW)	70		Mean body weight adult
Averaging Time$_{\text{non-cancer}}$ (AT)	Variable	days	Equal to Exposure Duration
Averaging Time$_{\text{cancer}}$ (AT)	25550	days	70 years
Cancer Potency Factor (CPF)	Variable	mg/kg-day^{-1}	Source: EPA – Chemical specific

Table B2. Average concentration of each contaminant used in each reach of Lake Roosevelt in the exposure assessment (2005).

Fish Species	Contaminant	Average Concentration (ppm)		
		Upper Reservoir Reach	Middle Reservoir Reach	Lower Reservoir Reach
Whitefish*	Arsenic	0.0185	0.026	0.027
	Mercury	0.07	0.0558	0.0764
	Thallium	0.043	0.039	0.041
	Total PCBs	0.0382	0.0162	0.0253
	Dioxin TEQ	8.86E-7	1.25E-6	8.18E-7
Walleye**	Arsenic	0.0088	0.011	0.013
	Mercury	0.227	0.241	0.334
	Thallium	0.026	0.026	0.065
	Total PCBs	0.00348	0.00476	0.00348
	Dioxin TEQ	1.91E-7	1.52E-7	1.16E-7
Large-scale sucker*	Arsenic	0.017	0.0104	0.018
	Antimony	0.085	0.050	0.055
	Cadmium	0.329	0.248	0.264
	Chromium	0.999	0.785	1.178
	Copper	2.068	0.688	0.765
	Iron	140.90	54.19	61.55
	Manganese	7.89	5.60	6.07
	Mercury	0.17	0.27	0.23
	Thallium	0.0324	0.031	0.034
	Zinc	39.17	21.14	18.90
	Total PCBs	0.1083	0.09114	0.10454
	Dioxin TEQ	1.06E-6	1.08E-6	9.08E-7
Rainbow Trout Wild **	Arsenic	0.0089	0.0074	0.0080
	Mercury	0.087	0.076	0.12
	Total PCBs	0.02383	0.0085	0.0057
	Dioxin TEQ	3.92E-7	5.45E-7	2.49E-7
Rainbow Trout Hatchery **	Arsenic	NA	0.0031	0.0041
	Mercury	NA	0.067	0.098
	Total PCBs	NA	0.00703	0.00784
	Dioxin TEQ	NA	5.96E-7	7.78E-7
Burbot *	Arsenic	0.073	0.070	0.084
	Chromium	0.434	0.354	0.458
	Mercury	0.138	0.175	0.196
	Total PCBs	0.030	0.02709	0.0266
	Dioxin TEQ	8.30E-7	6.59E-7	7.05E-7

* Whole fish
** Fillet
NA – not available
ppm – parts per million
PCBs – polychlorinated biphenyls
TEQ – Toxic Equivalent

Table B3. Exposure dose and non-cancer risk from ingesting fish at maximum concentration of contaminants in Lake Roosevelt (2005).

Fish Species	Contaminant	Estimated Dose				RfD/ MRL (mg/kg/day)	Hazard Quotient			
		Gen Child (mg/kg/day)	Gen Adult (mg/kg/day)	Sub Child (mg/kg/day)	Sub Adult (mg/kg/day)		Gen Child	Gen Adult	Sub Child	Sub Adult
Whitefish*	Mercury	4.43E-5	2.38E-5	3.80E-4	1.93E-4	1.00E-4	0.4	0.2	**4**	**2**
	Thallium	2.15E-5	1.15E-5	1.84E-4	9.36E-5	8.00E-5	0.3	0.1	**2**	1
	Total PCBs	3.08E-5	1.65E-5	2.64E-4	1.34E-4	2.00E-5	**2**	0.8	**13**	**7**
	Dioxin TEQ	9.80E-10	5.25E-10	8.40E-9	4.27E-9	1.00E-9	1	0.5	**8**	**4**
	Hazard Index = Sum of hazard quotient						**3.7**	**1.6**	**27**	**14**
Walleye**	Mercury	1.46E-4	7.80E-5	1.25E-3	6.35E-4	1.00E-4	**2**	0.8	**16**	**8**
	Thallium	3.45E-5	1.85E-5	2.96E-4	1.51E-4	8.00E-5	0.4	0.2	**4**	**2**
	Total PCBs	4.99E-5	2.68E-5	4.28E-4	2.18E-4	2.00E-5	**3**	1	**21**	**11**
	Dioxin TEQ	1.17E-10	6.28E-11	1.00E-9	5.11E-10	1.00E-9	0.1	0.06	1	0.5
	Hazard Index = Sum of hazard quotient						**5.5**	**2.1**	**42**	**22**
Large-scale Sucker*	Antimony	2.73E-4	1.46E-4	2.34E-3	1.19E-3	4.00E-4	0.7	0.4	**6**	**3**
	Cadmium	2.54E-4	1.36E-4	2.18E-3	1.11E-3	1.00E-3	0.3	0.1	**2**	1
	Chromium	3.83E-3	2.05E-3	3.28E-2	1.67E-2	3.00E-3	1	0.7	**11**	**6**
	Copper	2.26E-2	1.21E-2	1.94E-1	9.86E-2	4.00E-2	0.6	0.3	**5**	**3**
	Iron	9.29E-1	4.98E-1	7.96E+0	4.05E+0	7.00E-1	1	0.7	**11**	**6**
	Manganese	3.98E-2	2.13E-2	3.41E-1	1.73E-1	1.40E-1	0.3	0.2	**2**	**1**
	Mercury	1.40E-4	7.50E-5	1.20E-3	6.10E-4	1.00E-4	1	0.8	**12**	**6**
	Thallium	1.82E-5	9.75E-6	1.56E-4	7.93E-5	8.00E-5	0.2	0.1	**2**	1
	Zinc	1.68E-1	8.98E-2	1.44E+0	7.31E-1	3.00E-1	0.6	0.3	**5**	**2**
	Total PCBs	1.96E-4	1.05E-4	1.68E-3	8.52E-4	2.00E-5	**10**	**5**	**84**	**43**
	Dioxin TEQ	1.12E-9	6.00E10	9.60E-9	4.88E-9	1.00E-9	1	0.6	**10**	**5**
	Hazard Index = Sum of hazard quotient						**16.7**	**9.2**	**150**	**77**
Rainbow Trout Wild **	Mercury	5.60E-5	3.00E-5	4.80E-4	2.44E-4	1.00E-4	0.6	0.3	**5**	**2**
	Total PCBs	1.73E-5	9.25E-6	1.48E-4	7.53E-5	2.00E-5	0.9	0.5	**7**	**4**
	Dioxin TEQ	2.57E-10	1.38E-10	2.20E-9	1.12E-9	1.00E-9	0.3	0.1	**2**	1
	Hazard Index = Sum of hazard quotient						**1.8**	0.9	**14**	**7**
Rainbow Trout Hatchery **	Mercury	5.69E-5	3.05E-5	4.88E-4	2.48E-4	1.00E-4	0.6	0.3	**5**	**3**
	Total PCBs	4.67E-6	2.50E-6	4.00E-5	2.03E-5	2.00E-5	0.2	0.1	**2**	1
	Dioxin TEQ	4.38E-10	2.35E-10	3.76E-9	1.91E-9	1.00E-9	0.44	0.2	**4**	**2**
	Hazard Index = Sum of hazard quotient						**1.2**	0.6	**11**	**6**
Burbot *	Chromium	6.93E-4	3.71E-4	5.94E-3	3.02E-3	3.00E-3	0.2	0.1	**2**	1
	Mercury	1.13E-4	6.05E-5	9.68E-4	4.92E-4	1.00E-4	1	0.6	**10**	**5**
	Total PCBs	2.71E-5	1.45E-5	2.32E-4	1.18E-4	2.00E-5	1	0.7	**12**	**6**
	Dioxin TEQ	4.34E-10	2.33E-10	3.72E-9	1.89E-9	1.00E-9	0.4	0.2	**4**	**2**
	Hazard Index = Sum of hazard quotient						**2.6**	**1.6**	**28**	**14**

