Health Consultation

EVALUATION OF POLYCHLORINATED BIPHENYLS (PCBs) IN FISH FROM LONG LAKE
(A.K.A. LONG SPOKANE)

SPOKANE COUNTY, WASHINGTON

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U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry
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Health Consultation: A Note of Explanation

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

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

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HEALTH CONSULTATION

EVALUATION OF POLYCHLORINATED BIPHENYLS (PCBs) IN FISH FROM LONG LAKE (A.K.A. LONG SPOKANE)

CITY OF SPOKANE, SPOKANE COUNTY, WASHINGTON

Prepared by:
Washington State Department of Health
Under Cooperative Agreement with the
U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry

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in Fish from Long Lake (a.k.a. Lake Spokane)
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Foreword

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

The purpose of this health consultation is to identify and prevent harmful human health effects resulting from exposure to hazardous substances in the environment. The health consultation allows DOH to respond quickly to a request from concerned residents for health information on hazardous substances. It provides advice on specific public health issues. 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.

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

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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.
Carcinogen	Any substance that can cause or contribute to the production of cancer.
Chronic	A long period of time. A chronic exposure is one that lasts for a year or longer.
Congener	A single, unique, well-defined chemical compound in the PCB, dioxin or furan category. The name of the congener specifies the total number and position of each chlorine atoms.
Contaminant	Any chemical that exists in the environment or living organisms that is not normally found there.
Dose	A dose is the amount of a substance that gets into the body through ingestion, skin absorption or inhalation. It is calculated per kilogram of body weight per day.
Epidemiology	The study of the occurrence and causes of health effects in human populations. An epidemiological study often compares two groups of people who are alike except for one factor, such as exposure to a chemical or the presence of a health effect. The investigators try to determine if any factor (i.e., age, sex, occupation, economic status) is associated with the health effect.
Exposure	Contact with a chemical by swallowing, by breathing, or by direct contact (such as through the skin or eyes). Exposure may be short-term (acute) or long-term (chronic).

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.
Indeterminate public health hazard	Sites for which no conclusions about public health hazard can be made because data are lacking.
Ingestion rate	The amount of an environmental medium that could be ingested typically on a daily basis. Units for IR are usually liter/day for water, and mg/day for soil.
Minimal Risk Level (MRL)	An amount of chemical that gets into the body (i.e. dose) below which health effects are not expected. MRLs are derived by ATSDR for acute, intermediate, and chronic duration exposures by the inhalation and oral routes. Chronic oral MRLs are similar to EPA's oral reference doses (RfDs).
Oral Reference Dose (RfD)	An estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. RfDs are published by EPA and are given in milligrams of chemical per kilogram body weight per day (mg/kg-day).
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.

Risk	The probability that something will cause injury, linked with the potential severity of that injury. Risk is usually indicated by how many extra cancers may appear in a group of people who are exposed to a particular substance at a given concentration, in a particular pathway, and for a specified period of time. For example, a 1%, or 1 in 100 risk indicates that for 100 people who may be exposed, 1 person may experience cancer as a result of the exposure.
Route of exposure	The way in which a person my contact a chemical substance that includes ingestion, skin contact and breathing.
U.S. Environmental Protection Agency (EPA)	Established in 1970 to bring together parts of various government agencies involved with the control of pollution.
World Health Organization (WHO)	International health organization, within the United Nations, established in April 1948.

Background and Statement of Issues

The Washington State Department of Ecology (Ecology) asked the Washington State Department of Health (DOH) to review and evaluate possible health risks from exposure to polychlorinated biphenyls (PCBs) through consumption of Long Lake fish. This health consultation follows a previous consultation and fish consumption advisory for the Spokane River that was released in March 2001 and contained recommendations for sampling of Long Lake.[1] DOH prepares health consultations under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR).

Environmental Sampling

Long Lake (also known as Lake Spokane) represents the portion of the Spokane River from Long Lake Dam upstream to the confluence of the Little Spokane River. Fish sampling of Long Lake dates back to 1992 when a limited number of samples were collected and analyzed for PCBs. A much larger sampling effort occurred in 1993 and 1994 when Ecology sampled various fish species and analyzed them for both metals and PCBs. The 1993–94 sampling showed generally lower levels of PCBs and metals in Long Lake fish compared with locations sampled upstream (i.e., the upper river).[2] This discrepancy was not unexpected as the upper river contains known sources of PCBs as well as areas of contaminated sediment, particularly in the segment just upstream of Upriver Dam. In addition, the upper river is closer to the Coeur d'Alene basin, a known source of lead and other metals in the Spokane River. A summary of historical fish sampling data from Long Lake is contained in Appendix C.

The most recent sampling of Long Lake took place in June 2001 when Ecology, in coordination with the Washington Department of Fish and Wildlife, collected samples from an upper and lower region of the lake. Three composite samples for each of five species were gathered from the upper region that covers a 5.7-mile stretch downstream of the Little Spokane River confluence. Three composites of the same species were taken from the lower region of the lake that spanned 6.2 miles upstream from Long Lake Dam. The division of the lake was thought to be necessary to separate the upper part of the lake, which is closer to known sources of metals and PCBs in the upper river. No samples were taken from the center region between the upper and lower areas. The sample results were reported in November 2002 and are shown in Appendix B, Tables B1-B4.[3]

Polychlorinated Biphenyls (PCBs)

PCBs are a group of human-made, chlorinated, organic chemicals that were first introduced into commercial use in 1929 as insulating fluids for electric transformers and capacitors. Other applications were soon developed that included their use in hydraulic fluids, paint additives, plasticizers, adhesives, and fire retardants. Production of PCBs in the United States stopped in 1977 following concerns over toxicity and persistence in the environment.[4,5]

The 209 structural variations of PCBs—known as congeners—vary by the number and location of chlorine atoms on the base structure. In the United States, PCBs were produced by the Monsanto Company and given the trade name Aroclor. Aroclors are various mixtures of congeners defined by a four-digit number. The first two digits represent the number of carbon atoms (12) while the second two digits give the percentage of chlorine by weight for the congeners in that mixture.[a] In general, PCB persistence and toxicity increases with the degree of chlorination in the mixture (i.e., Aroclor 1260 is more persistent than Aroclor 1248).

Some PCB congeners have a structure and biological activity that is similar to dioxin. Dioxins are a family of chemicals produced by incomplete burning of organic material through both natural and industrial processes. Like PCBs, dioxins (and a very similar family of chemicals called furans) are persistent in the environment and have been shown to be toxic through a particular mechanism shared by certain PCB congeners. Toxic equivalency factors (TEFs) are used to account for the potential of these PCB congeners to exert dioxin-like toxicity. TEFs are available for 12 dioxin-like PCB congeners.[6] Each congener is multiplied by its TEF to give the dioxin toxic equivalent value (TEQ). The TEQs for each congener are then summed to give the overall PCB-TEQ. TEFs for each congener are based on the toxicity of one well-studied dioxin congener known as 2,3,7,8-tetrachlorodibenzo-p-dioxin.

A summary of the June 2001 Long Lake fish sample results for total PCBs and PCB-TEQs is contained in Table 1 and 2, respectively. Total PCBs can be calculated in a number of different ways. Appendix D, Table D6 provides a comparison of the various methods that can be used to calculate total PCBs. Total Aroclors are given in Table 1 for only those Aroclors that were detected, Aroclors 1248, 1254 and 1260. The total PCB values given in Table 1 were used to estimate exposure doses.