* Whole fish
** Fillet
RfD - EPA oral reference dose
MRL- ATSDR's Minimal Risk Level
Bold values exceed Hazard Quotient of 1
mg/kg/day - milligrams per kilogram body-weight per day
PCBs – polychlorinated biphenyls
TEQ – Toxic Equivalent
Gen – General population
Sub – Non-tribal high-end consumer

Table B4. Exposure dose and non-cancer risk from ingesting fish at average concentration of contaminants in the Upper Reservoir reach of Lake Roosevelt (2005).

Fish Species	Contaminant	Estimated Dose				RfD/ MRL (mg/kg/day)	Hazard Quotient			
		Gen Child (mg/kg/day)	Gen Adult (mg/kg/day)	Sub Child (mg/kg/day)	Sub Adult (mg/kg/day)		Gen Child	Gen Adult	Sub Child	Sub Adult
Whitefish*	Mercury	3.27E-5	1.75E-5	2.80E-4	1.43E-4	1.00E-4	0.3	0.2	**3**	1
	Thallium	2.01E-5	1.08E-5	1.72E-4	8.76E-5	8.00E-5	0.3	0.1	**2**	1
	Total PCBs	1.78E-5	9.55E-6	1.53E-4	7.77E-5	2.00E-5	0.9	0.5	**8**	**4**
	Dioxin TEQ	4.67E-10	2.50E-10	4.00E-9	2.03E-9	1.00E-9	0.5	0.3	**4**	**2**
	Hazard Index = Sum of hazard quotient						**2.0**	**1.1**	**17**	**8**
Walleye**	Mercury	1.06E-4	5.68E-5	9.09E-4	4.62E-4	1.00E-4	1	0.6	**9**	**5**
	Thallium	1.22E-5	6.55E-6	1.05E-4	5.33E-5	8.00E-5	0.2	0.08	1	0.7
	Total PCBs	1.62E-6	8.70E-7	1.39E-5	7.08E-6	2.00E-5	0.08	0.04	0.7	0.4
	Dioxin TEQ	8.91E-11	4.78E-11	7.64E-10	3.89E-10	1.00E-9	0.09	0.05	0.8	0.4
	Hazard Index = Sum of hazard quotient						**1.4**	0.8	**11.5**	**6.5**
Large-scale Sucker*	Antimony	3.95E-5	2.11E-5	3.38E-4	1.72E-4	4.00E-4	0.1	0.05	0.9	0.4
	Cadmium	1.54E-4	8.23E-5	1.32E-3	6.70E-4	1.00E-3	0.2	0.08	1	0.7
	Chromium	4.66E-4	2.50E-4	4.00E-3	2.03E-3	3.00E-3	0.2	0.08	1	0.7
	Copper	9.65E-4	5.17E-4	8.27E-3	4.21E-3	4.00E-2	0.02	0.01	0.2	0.1
	Iron	6.58E-2	3.52E-2	5.64E-1	2.87E-1	7.00E-1	0.09	0.05	0.8	0.4
	Manganese	5.50E-3	2.95E-3	4.72E-2	2.40E-2	1.40E-1	0.04	0.02	0.3	0.2
	Mercury	8.04E-5	4.31E-5	6.89E-4	3.50E-4	1.00E-4	0.8	0.4	**7**	**4**
	Thallium	1.51E-5	8.10E-6	1.30E-4	6.59E-5	8.00E-5	0.2	0.1	**2**	0.8
	Zinc	1.83E-2	9.79E-3	1.57E-1	7.97E-2	3.00E-1	0.06	0.03	0.5	0.3
	Total PCBs	5.05E-5	2.71E-5	4.33E-4	2.20E-4	2.00E-5	**3**	1	**22**	**11**
	Dioxin TEQ	4.95E-10	2.65E-10	4.24E-9	2.16E-9	1.00E-9	0.5	0.3	**4**	**2**
	Hazard Index = Sum of hazard quotient						**5.2**	**2.1**	**39.7**	**20.6**
Rainbow Trout Wild **	Mercury	4.04E-5	2.17E-5	3.47E-4	1.76E-4	1.00E-4	0.4	0.2	**4**	**2**
	Total PCBs	1.11E-5	5.95E-6	9.52E-5	4.84E-5	2.00E-5	0.6	0.3	**5**	**2**
	Dioxin TEQ	1.83E-10	9.80E-11	1.57E-9	7.97E-10	1.00E-9	0.2	0.1	**2**	0.7
	Hazard Index = Sum of hazard quotient						**1.2**	0.6	**11**	**4.7**
Rainbow Trout Hatchery **	Mercury	NA	NA	NA	NA	1.00E-4	NA	NA	NA	NA
	Total PCBs	NA	NA	NA	NA	2.00E-5	NA	NA	NA	NA
	Dioxin TEQ	NA	NA	NA	NA	1.00E-9	NA	NA	NA	NA
Burbot *	Chromium	2.02E-4	1.08E-4	1.73E-3	8.82E-4	3.00E-3	0.07	0.04	0.6	0.3
	Mercury	6.44E-5	3.45E-5	5.52E-4	2.81E-4	1.00E-4	0.6	0.4	**6**	**3**
	Total PCBs	1.40E-5	7.50E-6	1.20E-4	6.10E-5	2.00E-5	0.7	0.4	**6**	**3**
	Dioxin TEQ	3.87E-10	2.08E-10	3.32E-9	1.69E-9	1.00E-9	0.4	0.2	**3**	**2**
	Hazard Index = Sum of hazard quotient						**1.8**	1.0	**15.6**	**8.3**

* Whole fish
** Fillet
NA – not available
RfD - EPA oral reference dose
MRL- ATSDR's Minimal Risk Level
Bold values exceed Hazard Quotient of 1
mg/kg/day - milligrams per kilogram body-weight per day
PCBs – polychlorinated biphenyls
TEQ – Toxic Equivalent
Gen – General population
Sub – Non-tribal high-end consumer

Table B5. Exposure dose and non-cancer risk from ingesting fish at average concentration of contaminants in the Middle Reservoir reach of Lake Roosevelt (2005).