[a] Aroclor-1016 does not follow this naming convention.

Table 1. Total Polychlorinated Biphenyl (PCB) Concentrations In Fish Sampled In 2001 From Long Lake, Spokane County, Washington.

Location	Species	Tissue	Samples	# per composite	**Total PCBs** (ug/kg)		
					Mean	Min	Maximum
Upper Long Lake	Largemouth bass	Fillet	3	10	50	39	72
	Largescale sucker	Fillet	3	10	110	86	132
		Whole[a]	3	NA	265	164	336
	Mountain whitefish	Fillet	3	6	73	60	89
	Smallmouth bass	Fillet	3	5	42	32	54
	Yellow perch [b]	Fillet	3	10	<11	NA	<11
Lower Long Lake [c]	Largemouth bass	Fillet	3	4	56	47	64
	Largescale sucker	Fillet	3	9	92	63	112
		Whole[a]	2	NA	357	321	393
	Smallmouth bass	Fillet	3	5	31	17	39
	Yellow perch [b]	Fillet	3	11	<11	NA	<11

Note: PCB totals are calculated as the sum of Aroclors 1248, 1254, 1260 from composite samples.

a = Whole samples were analyzed from individual fish. .

b = All Aroclors were below detection in yellow perch. Detection limits reported in yellow perch for each Aroclor were either 10 or 11 ug/kg.

c = Mountain whitefish are not found in the lower region of the lake.

ug/kg = micrograms per kilogram also known as parts per billion (ppb).

Table 2. Polychlorinated Biphenyl (PCB) Toxic Equivalents (PCB-TEQ) Concentrations in fish Sampled In June 2001 From Long Lake, Spokane County, Washington.

Location	**Species**	**Tissue**	**Samples**	**# per composite**	**Result** (ng/kg)		
					Mean	Min	Maximum
Upper Long Lake	Largemouth bass	Fillet	3	10	1.7	1.2	2.4
	Largescale sucker	Fillet	3	10	3.1	2.8	3.5
	Mountain whitefish	Fillet	3	6	2.0	1.6	2.2
Lower Long Lake	Largemouth bass	Fillet	3	4	2.1	1.6	2.7
	Largescale sucker	Fillet	3	9	2.2	1.2	2.7

Note: PCB-TEQs are calculated using the toxic equivalency factors adopted by the World Health Organization in 1998. For all samples, congeners 105,114,118,126, and 156 made up 97 - 98% of the total PCB-TEQ.

ng/kg = nanograms per kilogram, also known as parts per trillion (ppt).

Metals

A more limited analysis for metals, including zinc, cadmium, lead, and mercury, was also performed on the June 2001 Long Lake fish samples. Lead and cadmium were not detected in any sample with a detection limit of 100 parts per billion (ppb) (i.e., lead and cadmium were not detected above 100 ppb). While detections of zinc are relevant for ecological assessment, they are not a concern for human health and will not be discussed or evaluated in this health consultation.

Mercury is a contaminant of concern in fish throughout Washington State and throughout much of the world. This is due to various factors that include waste disposal, discharge to water bodies, and air deposition from industrial sources such as coal-fired electric power plants. Mercury occurs naturally in several different forms. The most toxic form of mercury in fish is methylmercury. Methylmercury is converted from inorganic mercury by microorganisms that are present in the environment. Mercury concentrations for largemouth bass are given in Table 3 below. No other species was analyzed for mercury. While the mercury results presented in Table 3 represent total mercury, it has been established that more than 99 percent of all mercury in fish is methylmercury.[7]

Table 3. Mercury concentrations in fish sampled in June 2001 from Long Lake, Spokane County, Washington.

Location	Species	Tissue	Samples	# per composite	**Mercury** (ug/kg)		
					Mean	Min	Maximum
Upper Long Lake	Largemouth bass	Fillet	3	10	100	81	113
Lower Long Lake	Largemouth bass	Fillet	3	9	87	65	108

ug/kg = micrograms per kilogram also known as parts per billion (ppb).

Discussion

The following discussion provides a health risk evaluation for persons who eat fish from the Long Lake. This evaluation follows the same methodology used to establish the current fish consumption advisory for the Spokane River.[1] The approach will be summarized more briefly here.

Populations of Concern

The Spokane Regional Health District (SRHD) conducted a fish consumption survey of Spokane area residents that showed Long Lake to be the primary recreational fishing area for anglers in the greater Spokane area. No significant use by the Spokane tribe on Long Lake has been identified. Therefore, recreational consumption rates were used to estimate exposure to contaminants in Long Lake fish. Average and high-end consumption rates of 42 and 90 grams per day of fish were derived from a survey of Lake Roosevelt anglers and were used as the most appropriate estimate for Long Lake anglers.[b] While the SRHD survey provided good information regarding fishing habits, the size of the focus groups in that survey preclude deriving a good estimate of consumption rate. Appendix D, Table D1 provides the exposure assumptions used to calculate PCB doses for average and high-end consumers of Long Lake fish.

Noncancer Risk Evaluation

To evaluate the potential for *noncancer* adverse health effects that might result from exposure to PCBs in Long Lake, estimated doses for average and high-end consumers were calculated. These estimated doses were then compared to ATSDR’s minimal risk levels (MRLs) or EPA’s oral reference doses (RfDs). MRLs and RfDs are doses below which noncancer adverse health effects are not expected to occur (so called “safe” doses).[5] They are derived from toxic effect levels obtained from human populations and laboratory animal studies. This toxic effect level is divided by “safety factors” to give the lower, more protective MRL or RfD. A dose that exceeds the MRL indicates only the potential for adverse health effects. The magnitude of this potential can be inferred from the degree to which this value is exceeded by the exposure dose. If the

[b] Assuming that a meal size is 8 ounces, 42 g/day would be about 1 meal per week (~10 ounces) and 92 grams per day is almost 3 meals per week (~22 ounces).

estimated exposure dose is only slightly above the MRL, then that dose will fall well below the toxic effect level. The higher the estimated dose is above the MRL, the closer it will be to the toxic effect level.

> **Minimal Risk Levels (MRLs) and Oral Reference Doses (RfDs)**
>
> Different methods are used to select the toxic effect levels from which MRLs and RfDs are derived. The most common method is to use a lowest-observed adverse effect level (LOAEL) or a no-observed adverse effect level (NOAEL). The MRL and RfD for PCBs is derived from a LOAEL based on immune system effects seen in monkeys fed Aroclor-1254 in their diets.

Total polychlorinated biphenyls (PCBs)

Total PCB doses calculated for the average consumer of Long Lake fish exceed the respective chronic oral MRL for all species except yellow perch. All of the doses calculated for the high-end consumer exceed the PCB MRL. The MRL is based on a lowest-observed adverse effect level (LOAEL) of 0.005 milligrams per kilogram per day (mg/kg-day) where immune system changes were seen in monkeys chronically exposed to Aroclor-1254 in their diet. This LOAEL was divided by an uncertainty factor of 300 to give an MRL of 0.00002 mg/kg-day.[5,c] For comparison, the estimated dose can be divided by the MRL to give a value known as the *hazard quotient*, which provides a convenient method to measure the relative health risk associated with a dose. As the hazard quotient exceeds one and approaches the actual toxic effect level, the dose becomes more of a health concern (see Figure 2).