Fish Species	Contaminant	Estimated Dose				RfD/ MRL (mg/kg/day)	Hazard Quotient			
		Gen Child (mg/kg/day)	Gen Adult (mg/kg/day)	Sub Child (mg/kg/day)	Sub Adult (mg/kg/day)		Gen Child	Gen Adult	Sub Child	Sub Adult
Whitefish*	Mercury	2.59E-5	1.39E-5	2.22E-4	1.13E-4	1.00E-4	0.3	0.1	**2**	1
	Thallium	1.84E-5	9.84E-6	1.58E-4	8.01E-5	8.00E-5	0.2	0.1	**2**	1
	Total PCBs	7.56E-6	4.05E-6	6.48E-5	3.30E-5	2.00E-5	0.4	0.2	**3**	**2**
	Dioxin TEQ	6.65E-10	3.56E-10	5.70E-9	2.90E-9	1.00E-9	0.7	0.4	**6**	**3**
	Hazard Index = Sum of hazard quotient						**1.6**	0.8	**13**	**7**
Walleye**	Mercury	1.12E-4	6.02E-5	9.62E-4	4.89E-4	1.00E-4	1	0.6	**10**	**5**
	Thallium	1.22E-5	6.55E-6	1.05E-4	5.33E-5	8.00E-5	0.2	0.08	1	0.7
	Total PCBs	2.22E-6	1.19E-6	1.90E-5	9.68E-6	2.00E-5	0.1	0.06	1	0.5
	Dioxin TEQ	9.99E-11	5.35E-11	8.56E-10	4.35E-10	1.00E-9	0.1	0.05	0.9	0.4
	Hazard Index = Sum of hazard quotient						**1.4**	0.8	**12.9**	**6.6**
Large-scale Sucker*	Antimony	2.32E-5	1.24E-5	1.99E-4	1.01E-4	4.00E-4	0.06	0.03	0.5	0.3
	Cadmium	1.16E-4	6.20E-5	9.91E-4	5.04E-4	1.00E-3	0.1	0.06	1	0.5
	Chromium	3.66E-4	1.96E-4	3.14E-3	1.60E-3	3.00E-3	0.1	0.07	1	0.5
	Copper	3.21E-4	1.72E-4	2.75E-3	1.40E-3	4.00E-2	0.01	0.004	0.07	0.03
	Iron	2.53E-2	1.35E-2	2.17E-1	1.10E-1	7.00E-1	0.04	0.02	0.3	0.2
	Manganese	2.79E-3	1.49E-3	2.39E-2	1.22E-2	1.40E-1	0.02	0.01	0.2	0.09
	Mercury	1.26E-4	6.75E-5	1.08E-3	5.49E-4	1.00E-4	1	0.7	**11**	**6**
	Thallium	1.44E-5	7.73E-6	1.24E-4	6.29E-5	8.00E-5	0.2	0.1	**2**	0.8
	Zinc	9.87E-3	5.29E-3	8.46E-2	4.30E-2	3.00E-1	0.03	0.02	0.3	0.1
	Total PCBs	4.25E-5	2.28E-5	3.65E-4	1.85E-4	2.00E-5	**2**	1	**18**	**9**
	Dioxin TEQ	5.04E-10	2.70E-10	4.32E-9	2.20E-9	1.00E-9	0.5	0.3	**4**	**2**
	Hazard Index = Sum of hazard quotient						**4.1**	**2.3**	**38.4**	**19.5**
Rainbow Trout Wild **	Mercury	3.55E-5	1.90E-5	3.04E-4	1.55E-4	1.00E-4	0.4	0.2	**3**	**2**
	Total PCBs	3.97E-6	2.13E-6	3.40E-5	1.73E-5	2.00E-5	0.2	0.1	**2**	0.9
	Dioxin TEQ	2.54E-10	1.36E-10	2.18E-9	1.11E-9	1.00E-9	0.3	0.1	**2**	1
	Hazard Index = Sum of hazard quotient						0.9	0.4	**7**	**3.9**
Rainbow Trout Hatchery **	Mercury	3.11E-5	1.67E-5	2.67E-4	1.36E-4	1.00E-4	0.3	0.2	**3**	1
	Total PCBs	3.28E-6	1.76E-6	2.81E-5	1.43E-5	2.00E-5	0.2	0.08	1	0.7
	Dioxin TEQ	2.78E-10	1.49E-10	2.38E-9	1.21E-9	1.00E-9	0.3	0.2	**2**	1
	Hazard Index = Sum of hazard quotient						0.8	0.5	**6**	**2.7**
Burbot *	Chromium	1.65E-4	8.86E-5	1.42E-3	7.21E-4	3.00E-3	0.06	0.03	0.5	0.2
	Mercury	8.16E-5	4.37E-5	6.99E-4	3.56E-4	1.00E-4	0.8	0.4	**7**	**4**
	Total PCBs	1.26E-5	6.78E-6	1.08E-4	5.51E-5	2.00E-5	0.6	0.3	**5**	**3**
	Dioxin TEQ	3.08E-10	1.65E-10	2.64E-9	1.34E-9	1.00E-9	0.3	0.2	**3**	1
	Hazard Index = Sum of hazard quotient						**1.8**	0.9	**15.5**	**8.2**

* Whole fish
** Fillet
RfD - EPA oral reference dose
MRL- ATSDR's Minimal Risk Level
Bold values exceed Hazard Quotient of 1
mg/kg/day - milligrams per kilogram body-weight per day
PCBs – polychlorinated biphenyls
TEQ – Toxic Equivalent
Gen – General population
Sub – Non-tribal high-end consumer

Table B6. Exposure dose and non-cancer risk from ingesting fish at average concentration of contaminants in the Lower Reservoir reach of Lake Roosevelt (2005).