While the doses estimated for the average consumer exceed the MRL for most fish species, they are not very much above the MRL. Hazard quotients calculated for exposure to PCBs in Long Lake fish ranged from 0.5 for average consumers of yellow perch to 8.5 for high-end consumers of largescale sucker fillets. High-end consumption of whole largescale sucker at the maximum detected level results in a hazard quotient of 25.3 (Appendix D, Table D2).

The hazard quotients estimated for average consumption of *sport fish* (e.g., yellow perch, largemouth bass, smallmouth bass and mountain whitefish) ranged from 0.5 to 2.2 for average consumers and 1.1 to 5.7 for high-end exposure.

Largescale sucker (whole and fillet) contain the most PCBs of the Long Lake fish and so yield the highest exposure doses and health risks. The hazard quotient associated with consumption of Largescale sucker fillets is approximately 3 for average consumers and 8 for high-end consumers. From a health perspective, largescale sucker are the least desirable of all the fish sampled from Long Lake.

Estimated doses from eating yellow perch were the lowest of all species and did not exceed the MRL for the average consumer. High-end exposure estimates for consumption of yellow perch yield doses that are approximately equivalent to the MRL.

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[c] EPA provides an oral reference dose (RfD) for PCBs that is equivalent to and based on the same study as the MRL. RfDs have essentially the same definition as MRLs but the two are not always equivalent. ATSDR recently completed an update of the PCB chronic oral MRL and did not change it.

Average consumers of fish from Long Lake are not expected to experience adverse health effects from exposure to contaminants in those fish. Although high-end consumers of fish from Long Lake might be exposed at doses above health comparison values, these doses are not expected to cause adverse health effects, especially when considering the safety factor of 300 that was applied to derive the MRL (hazard quotient of 8.5 results from a dose that is about 35 times less that actual effect level, see Figure 2), the health benefits of fish consumption, and the reduction of PCB levels through cooking and preparation (see pages 12–13). PCB noncancer toxicity is discussed further in the following paragraphs.

Liver toxicity has been demonstrated in animals given high doses of PCBs.[8] Liver toxicity and developmental effects are also well documented in residents of Taiwan and Japan exposed to relatively high levels of PCBs through ingestion of contaminated rice oil. However, the association of these effects with PCB exposure is complicated by concurrent exposure to chlorinated dibenzofurans.[5]

While the “rice oil” incidents in Taiwan and Japan provide good evidence of PCB toxicity in humans, recent studies demonstrate that developmental effects can occur at lower levels of PCB exposure. Deficits in neurobehavioral function in children exposed *in utero* represent the most compelling evidence that environmental exposure to PCBs have caused adverse health effects in humans. Studies of various human populations exposed to PCBs, primarily through the ingestion of fish, have demonstrated deficits in neurobehavioral function. Learning deficits were maintained in the children of one Lake Michigan fish-eating cohort through 11 years of age. Animal studies have also shown adverse effects on development following prenatal exposure of the fetus. [5,9]

Thyroid dysfunction has also been associated with PCB exposure. Several *in vitro* and animal studies have shown a reduction in thyroid hormone (thyroxine) levels in response to PCB exposure.[10,11,12] A study in rats exposed *in utero* to PCBs found hearing deficits concurrent with decreasing thyroxine levels.[13] This finding suggests that interference with thyroxine levels could be a mechanism for the developmental effects associated with children exposed to PCBs prior to birth. The potential for PCBs to disrupt hormone function, including the endocrine system, has been suggested as a mechanism for the reproductive effects of PCBs seen in animals. Some human epidemiological studies provide support for the reproductive toxicity of PCBs, including effects on menstrual cycles in women and male fertility.[5]

Because of recent human developmental studies, ATSDR has revisited its MRL. ATSDR has concluded that immune system effects seen in monkeys still represent the most sensitive toxic endpoint of PCB exposure. Further, ATSDR concluded that the existing MRL based on this endpoint should not change and would be protective of the developmental effects found in the more recent human epidemiological studies discussed above.[5] DOH considers ATSDR’s chronic oral MRL for PCBs to be the most appropriate health comparison value for PCB exposure. It should be noted that ATSDR did derive a sub-chronic oral MRL for developmental effects of 0.00003 mg/kg-day. Use of this MRL in conjunction with a sub-chronic exposure scenario involving pregnant women exposed over some duration during pregnancy does not result in any significant differences versus the chronic exposure scenario used above.

Mercury

Only largemouth bass were analyzed for mercury in the June 2001 sampling of Long Lake fish. While no sources of mercury have been identified in the upper Spokane River or Long Lake, mercury is a nationwide problem due to atmospheric deposition. Bass are known to accumulate significant levels of mercury and are expected to be representative of higher-end mercury levels in Long Lake fish.

As with PCBs, developmental effects are the primary concern regarding methylmercury exposure and have been demonstrated in both animal and human studies. Recent evidence from two separate studies shows impaired development of children whose mothers were exposed to methylmercury by eating fish and whale meat. Mercury levels measured in the hair of these mothers correlated with decreased performance in motor and learning skills. A third study showed no impact on childhood development in children whose mothers were exposed to mercury in fish while pregnant. ATSDR used this latter study to derive a NOAEL for methylmercury of 0.0013 mg/kg/day upon which the chronic oral MRL of 0.0003 mg/kg/day is based.[7] EPA derived an oral RfD of 0.0001 mg/kg/day based on one of the former studies that found developmental effects. EPA estimates that about 5% of children exposed in the womb would be at risk for these effects if their mothers were exposed at a dose 10 times higher than the RfD. DOH recently derived a tolerable daily intake (TDI) range for methylmercury of 0.000035 to 0.00008 mg/kg/day based on impaired neurological development in children exposed *in utero*. The upper-bound of this range is consistent with EPA's oral RfD.[14,15]

Estimated doses of mercury for the average consumer of largemouth bass from Long Lake are below the EPA RfD, with hazard quotients of 0.7 for the upper lake and 0.6 for the lower lake. High-end exposure estimates give doses only slightly higher than the RfD, with hazard quotients of 1.6 and 1.7 for the upper and lower lake, respectively. This comparison indicates that exposure to mercury in largemouth bass from Long Lake is not a health concern for the average consumer and only of minimal concern for high-end consumers. It is important to note that the dose comparisons given here for mercury relate to *in utero* exposure and are not relevant to the general population but pertain to women of child-bearing age and children under 6 years of age. Other endpoints of mercury toxicity are not of concern at these levels of exposure.

Multiple Exposure and Toxicological Mixtures

The potential exists for different chemicals to interact in the body and increase or decrease the potential for adverse health effects. The vast number of chemicals in the environment makes it impossible to measure all the possible interactions between these chemicals. Individual cancer risk estimates can be added because they are measures of probability. When one is estimating noncancer risk, however, similarities must exist between the chemicals if the doses are to be added. Although some chemicals can interact to cause a toxic effect that is greater than the added effect, there is little evidence demonstrating such synergy at concentrations commonly found in the environment. In the case of contaminants measured in Long Lake large mouth bass, mercury and PCBs both impact childhood development following *in utero* exposure, therefore the hazard quotients of these two contaminants should be added and compared to a "combined RfD," also known as a hazard index (HI).

$$\text{HI} = \text{PCB dose} / \text{PCB MRL}_{\text{developmental}} + \text{mercury dose} / \text{mercury MRL}$$

It should be noted that the PCB MRL of 0.00002 mg/kg/day is based on immunological effects. A second MRL of 0.00003 mg/kg/day was derived by ATSDR to account for developmental effects. This MRL will be used to compute the developmental hazard associated with exposure to PCBs from consumption of Long Lake large mouth bass.

A hazard index of 1.9 for the average consumer of largemouth bass to 5.1 for high-end exposures resulted from this approach. While PCBs are the main contributor to the risks associated with eating bass from Long Lake, the levels are consistent with those found in fish from other fresh water bodies in Washington State. Overall, the heath risks from eating Long Lake bass are minimal and probably outweighed by the nutritional benefits for most consumers.

Cancer Risk Evaluation

Cancer risks from exposure to total PCBs and PCB-TEQs in Long Lake fish are discussed below. EPA considers methylmercury to be a possible human carcinogen (Group C) based on limited evidence in animals and inadequate evidence in humans. However, no cancer potency factor is available from EPA with which to estimate cancer risk from exposure to methylmercury.

Total polychlorinated biphenyls (PCBs)

PCBs are classified as a probable human carcinogen (Group B2) by EPA based on sufficient evidence of cancer in animals, but inadequate evidence in humans.[8] Cancer risk estimates assume long-term exposure (i.e., 30 years) averaged over a 70-year lifetime. This average daily dose is then multiplied by a measure of toxicity—the cancer potency factor (or slope factor)—to produce an estimate of carcinogenic risk. Cancer risks from exposure to total PCBs estimated for average and high-end consumers of Long Lake fish ranged from 8 in 100,000 to 4 in 10,000 (Appendix D, Table D2).

Some cancer potency factors are derived from human population data while 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 thinking suggests that there is no "safe dose" of a carcinogen and that a very small dose of a carcinogen will give a very small cancer risk. Cancer risk estimates are, therefore, not *yes/no* answers but measures of chance (probability). The validity of the "no safe dose" assumption for 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. Despite the associated uncertainty, cancer risk estimates are useful in determining the magnitude of a cancer threat.

While high-dose animal studies demonstrate that PCBs can cause liver tumors in rats, evidence that PCBs can cause cancer in humans is conflicting. Some studies have linked human exposure to organochlorines with breast cancer while other studies have found no association. [16,17,18,19,20,21,22,23,24]. Other studies suggest a link between PCB exposure in humans and non-Hodgkin's lymphoma (NHL) based on higher PCB blood serum levels in NHL patients versus controls.[25,26] One recent analysis of a large cohort of workers exposed while manufacturing PCB-containing transformers showed no increase in mortality despite high PCB blood-serum levels.[27] The previously mentioned rice oil-poisoning incident in Taiwan did not reveal elevations in cancer mortality.[28] However, an examination of residents similarly exposed in Japan did show an increase in mortality from liver cancer.[29]

The data supporting the potential for PCBs to cause cancer in humans at the levels associated with environmental exposure is not clear. Noncancer endpoints, however, are well documented, particularly with respect to developmental effects in humans. The cancer risk associated with chronic exposure at the MRL is estimated at 2 cancers per 100,000 persons exposed over a lifetime.[d] EPA's guidance on fish advisories suggests the use of a target cancer risk of 1 cancer per 100,000 persons exposed indicating that the noncancer approach is sufficiently protective.[30]

Polychlorinated biphenyl toxic equivalents (PCB-TEQs)

The potential for adverse health effects resulting from environmental exposure to dioxin-like PCBs is difficult to estimate. ATSDR has an MRL for 2,3,7,8-tetrachlorodibenxo-p-dioxin (2,3,7,8-TCDD) of 1 picogram per kilogram body weight per day (pg/kg/day).[e] The World Health Organization (WHO) proposes a tolerable daily intake of 1–4 TEQ pg/kg-day for dioxin and dioxin-like compounds. To make a valid comparison to this MRL, analysis of all dioxins and dioxin-like congeners is required, which includes the 12 dioxin-like (or co-planar) PCBs, 17 dioxins and 10 furans. However, the PCB-TEQs given in Table 2 for Long Lake fish provide a useful comparison with the MRL.

Doses calculated for PCB-TEQ levels exceed the ATSDR MRL for each of the three species analyzed with largescale sucker having highest PCB-TEQ levels. Hazard quotients ranged from 1 to 4.4 and cancer risks from 8 in 100,000 to 3 in 10,000 (Appendix D, Tables D3 and D4). These risk estimates would be higher if dioxins and furans were also analyzed. It should be noted that cancer risks were calculated using the old 2,3,7,8-TCDD cancer potency factor. EPA's new reassessment of dioxin and dioxin-like furan and PCB congeners recommends an even higher cancer potency factor that would yield 6–7 fold higher cancer risk estimates.

EPA is not proposing an RfD for dioxins and dioxin-like compounds. The agency states in its draft reassessment that "any RfD that the Agency would recommend under the traditional approach for setting an RfD is likely to be 2–3 orders of magnitude (100 to 1,000 times) below current background intakes and body burdens." Comparison with background is, therefore, an essential step in evaluating site-specific exposures to dioxins, including dioxin-like PCBs.

Comparison with Background

The widespread presence of PCBs in fish throughout the United States and the world suggests that health risks associated with consumption of Long Lake fish be compared with an estimate of background risk.[5] The degree by which PCB concentrations in Long Lake fish exceed background is a necessary consideration in determining public health actions. It is difficult to choose a water body from which to derive an actual "background" level of PCBs in fish. Because

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[d] This cancer risk was calculated by assuming a daily dose at the MRL of 0.00002 mg/kg-day for a duration of 30 years averaged over a 70-year lifetime. This gives a lifetime-average daily dose of 8.6E-6 mg/kg-day that can be multiplied by the Aroclor cancer potency factor of 2.0 per mg/kg-day to give a risk of 1.7E-05.

[e] As noted in ATSDR's Toxicological Profile for Chlorinated Dibenzo-P-Dioxins, it is ATSDR's policy to use the 2,3,7,8-TCDD MRL for other dioxin-like compounds, expressed in total TEQs.

PCBs have been introduced into the environment entirely through human activity, real environmental background levels would be zero. However, considering the widespread dispersion of PCBs throughout the world from atmospheric deposition, “background” can be represented by contaminant levels in fish from those water bodies not impacted by specific point-sources of pollution.

Total polychlorinated biphenyls (PCBs)

Studies are available with which to compare PCB (Aroclor) levels in Long Lake fish with fish from other fresh water bodies in Washington State. Such comparisons are often complicated by differences in study design. Some of these differences include analytical methods, detection limits, species, size and tissue type (e.g., whole body versus fillet sample preparations). Despite these confounding factors, it useful to consider the PCB levels encountered in various fish throughout the state.

Recent sampling of Lake Whatcom in 1998, Ward Lake in 1999 and the Elwha River in 1999 found some of the lowest PCB levels in freshwater fish from Washington with fillet samples ranging from 9 to 19 ppb.[31] It should be noted that the previously mentioned health consultation used a species-specific background value of 13 ppb for rainbow trout extracted from the Lower Elwha data for comparison with upper Spokane River rainbow trout.[1] However, this comparison is questionable as the size of the Lower Elwha trout were about 3-fold less than those sampled in the upper Spokane River. Persistent bioaccumulative contaminants such as PCBs generally increase with the age and size of the fish, although other factors such as diet, metabolism and lipid content also play a role. The 2001 sampling of Long Lake appears to support this relationship with respect to PCB concentration although compositing makes the correlation difficult to firmly establish.[3]

More recently, Ecology sampled fish from 14 Washington rivers and lakes in 2001 as part of the Washington State Toxics Monitoring Program (WSTMP) and found total PCB levels ranging from 10.8 to 132 ppb.[32,f] This range is likely high relative to environmental background ranges—site selection criteria included consideration of known hazardous waste sites and previous sampling. A compilation of PCB analytical results for fish samples (fillet and whole samples) obtained from Washington water bodies between 1992 and 1998 (excluding the Spokane River and Long Lake) yielded a median value of 36 ppb.[33] This database was expanded to include the recent Ecology WSTMP sampling along with sampling of the Columbia River Basin, including Lake Roosevelt, between 1994 and 1998. Table 4 below provides summary statistics from this database separated by tissue type (fillets with skin and whole body).