Fish Species	Contaminant	Estimated Dose				RfD/ MRL (mg/kg/day)	Hazard Quotient			
		Gen Child (mg/kg/day)	Gen Adult (mg/kg/day)	Sub Child (mg/kg/day)	Sub Adult (mg/kg/day)		Gen Child	Gen Adult	Sub Child	Sub Adult
Whitefish*	Mercury	3.57E-5	1.91E-5	3.06E-4	1.55E-4	1.00E-4	0.4	0.2	**3**	**2**
	Thallium	1.89E-5	1.01E-5	1.62E-4	8.24E-5	8.00E-5	0.2	0.1	**2**	1
	Total PCBs	1.48E-5	7.93E-6	1.27E-4	6.45E-5	2.00E-5	0.7	0.4	**6**	**3**
	Dioxin TEQ	6.86E-10	3.68E-10	5.88E-9	2.99E-9	1.00E-9	0.7	0.4	**6**	**3**
	Hazard Index = Sum of hazard quotient						**2**	**1.1**	**15**	**9**
Walleye**	Mercury	1.56E-4	8.34E-5	1.33E-3	6.79E-4	1.00E-4	**2**	0.8	**13**	**7**
	Thallium	3.03E-5	1.63E-5	2.60E-4	1.32E-4	8.00E-5	0.4	0.2	**3**	**2**
	Total PCBs	1.62E-6	8.70E-7	1.39E-5	7.08E-6	2.00E-5	0.08	0.04	0.7	0.4
	Dioxin TEQ	1.08E-10	5.80E-11	9.28E-10	4.72E-10	1.00E-9	0.1	0.06	0.9	0.5
	Hazard Index = Sum of hazard quotient						**2.6**	**1.1**	**17.6**	**9.9**
Large-scale Sucker*	Antimony	2.55E-5	1.37E-5	2.19E-4	1.11E-4	4.00E-4	0.06	0.03	0.6	0.3
	Cadmium	1.23E-4	6.60E-5	1.06E-3	5.37E-4	1.00E-3	0.1	0.07	1	0.5
	Chromium	5.50E-4	2.94E-4	4.71E-3	2.40E-3	3.00E-3	0.2	0.1	**2**	0.8
	Copper	3.57E-4	1.91E-4	3.06E-3	1.56E-3	4.00E-2	0.01	0.005	0.08	0.04
	Iron	2.87E-2	1.54E-2	2.46E-1	1.25E-1	7.00E-1	0.04	0.02	0.4	0.2
	Manganese	NA	NA	NA	NA	1.40E-1	NA	NA	NA	NA
	Mercury	1.07E-4	5.74E-5	9.18E-4	4.67E-4	1.00E-4	1	0.6	**9**	**5**
	Thallium	1.59E-5	8.54E-6	1.37E-4	6.95E-5	8.00E-5	0.2	0.1	**2**	0.9
	Zinc	8.82E-3	4.73E-3	7.56E-2	3.85E-2	3.00E-1	0.03	0.02	0.3	0.1
	Total PCBs	4.88E-5	2.61E-5	4.18E-4	2.13E-4	2.00E-5	**2**	1	**21**	**11**
	Dioxin TEQ	4.24E-10	2.27E-10	3.63E-9	1.85E-9	1.00E-9	0.4	0.2	**4**	**2**
	Hazard Index = Sum of hazard quotient						**4.0**	**2.1**	**40.4**	**20.8**
Rainbow Trout Wild **	Mercury	5.60E-5	3.00E-5	4.80E-4	2.44E-4	1.00E-4	0.6	0.3	**5**	**2**
	Total PCBs	2.66E-6	1.43E-6	2.28E-5	1.16E-5	2.00E-5	0.1	0.07	1	0.6
	Dioxin TEQ	1.16E-10	6.23E-11	9.96E-10	5.07E-10	1.00E-9	0.1	0.06	1	0.5
	Hazard Index = Sum of hazard quotient						0.8	0.4	**7**	**3.1**
Rainbow Trout Hatchery **	Mercury	4.58E-5	2.46E-5	3.93E-4	2.00E-4	1.00E-4	0.5	0.3	**4**	**2**
	Total PCBs	3.66E-6	1.96E-6	3.14E-5	1.59E-5	2.00E-5	0.2	0.1	**2**	0.8
	Dioxin TEQ	3.63E-10	1.95E-10	3.11E-9	1.58E-9	1.00E-9	0.4	0.2	**3**	**2**
	Hazard Index = Sum of hazard quotient						1.1	0.6	**9**	**4.8**
Burbot *	Chromium	2.14E-4	1.14E-4	1.83E-3	9.31E-4	3.00E-3	0.07	0.04	0.6	0.3
	Mercury	9.14E-5	4.90E-5	7.83E-4	3.98E-4	1.00E-4	0.9	0.5	**8**	**4**
	Total PCBs	1.06E-5	5.70E-6	9.12E-5	4.64E-5	2.00E-5	0.5	0.3	**5**	**2**
	Dioxin TEQ	3.29E-10	1.76E-10	2.82E-9	1.43E-9	1.00E-9	0.3	0.2	**3**	1
	Hazard Index = Sum of hazard quotient						**1.8**	1.0	**16.6**	**7.3**

* Whole fish
** Fillet
NA – not available
RfD - EPA oral reference dose
MRL- ATSDR's Minimal Risk Level
Bold values exceed Hazard Quotient of 1
mg/kg/day - milligrams per kilogram body-weight per day
PCBs – polychlorinated biphenyls
TEQ – Toxic Equivalent
Gen – General population
Sub – Non-tribal high-end consumer

Table B7. Adult exposure dose and cancer risk from ingesting fish at maximum concentration of contaminant in Lake Roosevelt (2005).

Fish Species	Contaminant	Estimated Dose		Cancer Slope Factor $(mg/kg/day)^{-1}$	Excess Cancer Risk	
		Gen Adult (mg/kg/day)	Sub Adult (mg/kg/day)		Gen Adult	Sub Adult
Whitefish*	Arsenic	7.80E-6	6.35E-5	5.7	2E-5	**2E-4**
	Total PCBs	1.65E-5	1.34E-4	2	1E-5	**1E-4**
	Dioxin TEQ	5.25E-10	4.27E-9	150000***	3E-5	**3E-4**
	Sum of cancer risks				6E-5	**6E-4**
Walleye**	Arsenic	4.48E-6	3.64E-5	5.7	1E-5	9E-5
	Total PCBs	3.50E-6	2.85E-5	2	3E-6	2E-5
	Dioxin TEQ	6.10E-11	4.96E-10	150000***	4E-6	3E-5
	Sum of cancer risks				2E-5	**1E-4**
Large-scale Sucker*	Arsenic	8.35E-6	6.80E-5	5.7	2E-5	**2E-4**
	Total PCBs	1.05E-4	8.52E-4	2	9E-5	**7E-4**
	Dioxin TEQ	6.00E-10	4.88E-9	150000***	4E-5	**3E-4**
	Sum of cancer risks				**2E-4**	**1E-3**
Rainbow Trout Wild**	Arsenic	2.53E-6	2.06E-5	5.7	6E-6	5E-5
	Total PCBs	9.25E-6	7.53E-5	2	8E-6	6E-5
	Dioxin TEQ	1.38E-10	1.12E-9	150000***	9E-6	7E-5
	Sum of cancer risks				2E-5	**2E-4**
Rainbow Trout Hatchery**	Arsenic	2.03E-6	1.65E-5	5.7	5E-6	4E-5
	Total PCBs	2.50E-6	2.03E-5	2	2E-6	2E-5
	Dioxin TEQ	2.35E-10	1.91E-9	150000***	2E-5	1E-4
	Sum of cancer risks				3E-5	**2E-4**
Burbot*	Arsenic	2.40E-5	1.95E-4	5.7	6E-5	**5E-4**
	Total PCBs	1.45E-5	1.18E-4	2	1E-5	1E-4
	Dioxin TEQ	2.33E-10	1.89E-9	150000***	1E-5	1E-4
	Sum of cancer risks				8E-5	**7E-4**

* Whole fish
** Fillet
***HEAST = EPA's Health Effects Assessment Summary Tables [32]
Bold values exceed EPA's acceptable cancer risk
mg/kg/day - milligrams per kilogram body-weight per day
PCBs – polychlorinated biphenyls
TEQ – Toxic Equivalent
Gen – General population
Sub – Non-tribal high-end consumer

Table B8. Adult exposure dose and cancer risk from ingesting fish at average concentration of contaminants in the Upper Reservoir reach of Lake Roosevelt (2005).