[f] Upper Long Lake was included as part of this sampling effort but the Long Lake sample was analyzed for mercury only.

Table 4. Total Polychlorinated Biphenyls (PCBs) in Washington State Fish Sampled Between 1992 and 2001 (excluding the Spokane River and Long Lake) in ug/kg.

Tissue Type	# of samples	Mean	Median	Minimum	Maximum
Fillets with skin	133	59	30	3.4	1119
Whole body	108	99	78	10	379
All samples	241	77	48	3.4	1119

NOTE: Total PCBs calculated as sum of Aroclors using one-half detection limit for non-detects.

ug/kg = micrograms per kilogram also known as parts per billion (ppb).

The best comparisons between fish from different water bodies would use the same species and size of fish. EPA sampled several different species of fish in the Columbia River basin between 1996 and 1998.[34] A species-specific comparison of total Arolcor concentrations between this data set and the 2001 Long Lake data is provided in Table 5 below. The Columbia Basin study considered various factors when selecting sites for sampling. Samples were preferentially taken from high-use fishing areas and areas near known sources of contaminants. It is not clear whether the bias introduced by preferentially selecting sampling sites according to these factors produced higher PCB results than would a random sample.

Table 5. Comparison of Total Polychlorinated Biphenyls (PCBs) in Washington State fish from the Columbia Basin and Long Lake.

Species	Tissue Type	Number of samples		Mean Length (mm)		Mean Weight (g)		PCB (ug/kg)							
								Mean		Median		Minimum		Maximum	
		CB	LL	CB	LL	CB	LL	CB	LL	CB	LL	CB	LL	CB	LL
Smallmouth bass	Fillet	3	6	442	288	1434	362	174	36	111	38	107	17	303	54
	Whole	3	NA	448	NA	1417	NA	196	NA	166	NA	138	NA	284	NA
Mountain whitefish	Fillet	12	3	335	265	395	169	181	73	49	70	27	60	1119	89
	Whole	12	NA	325	NA	350	NA	123	NA	102	NA	47	NA	25	NA
Largescale sucker	Fillet	19	6	489	457	1175	878	42	101	24	106	18	63	104	132
	Whole	23	5	455	462	976	954	65	302	50	321	16	164	165	393

NOTE: Fish fillets were analyzed with skin for both the Columbia Basin and Long Lake samples.

CB = Composite samples collected from Columbia Basin waters between 1996 and 1998 included the following rivers: Columbia, Yakima, Umatilla, Snake and Deschutes.

LL = Composite samples collected in 2001 from both the upper and lower reaches of Long Lake.

ug/kg = micrograms per kilogram also known as parts per billion (ppb).

The comparison given above indicates that mean total PCB levels in Long Lake smallmouth bass and mountain whitefish are lower than those in the Columbia Basin, while largescale sucker levels are higher. It is important to note that bass and whitefish sampled from Columbia Basin rivers were larger than those caught in Long Lake. It is necessary to identify differences in age, size and weight when making comparisons of contaminant burdens in fish caught from different water bodies. In terms of accurately assessing human exposure, however, the sampling methodology is assumed to mimic the angler's catch from each water body and so be representative of fish consumed. According to Ecology staff, fish sampled from Long Lake in 2001 are representative of what an angler would catch.

Total PCBs in largescale sucker from Long Lake are only slightly lower than levels found in the upper Spokane River (see Table D5, Appendix D). Mountain whitefish sampled in the upper river clearly have higher PCB levels than those in Long Lake, but were also substantially larger fish.

Polychlorinated biphenyl dioxin toxic equivalents (PCB-TEQ)

Very little data is available with which to compare directly PCB-TEQ levels found in the Long Lake 2001 sampling. Toxic equivalency factors (TEFs) were not developed for PCBs until 1994 when the World Health Organization (WHO) adopted a scheme that included TEFs for 13 congeners. The more recent TEF scheme adopted by the WHO in 1998 provides 12 TEF values for the dioxin-like PCB congeners.[6,35] Several state and nationwide sampling efforts have measured TEQ values based on dioxin and furan congeners only. EPA's dioxin reassessment provides a national PCB-TEQ background level of 1.2 ppt in freshwater fish, which is equivalent to their TEQ estimate for dioxin and furans.

As part of the WSTMP effort mentioned above, Ecology took a single composite sample from each of four lakes and found a dioxin-furan TEQ range of 0.20 to 1.05 ppt.[30,g] In nearby Lake Roosevelt, dioxin-furan TEQ levels ranged from 0.3 to 2.54 ppt in six species of fish sampled in 1994.[36,h] Both of these dioxin-furan TEQ ranges are based on the old EPA 1989 TEFs. More recent sampling of rainbow trout (wild and net-penned) from Lake Roosevelt gave an average overall TEQ of 0.9 with dioxin-like PCBs accounting for more than 70% of this value.[37]

The recent EPA Columbia Basin study again provides some species-specific comparisons as shown in Table 6.

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[g] Samples were taken in 2001 from Green Lake (common carp), McIntosh Lake (brown trout), Liberty Lake (brown trout) and Lake Whatcom (cutthroat trout). Composite size ranged from 5 to 10 individuals.

[h] While these dioxin-furan TEQs are based on the old EPA TEF scheme, the range calculated with the new scheme was virtually identical at 0.35–2.58 ppt.

Table 6. Comparison of Polychlorinated Biphenyl Dioxin Toxic Equivalents (PCB-TEQ) in Washington State Fish from the Columbia Basin and Long Lake.

Species	Tissue Type	Number of samples		Mean Length (mm)		Mean Weight (g)		PCB TEQ (ng/kg)							
								Mean		Median		Minimum		Maximum	
		CB	LL	CB	LL	CB	LL	CB	LL	CB	LL	CB	LL	CB	LL
Mountain whitefish	Fillet	12	3	335	265	395	169	5.5	2.0	1.8	1.9	0.11	1.7	36	2.3
Largescale sucker	Fillet	19	6	489	457	1175	878	0.79	2.6	0.49	2.7	0.17	1.2	3.3	3.5

Note: Fish fillets were analyzed with skin for both the Columbia Basin and Long lake samples.

CB = Samples collected from Columbia Basin waters between 1996 and 1998 included the following rivers: Columbia, Yakima, Umatilla, Snake, and Deschutes.

LL = Samples collected in 2001 from both the upper and lower reaches of Long Lake.

ug/kg = micrograms per kilogram also known as parts per billion (ppb).