Fish Species	Contaminant	Estimated Dose		Cancer Slope Factor $(mg/kg/day)^{-1}$	Excess Cancer Risk	
		Avg. Gen Adult (mg/kg/day)	Avg. Sub Adult (mg/kg/day)		Avg. Gen Adult	Avg. Sub Adult
Whitefish*	Arsenic	4.62E-6	3.76E-5	5.7	1E-5	9E-5
	Total PCBs	9.55E-6	7.77E-5	2	8E-6	7E-5
	Dioxin TEQ	2.50E-10	2.03E-9	150000***	1E-5	1E-4
	Sum of cancer risks				3E-5	**3E-4**
Walleye**	Arsenic	2.20E-6	1.79E-5	5.7	5E-6	4E-5
	Total PCBs	8.70E-7	7.08E-6	2	7E-7	6E-6
	Dioxin TEQ	4.78E-11	3.89E-10	150000***	3E-6	3E-5
	Sum of cancer risks				9E-6	7E-5
Large-scale Sucker*	Arsenic	4.34E-6	3.53E-5	5.7	1E-5	9E-5
	Total PCBs	2.71E-5	2.20E-4	2	2E-5	2E-4
	Dioxin TEQ	2.65E-10	2.16E-9	150000***	2E-5	1E-4
	Sum of cancer risks				5E-5	**4E-4**
Rainbow Trout Wild**	Arsenic	2.21E-6	1.80E-5	5.7	5E-6	4E-5
	Total PCBs	5.95E-6	4.84E-5	2	5E-6	4E-5
	Dioxin TEQ	9.80E-11	7.97E-10	150000***	6E-6	5E-5
	Sum of cancer risks				2E-5	**1E-4**
Rainbow Trout Hatchery**	Arsenic	NA	NA	5.7	NA	NA
	Total PCBs	NA	NA	2	NA	NA
	Dioxin TEQ	NA	NA	150000***	NA	NA
	Sum of cancer risks				NA	NA
Burbot*	Arsenic	1.81E-5	1.47E-4	5.7	4E-5	**4E-4**
	Total PCBs	7.50E-6	6.10E-5	2	6E-6	5E-5
	Dioxin TEQ	2.08E-10	1.69E-9	150000***	1E-5	1E-4
	Sum of cancer risks				6E-5	**6E-4**

* Whole fish
** Fillet
***HEAST = EPA's Health Effects Assessment Summary Tables [32]
NA – not available
Bold values exceed EPA's acceptable cancer risk
mg/kg/day - milligrams per kilogram body-weight per day
PCBs – polychlorinated biphenyls
TEQ – Toxic Equivalent
Gen – General population
Sub – Non-tribal high-end consumer
Avg - Average

Table B9. Adult exposure dose and cancer risk from ingesting fish at average concentration of contaminants in the Middle Reservoir reach of Lake Roosevelt (2005).

Fish Species	Contaminant	Estimated Dose		Cancer Slope Factor $(mg/kg/day)^{-1}$	Excess Cancer Risk	
		Avg. Gen Adult (mg/kg/day)	Avg. Sub Adult (mg/kg/day)		Avg. Gen Adult	Avg. Sub Adult
Whitefish*	Arsenic	5.01E-6	4.07E-5	5.7	1E-5	1E-4
	Total PCBs	4.05E-6	3.30E-5	2	3E-6	3E-5
	Dioxin TEQ	3.56E-10	2.90E-9	150000***	2E-5	**3E-4**
	Sum of cancer risks				3E-5	**4E-4**
Walleye**	Arsenic	2.79E-6	2.27E-5	5.7	7E-6	6E-5
	Total PCBs	1.19E-6	9.68E-6	2	1E-6	8E-6
	Dioxin TEQ	5.35E-11	4.35E-10	150000***	3E-6	3E-5
	Sum of cancer risks				1E-5	**1E-4**
Large-scale Sucker*	Arsenic	4.33E-6	3.53E-5	5.7	1E-5	9E-5
	Total PCBs	2.28E-5	1.85E-4	2	2E-5	**2E-4**
	Dioxin TEQ	2.70E-10	2.20E-9	150000***	2E-5	1E-4
	Sum of cancer risks				5E-5	**4E-4**
Rainbow Trout Wild**	Arsenic	1.85E-6	1.51E-5	5.7	5E-6	4E-5
	Total PCBs	2.13E-6	1.73E-5	2	2E-6	1E-5
	Dioxin TEQ	1.36E-10	1.11E-9	150000***	9E-6	7E-5
	Sum of cancer risks				2E-5	**1E-4**
Rainbow Trout Hatchery**	Arsenic	7.70E-7	6.27E-6	5.7	2E-6	2E-5
	Total PCBs	1.76E-6	1.43E-5	2	2E-6	1E-5
	Dioxin TEQ	1.49E-10	1.21E-9	150000***	1E-5	8E-5
	Sum of cancer risks				1E-5	**1E-4**
Burbot*	Arsenic	1.75E-5	1.42E-4	5.7	4E-5	**3E-4**
	Total PCBs	6.78E-6	5.51E-5	2	6E-6	5E-5
	Dioxin TEQ	1.65E-10	1.34E-9	150000***	1E-5	9E-5
	Sum of cancer risks				6E-5	**4E-4**

* Whole fish
** Fillet
***HEAST = EPA's Health Effects Assessment Summary Tables [32]
Bold values exceed EPA's acceptable cancer risk
mg/kg/day - milligrams per kilogram body-weight per day
PCBs – polychlorinated biphenyls
TEQ – Toxic Equivalent
Gen – General population
Sub – Non-tribal high-end consumer
Avg - Average

Table B10. Adult exposure dose and cancer risk from ingesting fish at average concentration of contaminants in the Lower Reservoir reach of Lake Roosevelt (2005).

Fish Species	Contaminant	Estimated Dose		Cancer Slope Factor $(mg/kg/day)^{-1}$	Excess Cancer Risk	
		Avg. Gen Adult (mg/kg/day)	Avg. Sub Adult (mg/kg/day)		Avg. Gen Adult	Avg. Sub Adult
Whitefish*	Arsenic	6.85E-6	5.57E-5	5.7	2E-5	1E-4
	Total PCBs	7.93E-6	6.45E-5	2	7E-6	6E-5
	Dioxin TEQ	3.68E-10	2.99E-9	150000***	2E-5	**2E-4**
	Sum of cancer risks				5E-5	**4E-4**
Walleye**	Arsenic	3.31E-6	2.69E-5	5.7	8E-6	7E-5
	Total PCBs	8.70E-7	7.08E-6	2	7E-7	6E-6
	Dioxin TEQ	5.80E-11	4.72E-10	150000***	4E-6	3E-5
	Sum of cancer risks				1E-5	**1E-4**
Large-scale Sucker*	Arsenic	4.56E-6	3.71E-5	5.7	1E-5	9E-5
	Total PCBs	2.61E-5	2.13E-4	2	2E-5	**2E-4**
	Dioxin TEQ	2.27E-10	1.85E-9	150000***	1E-5	1E-4
	Sum of cancer risks				4E-5	**4E-4**
Rainbow Trout Wild**	Arsenic	2.00E-6	1.63E-5	5.7	5E-6	4E-5
	Total PCBs	1.43E-6	1.16E-5	2	1E-6	1E-5
	Dioxin TEQ	6.23E-11	5.07E-10	150000***	4E-6	3E-5
	Sum of cancer risks				1E-5	8E-5
Rainbow Trout Hatchery**	Arsenic	1.02E-6	8.26E-6	5.7	3E-6	2E-5
	Total PCBs	1.96E-6	1.59E-5	2	2E-6	1E-5
	Dioxin TEQ	1.95E-10	1.58E-9	150000***	1E-5	1E-4
	Sum of cancer risks				2E-5	**1E-4**
Burbot*	Arsenic	2.09E-5	1.70E-4	5.7	5E-5	**4E-4**
	Total PCBs	5.70E-6	4.64E-5	2	5E-6	4E-5
	Dioxin TEQ	1.76E-10	1.43E-9	150000***	1E-5	9E-5
	Sum of cancer risks				7E-5	**5E-4**