PCB-TEQ levels in mountain whitefish from Long Lake are lower than those sampled from Columbia Basin waters. As noted above, the smaller size of the Long Lake mountain whitefish could account for the lower result. It is also useful to note that the median values are nearly identical, suggesting a skewed distribution in the Columbia Basin whitefish sample. Both the mean and median PCB-TEQ values for Long Lake largescale sucker are higher than those found in the Columbia Basin study. Because the Long Lake suckers were somewhat smaller in size, the higher PCB-TEQs in these fish cannot be explained by size differences.

Mercury

Ecology recently completed a survey of mercury in bass that included 20 lakes throughout the state. The survey examined primarily largemouth bass and found mercury ranging from 22 to 1280 ug/kg, with an average concentration of 217 ug/kg. Mercury in largemouth bass sampled from both reaches of Long Lake on 2001 ranged from 65 to 113 ug/kg, with an average of 93 ug/kg. This comparison indicates that mercury levels in bass from Long Lake are similar or lower than those from other water bodies in the state.

Benefits of Fish Consumption

It is important to consider the very real benefits of eating fish. Fish is an excellent source of protein and has been associated with reduced risk of coronary heart disease. The health benefits of eating fish have been associated with low levels of saturated versus unsaturated fats. Saturated fats are linked with increased cholesterol levels and risk of heart disease, while unsaturated fats (e.g., omega-3 polyunsaturated fatty acid) are an essential nutrient. Fish also provide a good source of some vitamins and minerals.[38, 39] The American Heart Association recommends two servings of fish per week as part of a healthy diet.[40]

The health benefits of eating fish deserve particular consideration when 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.[36] No subsistence-consuming populations that fish Long Lake were identified in this assessment.

All fish, including commercially purchased fish, have PCBs and other contaminants in them. For this reason, it is important to inform consumers to choose fish that generally have the lowest levels of contaminants, and provide other tips with which people can reduce their exposure to contaminants. For instance, PCB exposure from fish consumption can be significantly reduced through specific types of preparation and cooking. Reduction of PCBs in the fish meal varies considerably by species and type of preparation. Simply removing the skin of the fish has been shown to reduce PCB exposure.[41] An average reduction of 30 percent was estimated for fat-trimmed, fillet meals of Great Lakes fish.[42] Furthermore, cooking fish also reduces PCB levels in the fillets by more than 20%, and in some cases, PCBs were nearly entirely removed through cooking.[43, 44]

Fish consumption advice should take into account that eating alternative sources of protein also has risks. For instance, increasing the consumption rate of 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.

Chemical Exposure and Children

Children can be uniquely vulnerable to the hazardous effects of many environmental toxicants.

The developing fetus is clearly sensitive to PCB and mercury exposures. The developing fetus must, therefore, be considered when addressing health hazards posed by PCBs and mercury, both of which are known to accumulate in fish.

Although the MRL and RfD for PCBs is based on immune system effects, it represents the most sensitive endpoint of PCB toxicity and is, therefore, protective of the developing fetus. To ensure that a health protective approach was used, however, the combined effects of PCBs and mercury on the developing fetus were estimated for largemouth bass, a species predicted to have the highest mercury levels.

Other Fish Species

The recent sampling of Long Lake fish evaluated above included five species: mountain whitefish, largemouth bass, smallmouth bass, largescale sucker and yellow perch. However, other species are known to exist in the lake, including blue gill, crappie, common carp, northern pikeminnow (a.k.a. squawfish) and brown trout.

The only data available on these other species include a single composite sample of white crappie and brown trout and three composites of northern pikeminnow taken in 1994 (see Appendix C). Brown trout and northern pikeminnow sampled in 1994 had elevated levels of PCBs compared to different Long Lake fish sampled in 2001. PCB levels, however, may have declined in these other species since the 1994 sampling, as appears to be the case for sucker, bass and whitefish. It is clear that crayfish do not accumulate PCBs to any great extent, as evidenced by samples taken in Long Lake and the upper river since 1993.[1]

In some instances, a representative species can be used to assess groups of fish that would be expected to accumulate similar amounts of contaminants. For example, it could be assumed that carp might contain levels of PCBs similar to sucker since they are both bottom feeders. While feeding habits might be similar, differences in size, metabolism and lifespan can make this extrapolation tenuous.

Existing Fish Consumption Advisories

DOH has issued two state-wide fish consumption advisories recommending that 1) women of child-bearing age and children under 6 years of age limit their consumption of canned tuna fish and not eat swordfish, shark, tilefish, king mackerel, or fresh-caught or frozen tuna steak, and 2) women of child-bearing age and children under 6 years of age limit their consumption of large and smallmouth bass to no more than two meals per month. More information regarding these advisories is available at http://www.doh.wa.gov/ehp/oehas/EHA_fish_adv.htm or by calling toll-free 1-877-485-7316.

In conjunction with this evaluation, the existing fish consumption advisory released in March 2001 for upstream portions of the river has been revised. The revisions segment the river into three portions, including Long Lake. For upstream reaches of the Spokane River, DOH recommends no consumption of fish caught between the Idaho border and Upriver Dam, and advises a limit of one meal per month for fish caught between Upriver Dam and Nine Mile Dam. As noted below in the *Recommendations* section of this document, the Long Lake segment does not require meal limits, but anglers are advised to prepare and cook fish caught in Long Lake in a manner that will reduce PCB levels.

Fish meal limits

The following meal limits in Table 7 were derived from average mercury and PCB levels in Long Lake fish. These limits were calculated using average concentration estimates of mercury and PCBs for various fish species with a target hazard index of 1. These limits represent consumption rates that would be protective of persons who consume fish from Long Lake based on straight risk assessment. Factors such as the benefits of fish consumption, reduction of contaminants through cooking and preparation, background contaminant levels in fish, and access to other sources of fish or protein were not considered when calculating these meal limits.

Table 7. Meal Limits Based on PCBs, Mercury, Long Lake Fish, Washington.[a]

Fish Species	Recommended 8-ounce meals per month	
	Developmental [b]	Immune [c]
Large Mouth Bass	3	3.2
Small Mouth Bass	6.5	5.1
Largescale Sucker	2.4	1.8
Mountain Whitefish	3.3	2.6
Yellow Perch	Unlimited	Unlimited

a= Large mouth bass were the only species sampled for mercury

b = Based on developmental endpoint of PCBs and mercury assuming a female body weight of 60 kg

c = Based on the Immune endpoint of PCBs, assuming an adult body weight of 70 kg

Applying the Table 7 meal limits across the general population assumes that meal size will decrease proportionately with body weight. Such an assumption could result in an underestimate of exposure for consumers who eat proportionately more fish per unit of body weight. Table 8 demonstrates how an eight-ounce meal for a 70-kilogram adult would change to remain proportional with body weight.

Table 8. Standard Fish Meal Size Adjusted for Body Weight [a]

Body Weight (lbs)	Body Weight (kg)	Adjusted Meal Size (oz)
200	90.7	10.4
154	**70**	**8**
150	68.0	7.8
100	45.4	5.2
50	22.7	2.6
25	11.3	1.3
20	9.1	1.0

a = Based on an 8-ounce meal for a 70 kg adult.

lbs = pounds kg = kilograms

Conclusions

1. Average consumers of sport fish from Long Lake are not expected to experience adverse health effects from exposure to contaminants in those fish. *No apparent public health hazard* exists for average consumers of Long Lake sport fish.

2. High-end consumers of sport fish from Long Lake might be exposed at doses only slightly above health comparison values.

   - Although these doses are not expected to cause adverse health effects, prudent public health measures such as cooking and cleaning fish to reduce exposure to PCBs through fish consumption can lower potential risk associated with PCBs in fish.