* Whole fish
** Fillet
***HEAST = EPA's Health Effects Assessment Summary Tables [32]
Bold values exceed EPA's acceptable cancer risk
mg/kg/day - milligrams per kilogram body-weight per day
PCBs – polychlorinated biphenyls
TEQ – Toxic Equivalent
Gen – General population
Sub – Non-tribal high-end consumer
Avg - Average

Appendix C: Lead Exposure Fish Ingestion Scenario Used in the IEUBK Model

This section provides inputs for the Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK). The following inputs to the model were used to account for the average fish ingestion lead exposures from/in Lake Roosevelt, Washington.

Consumption rates: General population (Gen) child – 7 grams (g)/day: Non-tribal high-end consumer (Sub) child – 60 g/day. IEUBK model assumes that a child's total meat intake is 93.5 g/day. The target goal is no more than 5% of the community with BLLs above 5 micrograms per deciliter (µg/dL). Fish only, soil fraction was not calculated in the model. Default assumptions were used unless noted.

Table C1. Blood lead values determined using the IEUBK model for lead in fish at Lake Roosevelt, Washington (2005).

Fish Species	Average Concentration (ppm)			Percent meat intake as fish (%)		Blood Lead level in percent above 5 ug/dl Age range 0 - 84 months					
						Upper Reach		Middle Reach		Low Reach	
	Upper Reach	Middle Reach	Low Reach	Gen Child	Sub Child	Gen Child	Sub Child	Gen Child	Sub Child	Gen Child	Sub Child
Whitefish*	0.225	0.069	0.050	7.5	64	0.017	0.977	0.009	0.055	0.008	0.032
Walleye**	0.0005	0.019	0.024			0.007	0.006	0.007	0.012	0.007	0.014
Large-scale Sucker*	5.43	2.13	0.66			**16.55**	**99.23**	1.38	**83.04**	0.076	**17.71**
Rainbow Trout Wild**	0.015	0.013	0.006			0.007	0.01	0.007	0.009	0.007	0.007
Rainbow Trout Hatchery**	NA	0.006	0.006			NA	NA	0.007	0.007	0.007	0.007
Burbot*	0.067	0.113	0.086			0.009	0.052	0.011	0.157	0.009	0.054

* Whole fish
** Fillet
NA – not available
Bold values exceed the target value of 5% blood lead concentration above 5 ug/dl.
Gen – General population
Sub – Non-tribal high-end consumer
% - percent
ppm – parts per million
µg/dL - micrograms per deciliter
Results are based on the IEUBK Model Version 1.1 Build 11

Lead Exposure Fish Ingestion Scenario Used in the Adult Lead Model

This section provides inputs for the Adult lead model. The following inputs to the model were used to account for the average fish ingestion lead exposures from/in Lake Roosevelt, Washington.

Consumption rates: General population (Gen) 17.5 g/day: Non-tribal high-end consumer (Sub) 142.4 g/day. The target goal is no more than 5% of the community with BLLs above 5 µg/dL. Fish only, soil fraction was not calculated in the model. Default assumptions were used unless noted.

Table C2. Blood lead values determined using the Adult lead model for lead in fish at Lake Roosevelt, Washington (2005).

Fish Species	**Average Concentration (ppm)**			**Average Mother Blood Lead concentration in ug/dl Fetus Blood Lead in percent above 5 ug/dl**						
	Upper Reach	**Middle Reach**	**Low Reach**		**Upper Reach**		**Middle Reach**		**Low Reach**	
					Gen	Sub	Gen	Sub	Gen	Sub
Whitefish*	0.225	0.069	0.050	mother	1.7	3.0	1.6	2.0	1.5	1.8
				fetus	**5.4**	**20.8**	4.3	**8.1**	4.2	**6.8**
Walleye**	0.0005	0.019	0.024	mother	1.5	1.5	1.5	1.6	1.5	1.7
				fetus	3.9	3.9	4.0	4.9	4.0	**5.2**
Large-scale Sucker*	5.43	2.13	0.66	mother	6.1	**38.6**	3.3	**16.1**	2.1	6.0
				fetus	**54.7**	**99.6**	**24.0**	**92.4**	**9.0**	**54.2**
Rainbow Trout Wild**	0.015	0.013	0.006	mother	1.5	1.6	1.5	1.6	1.5	1.5
				fetus	4.0	4.7	4.0	4.6	3.9	4.2
Rainbow Trout Hatchery**	NA	0.006	0.006	mother	NA	NA	1.5	1.5	1.5	1.5
				fetus	NA	NA	3.9	4.2	3.9	4.2
Burbot*	0.067	0.113	0.086	mother	1.6	2.0	1.6	2.3	1.6	2.1
				fetus	4.3	**8.0**	4.6	**11.4**	4.4	**9.4**

* Whole fish
** Fillet
NA – not available
Bold values exceed the target value of 5% or mother's average blood lead concentration above 5 ug/dl.
Gen – General population
Sub – Non-tribal high-end consumer
% - percent
ppm – parts per million
µg/dL - micrograms per deciliter

Appendix D - Meal Limit Calculations

Several contaminants of concern are present in fish from Lake Roosevelt; however, only meal limits for mercury were calculated due to the high uncertainty of the PCBs, arsenic, and lead in large-scale suckers. Meal limits were calculated based on developmental endpoints for mercury assuming a 132 pounds (lbs) (60 kilogram (kg) woman. Meal limits were calculated using the equation below in conjunction with the RfD as the target risk value and the exposure parameters provided in Table D1 below. Table D2 provides fish meal limits based on the single contaminant mercury that would be protective of people who eat fish from Lake Roosevelt.

Meal Limit = recommended fish meal limit per month (meal/month)

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

Table D1. Exposure parameters used to calculate recommended fish consumption limits for reaches of Lake Roosevelt in northeast Washington.

Meal Limit = [RfD*BW* DM]/C * MS		
Exposure Parameter	**Endpoint**	**Units**
	Developmental	
Average Concentration (C)	Variable	ug/kg
Mercury (RfD)	0.1	ug/kg/day
Days per month (DM)	30.4	days/month
Mean Body Weight (BW)	60	kg
Meal size (MS)	0.227	kg

kg - kilogram
µg/kg - micrograms per kilogram
µg/kg/day - micrograms per kilogram body-weight per day
RfD - EPA oral reference dose

Table D2. Calculated meal limits (meals/month) for Lake Roosevelt fish in northeast Washington for a 132 lbs (60 kg) woman based on methylmercury contaminant concentrations.

Species	Upper	Middle	Lower
Whitefish (Whole)	11.5	14.4	10.5
Walleye (Fillet)	3.5	3.3	2.4
Large-scale Sucker (Whole)	4.7	3.0	3.4
Wild Rainbow Trout (Fillet)	9.3	10.6	6.7
Hatchery Rainbow Trout (Fillet)	NA	12.0	8.2
Burbot (Whole)	5.8	4.6	4.1

NA – not available

Applying the Table D2 meal limits across the general population assumes that meal size will decrease or increase proportionately with body weight. Such an assumption could result in underestimating exposure for consumers who eat proportionately more fish per unit of body weight. Table D3 demonstrates how an 8-ounce meal for a 154 lbs (70-kg) adult would change to remain proportional with body weight.

Table D3. Adjustment of fish meal size based on the body weight of the consumer.

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

Appendix E – Chemical Specific Toxicity

Antimony

Antimony is a naturally-occurring element in the earth's soil. Background soil antimony concentrations range between 3.1 and 7.6 parts per million (ppm) in Washington [43]. The main routes of exposure to antimony are inhaling contaminated soil or dust particles and ingesting contaminated water or food. Antimony-contaminated soil can accidentally be ingested by hand-to-mouth activity that could increase exposure. EPA established an oral reference dose (RfD) for antimony of 0.0004 mg/kg/day based on animal studies that showed it can cause a decrease in blood glucose levels and altered cholesterol levels [30]. EPA has not classified antimony as to human health carcinogenicity.

Arsenic

Arsenic is a naturally occurring element in the earth's soil. Background soil arsenic concentrations in Eastern Washington range from about 0.5 to 10.3 ppm [43]. However, widespread uses of arsenic-containing pesticides and emissions from smelters have resulted in significantly higher levels of arsenic on many properties in the state. There are two forms of arsenic: organic and inorganic. The EPA-established RfD for arsenic is 0.0003 mg/kg/day based on skin color changes and excessive growth of tissue (human data) [22]. EPA classifies the inorganic form of arsenic as a human carcinogen. The current EPA slope factor for arsenic is 1.5 per mg/kg/day. The recent EPA IRIS review draft for the Science Advisory Board presented a slope factor for combined lung and bladder cancer of 5.7 per mg/kg/day [44]. The slope factor calculated from the work by the National Research Council is about 21 per mg/kg/day [23]. These slope factors could be higher if the combined risks for all arsenic-associated cancers (bladder, lung, skin, kidney, liver, etc.) were evaluated. DOH will not be using the slope factor of 1.5 per mg/kg/day due to the arsenic weight of evidence approach. For this or any other health consultation, DOH will use a slope factor of 5.7 per mg/kg/day, which appears to reflect EPA's Review Draft assessment.

Inorganic arsenic is much more harmful to humans than organic arsenic; therefore, DOH bases any health evaluation on levels of inorganic arsenic present in fish samples. Generally, inorganic arsenic in fish and shellfish ranges from about 1%-20% of the total arsenic [22, 23, 24, 25]. The U.S. Food and Drug Administration (FDA) assume 10% of the total arsenic estimated as inorganic arsenic [25]. A small percentage of Lake Roosevelt samples have arsenic speciation data. The speciation data could have been used to calculate the estimated dose from exposure to inorganic arsenic in fish. However, DOH assumed that 10% of the total arsenic detected in the fish sampled was inorganic arsenic and calculated an estimated inorganic arsenic dose (See section: Arsenic and Lead Uncertainty).

Cadmium

Cadmium is a naturally-occurring element in the earth's crust. Cadmium is used mainly in batteries, pigments, metal coatings, and metal alloys. Cadmium is found in most foods at low levels, with the lowest levels found in fruits and the highest levels found in leafy vegetables and potatoes. Shellfish have higher cadmium levels (up to 1 ppm) than other types of fish or meat. Cadmium is stored in the liver and kidneys and slowly leaves the body in the urine and feces [45]. However, high levels of cadmium will cause kidney damage and cause bones to become fragile and break easily. Occupational exposure to inhaled cadmium is suspected to be a cause of lung cancer in workers while animal studies have confirmed the ability of cadmium to cause lung tumors via the inhalation route. Studies of workers exposed to airborne cadmium also suggest a link with prostate cancer. The ability of cadmium to cause cancer via the oral route is disputed. The RfD for cadmium ingested with food is 0.001 mg/kg/day.

Chromium

Chromium is a naturally occurring element in the earth's soil. Chromium is found in three main forms - chromium 0 (metal), chromium III (trivalent chromium), and chromium VI (hexavalent chromium). Chromium III is an essential nutrient required by the body. Chromium VI is more easily absorbed and harmful. Ingesting large amounts of chromium (VI) can cause stomach ulcers, kidney and liver damage, and even death. However, some of the ingested chromium VI is converted to chromium III and most will exit the body in feces within a few days never entering the bloodstream. Only about 2% of chromium ingested passes through intestinal walls and enters the bloodstream [46, 47, 48]. The EPA-established RfD for chromium VI is 0.003 mg/kg/day. Chromium evaluated in this consultation represents total chromium as opposed to chromium VI. Dose calculations, however, do not attempt to fractionate chromium concentrations. Total chromium is considered to be all chromium VI for evaluation purposes.

Copper

Copper is a naturally occurring element in the earth's soil. Background soil copper concentrations in Eastern Washington range from about 4 ppm to 53 ppm [43]. Copper is an essential element for good health. Once ingested, copper rapidly enters the bloodstream and is distributed throughout the body after ingestion. Copper combines with protein and iron to make hemoglobin, which transports oxygen in the blood from the lungs to other parts of the body. Copper usually takes several days to leave the body in feces and urine. However, exposure to very high doses of copper can cause liver and kidney damage and even death [31]. Water containing high levels of copper may cause nausea, vomiting, stomach cramps, or diarrhea when ingested. In addition, long-term exposure to copper dust can irritate the nose, mouth, and eyes and cause headaches, dizziness, nausea, and diarrhea. The EPA Region 3 established RfD for copper is 0.04 mg/kg/day, based on the Health Effects Assessment Summary Tables (HEAST) [32].

Dioxins and Furans

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

2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) is the most toxic of the dioxin congeners and 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 [33]. Long-term exposure to dioxins could increase the likelihood of developing cancer. Studies of rats and mice exposed to TCDD found that these exposures resulted in thyroid and liver cancer [49]. EPA considers TCDD to be a probable human carcinogen and developed a cancer slope factor of $1.5x\ 10^{5}$ per mg/kg/day [50, 51].

Iron

Iron is a naturally-occurring element in the earth's soil. Background soil iron concentrations in Eastern Washington range from about 9,670 ppm to 30,000 ppm [43]. Iron is essential in the maintenance and production of hemoglobin and myoglobin without which the body cannot sustain basic life functions. Iron combines with protein and copper to make hemoglobin, which transports oxygen in the blood from the lungs to other parts of the body. Generally, acute iron poisoning is the result of children accidentally overdosing on iron-containing supplements and not from incidentally ingesting iron in soil or sediment. The EPA-established provisional RfD for iron is 0.7 mg/kg/day [34].

Lead – Occurrence, Health Concerns, and Risks

Lead is a naturally occurring chemical element that is normally found in soil. In Washington, normal background concentrations rarely exceed 20 ppm [43]. However, widespread use of certain products (such as leaded gasoline, lead-containing pesticides, and lead-based paint) and emissions from certain industrial operations (such as smelters) have resulted in significantly higher levels of lead in many areas of the state.