3. Polychlorinated biphenyls (PCBs) in popular sport-caught fish from Long Lake are generally lower than in the upper Spokane River. Consumption of sport fish from Long Lake is preferred over the consumption of fish from other upstream portions of the Spokane River.

4. Average and high-end consumption of yellow perch is not expected to result in any adverse health effects.

   - Yellow perch contain the lowest levels of PCBs in any fish sampled from Long Lake.

5. Levels of total PCBs and dioxin-like PCBs in Long Lake largemouth bass and mountain whitefish are similar to those in fish from other water bodies in Washington State.

6. Largescale sucker from Long Lake have PCB levels only slightly lower than those found in the upper river and higher than sucker data recently gathered from Columbia Basin rivers.

7. Largescale sucker appear to have slightly higher PCB-TEQ levels than sucker found in Columbia Basin rivers, which would be consistent with the higher total PCB levels.

8. Largescale sucker are the least desirable of all the fish sampled from Long Lake from a health perspective, but average consumers of fish from Long Lake are not expected to experience adverse health effects from exposure to contaminants in those fish. Although high-end consumers of fish from Long Lake might be exposed at doses above health comparison values, these doses are not expected to cause adverse health effects, especially when considering the safety factor of 300 that was applied to derive the MRL (hazard quotient of 8.5 results from a dose that is about 35 times less that actual effect level), the health benefits of fish consumption, and the reduction of PCB levels through cooking and preparation.

9. Other species of fish not targeted by sport fisherman that are likely or known to be present in the lake, such as common carp and bluegill, have not been sampled.

10. The historical data do not allow for any conclusions about whether PCB levels in Long Lake fish have decreased to any significant extent since the first samples were analyzed in 1992.

Recommendations

1. Although this health consultation makes no meal limit recommendations for Long Lake fish, DOH recommends providing health education to Long Lake fish consumers including instructions on how to clean and cook fish in a manner that reduces a person's exposure to PCBs in their diet (see Public Health Action Plan).

Public Health Action Plan

Actions taken

1. DOH has communicated the following advice to Long Lake anglers:

    - Eat only fillets or gutted fish—do not eat the whole fish.
    - Do not eat the skin—if possible, remove the skin prior to cooking.
    - Cook fish so that drippings do not remain in the meal (i.e., broil or bake on a drip pan).
    - Choose yellow perch before eating other types of fish from Long Lake.

These precautions are particularly important with respect to largescale sucker and other non-sport fish (e.g. northern pikeminnow, crappie), which contain, or may contain, higher levels of PCBs than sport fish.

Pregnant women, women of child-bearing age, breast-feeding women, and children under 6 years of age should pay special attention to these recommendations.

2. DOH conducted fish cleaning demonstrations to various angler communities in the Spokane area. Demonstrations were also given to representatives from different ethnic groups so that the skills could be transferred to non-English speakers.

3. DOH has updated fact sheets for the Spokane River to include information on Long Lake fish. The fact sheets also show preparation and cooking methods to reduce a fish consumer's exposure to PCBs. In addition to English language fact sheets, Spanish, Hmong, Vietnamese, and Russian language versions were prepared to account for the cultural diversity in the Spokane River valley.

Actions planned

1. DOH will work with the Spokane Regional Health District to continue health education activities in the Spokane River Basin (including Long Lake).

2. DOH will work with Ecology and the Spokane Regional Health District to update fish advisories in the Spokane River Basin as fish sampling data are made available in the future.

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

Technical Project Officer, CAT, SPAB, DHAC

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

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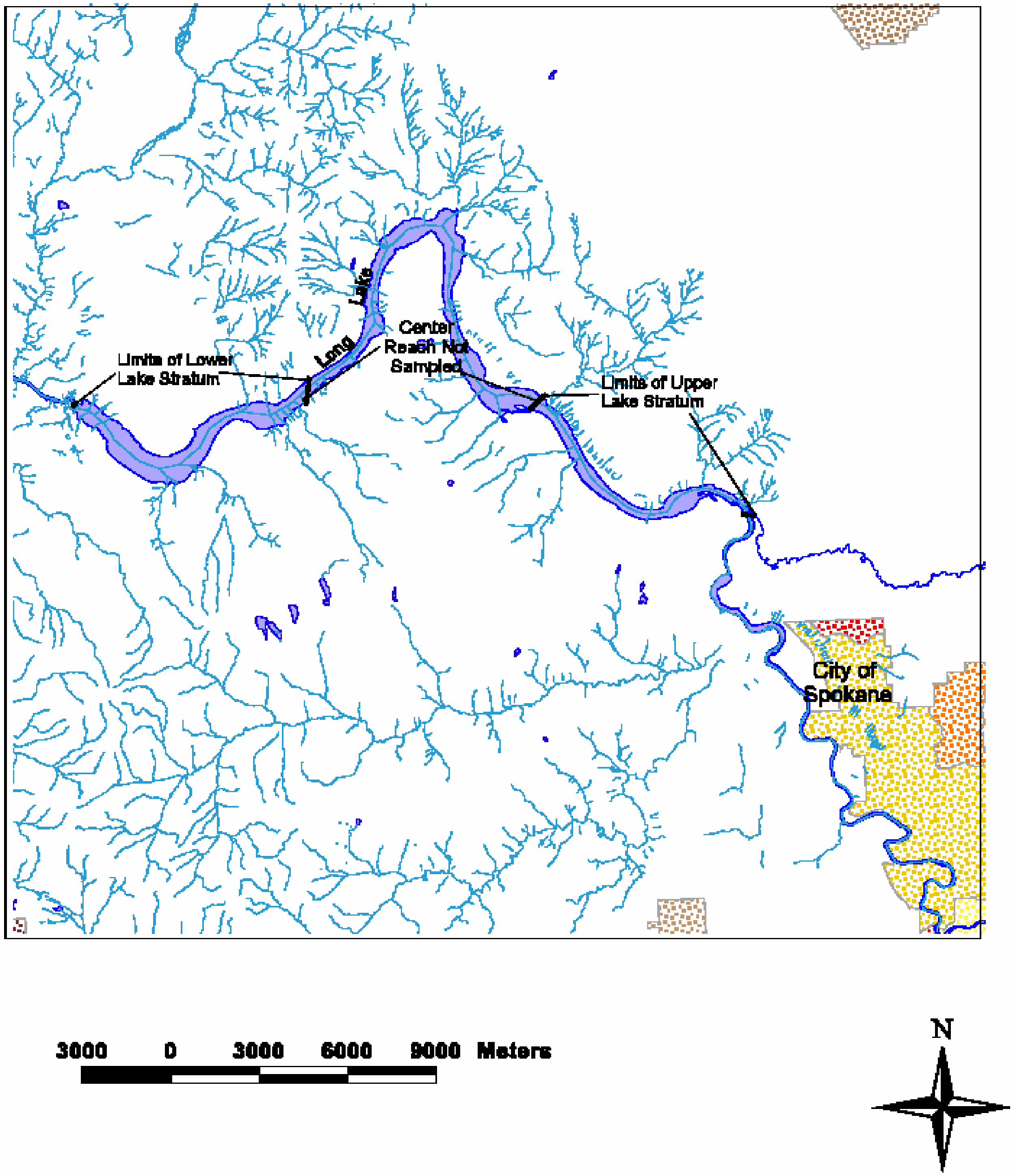
Appendix A. Figures