Elimination of lead in gasoline and solder used in food and beverage cans has greatly reduced exposure to lead. Currently, the main pathways of lead exposure in children are ingestion of paint chips, contaminated soil and house dust, and drinking water in homes with old plumbing.

Children less than seven years old are particularly vulnerable to the effects of lead. Compared to older children and adults, younger children tend to ingest more dust and soil, absorb significantly more of the lead that they swallow, and more of the lead that they absorb can enter their developing brains. Pregnant women and women of childbearing age should also be aware of lead in their environment because lead ingested by a mother can affect the unborn fetus.

Health Effects

Exposure to lead can be monitored by measuring the level of lead in the blood. In general, blood lead rises 1-5 µg/dl for every 1,000 ppm increase in soil or dust concentration [52]. The CDC has recently updated its definition for elevated BLL to greater than, or equal to, 5 µg/dl [20]. Previously, CDC had defined an elevated BLL as greater than or equal to 10 µg/dl [53]. However, there is growing evidence that damage to the central nervous system resulting in learning problems can occur at blood lead levels less than 10 µg/dl. U.S. state childhood lead programs 2006 data showed 1.21% of children tested in the U.S. had blood lead levels greater than 10 µg/dl [54].

Lead poisoning can affect almost every system of the body and often occurs with no obvious or distinctive symptoms. Depending on the amount of exposure a child has, lead can cause behavior and learning problems, central nervous system damage, kidney damage, reduced growth, hearing impairment, and anemia [55].

In adults, lead can cause health problems such as high blood pressure, kidney damage, nerve disorders, memory and concentration problems, difficulties during pregnancy, digestive problems, and pain in the muscles and joints [55]. These health effects have usually been associated with blood lead levels greater than 30 µg/dl.

Because of chemical similarities to calcium, lead can be stored in bone for many years. Even after exposure to lead has been reduced, lead stored in bone can be released back into the blood where it can have harmful effects. Normally this release occurs relatively slowly. However, certain conditions such as pregnancy, lactation, menopause, and hyperthyroidism can cause more rapid release of the lead, which could lead to a significant rise in blood lead levels [56].

Manganese

Manganese is a naturally occurring metal that is found in many types of rocks. Background soil manganese concentrations in Eastern Washington range from about 233 ppm to 769 ppm [43]. Manganese is an essential trace element, is necessary for good health, and can be found in several food items including grains, cereals, and tea. Manganese is required by the body to break down amino acids and produce energy. Incidental ingestion of soil containing manganese can result in an increase in manganese in the body; however, most manganese is excreted in feces. Only about 3% to 5% of manganese ingested is absorbed [35]. Manganism (mental and emotional disturbances or body movements that are slow and clumsy) is a condition that typically is the result of inhaling high levels of manganese dust in the air. It is uncertain whether eating or drinking products with too much manganese can cause symptoms of manganism. EPA's established RfD for manganese in food is 0.14 mg/kg/day.

Mercury

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

Ingested methylmercury is readily absorbed, binds with the cysteine amino acid, and crosses the blood-brain barrier. In Minamata Bay, Japan, mothers who were exposed to high amounts of methyl mercury but were asymptomatic gave birth to severely affected infants. Other epidemiologic studies that have shown developmental effects in both animal and human studies are the basis for this primary concern about methylmercury exposure. The EPA-established RfD for mercury is 0.0001 mg/kg/day.

Mercury evaluated in this report represents total mercury as opposed to methylmercury. Dose calculations, however, do not attempt to fractionate the mercury concentrations because almost all mercury in fish is methylmercury; we assumed that Lake Roosevelt results were all methylmercury.

Polychlorinated Biphenyls (PCBs)

PCBs are a mixture of man-made organic chemicals. There are no known natural sources of PCBs in the environment. The manufacture of PCBs stopped in the U.S. in 1977 because of evidence that it could build up in the environment and cause toxic health effects. Although no longer manufactured, PCBs can still be found in certain products such as old fluorescent lighting fixtures, old microscope oil, and old hydraulic oil and electrical devices or appliances containing PCB capacitors made before PCB use was stopped. Prior to 1977, PCBs entered the environment (soil, water, and air) during the manufacture and use of PCBs. Today, PCBs still enter the environment from poorly maintained hazardous waste sites, illegal or improper dumping of PCB wastes such as old hydraulic oil, leaks from electrical transformers that contain PCB oils, and disposal of old consumer products that contain PCBs [36].

PCBs enter the environment as mixtures of individual components known as congeners. There are 209 structural variations of PCB congeners, which differ in the number and location of chlorine atoms on the chemical structure. Most PCBs produced commercially in the U.S. were sold under the trade name Aroclor. The name Aroclor 1254, for example, means that the molecule contains 12 carbon atoms (the first 2 digits) and about 54% chlorine by weight (second 2 digits). No Aroclor mixture contains all 209 congeners.

PCBs do not easily breakdown and are found worldwide because of their persistence. Small amounts of PCBs can be found in almost all outdoor and indoor air, soil, sediments, surface water, and animals. PCBs bioaccumulate in the food chain and are stored in fat cells. The major dietary source of PCBs is fish. PCBs are also found in meats and dairy products [36].

PCBs can get into people's bodies by ingestion, inhalation, and dermal (skin) contact. Some of the PCBs that enter the body are metabolized and excreted from the body within a few days; others stay in the body fat and liver for months and even years. PCBs collect in milk fat and can enter the bodies of infants through breastfeeding [36]. Skin irritation, vomiting, nausea, diarrhea, abdominal pain, eye irritation, and liver damage can occur in people acutely exposed to high levels of PCBs in occupational settings [36]. However, health effects relevant to low-level environmental exposures are immunological effects in monkeys (Aroclor 1254 - RfD of 0.00002 mg/kg/day) and developmental effects in children exposed to PCBs in the womb because mothers ate PCB contaminated fish [36]. Toxicity equivalency factors (TEFs) have been developed for several dioxin-like PCB congeners.

Thallium

Thallium is a naturally occurring metal found in the environment. When thallium is ingested in drinking water, it is absorbed rapidly and distributed to various parts of the body. About half of the ingested thallium will leave the body in urine or feces within 3 days. Ingesting high levels of thallium compounds in cases of human poisoning puts the liver, kidney, respiratory, and cardiovascular systems at risk [37]. Hair loss may also occur with thallium exposure. The EPA-established RfD for thallium is 0.00008 mg/kg/day.

Zinc

Zinc is a naturally-occurring element found in the earth's soil. Background soil zinc concentrations in Eastern Washington range from about 26 ppm to 82 ppm [41]. Zinc compounds are used as ingredients in many common products such as vitamin supplements, sun blocks, diaper rash ointments, deodorants, athlete's foot preparations, acne and poison ivy preparations, and antidandruff shampoos [38]. Ingesting high levels of zinc for short periods may cause stomach cramps, nausea, and vomiting. Ingesting high levels of zinc for long periods may cause anemia, damage the pancreas, and decrease levels of high-density lipoprotein (HDL) cholesterol [38]. The EPA established RfD for zinc is 0.3 mg/kg/day.