Figure 1. Long Lake Sampling Segments (Adapted from Reference 3)



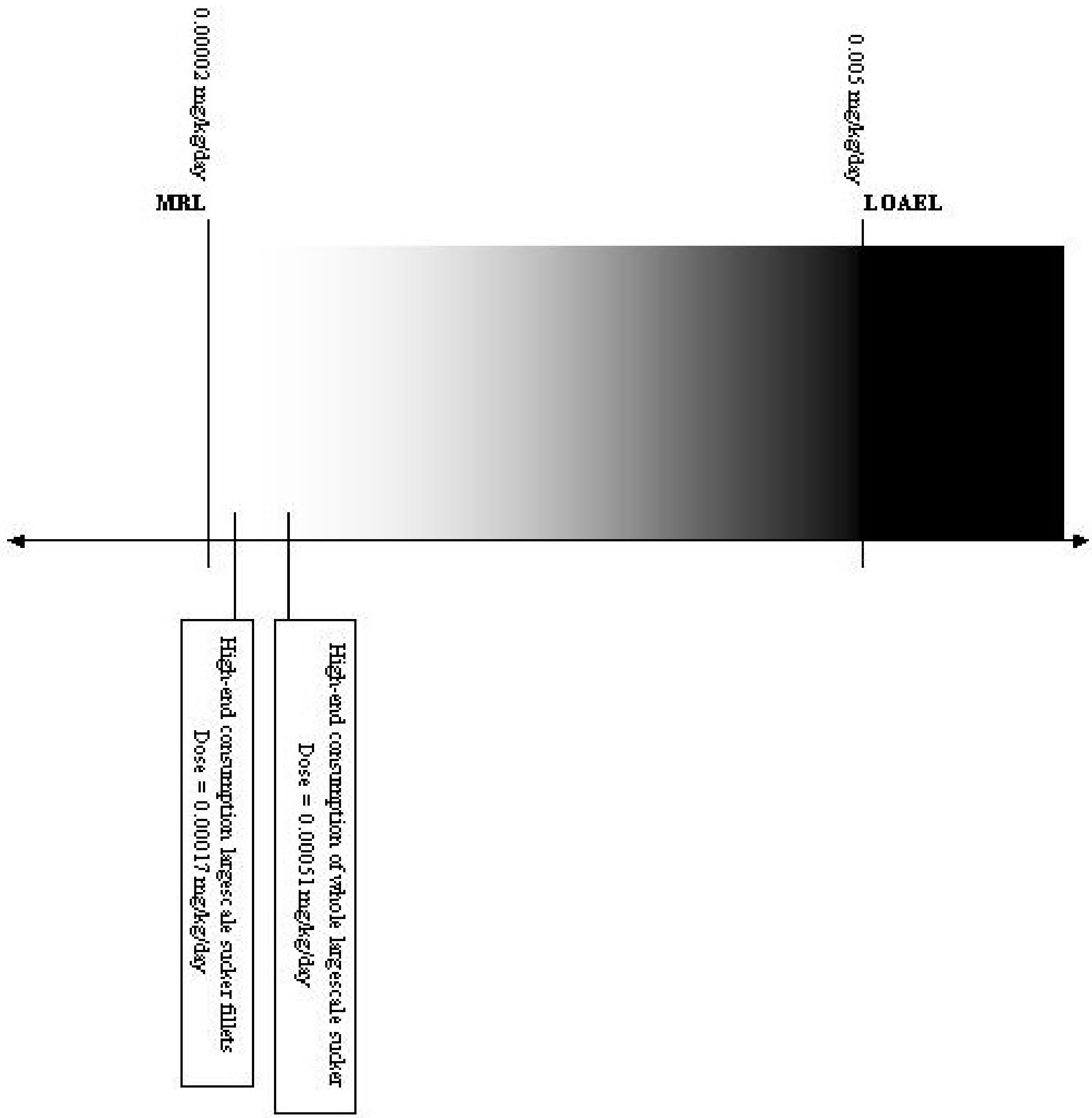


Figure 2. Worst-Case Exposures to PCBs in Long Lake Largescale Sucker Exceed the MRL.

Adverse health effects do not necessarily occur when an MRL is exceeded, but the likelihood increases as a dose approaches an actual toxic effect level (white = less likely, black = more likely). The likelihood of adverse health effects occurring as a result of these exposures is relatively low.

Appendix B. 2001 Long Lake Fish Sampling Results

Table B1. Polychlorinated Biphenyl and Metals Results for June 2001 Samples of Upper Long Lake Fish, Spokane County, Washington (ug/kg)

MEL ID Number	Sample ID		Zinc		Cd		Pb		Hg		PCB 1016		PCB 1221		PCB 1232		PCB 1242		PCB 1248		PCB 1254		PCB 1260		% lipid
15-8307	ULL-LMB	1	7930		100	U	100	U	113		11	u	11	u	11	u	11	u	22		37		13		0.76
15-8311	ULL-LMB	2	7380		100	U	100	U	81.1		11	u	11	u	11	u	11	u	11	j	20		7.8	j	0.33
15-8306	ULL-LMB	3	7720		100	U	100	U	105		10	u	10	u	10	u	10	u	11		23		5.2	nj	0.61
13-8280	ULL-LRS	1	10450		100	U	100	U			28	u	28	u	28	u	28	u	21	j	53	nj	38		1.83
13-8287	ULL-LRS	2	15900		100	U	100	U			11	u	11	u	11	u	11	u	35		69		28		1.89
13-8286	ULL-LRS	3	15900		100	U	100	U			11	u	11	u	11	u	11	u	14	nj	38	nj	34		1.55
13-8285	ULL-LRS	W1									22	u	22	u	22	u	22	u	20	nj	73		71		1.46
13-8283	ULL-LRS	W2	22300		280		730				51	u	51	u	51	u	51	u	82		160		94		4.02
13-8284	ULL-LRS	W3									22	u	22	u	22	u	22	u	89	nj	150		55		5.52
15-8308	ULL-MHF	1									11	u	11	u	11	u	11	u	19		43	nj	27		1.88
15-8309	ULL-MHF	2									11	u	11	u	11	u	11	u	11		29		20		1.53
15-8310	ULL-MHF	3	11700		100	U	100	U			11	u	11	u	11	u	11	u	16		34		20	nj	1.83
13-8291	ULL-SMB	1	5910		100	U	100	U			11	u	11	u	11	u	11	u	4.1	j	19	nj	9.3	j	0.46
13-8293	ULL-SMB	2									11	u	11	u	11	u	11	u	12		27		15		0.69
13-8292	ULL-SMB	3									11	u	11	u	11	u	11	u	9.5	j	21		9	j	0.43
14-8300	ULL-YPC	1									11	u	11	u	11	u	11	u	11	u	11	u	11	u	0.26
14-8301	ULL-YPC	2	11900		100	U	100	U			11	u	11	u	11	u	11	u	11	u	11	u	11	u	0.35
14-8302	ULL-YPC	3									11	u	11	u	11	u	11	u	11	u	11	u	11	u	0.33

LMB = Largemouth bass   LRS = Largescale sucker   MHF = Mountain whitefish   SMB = Smallmouth bass   YPC = Yellow perch   U = not detected   j = estimated value

ug/kg = micrograms per kilogram; also known as parts per billion (ppb).

Table B2. Polychlorinated Biphenyl and Metals Results for June 2001 Samples of Lower Long Lake Fish, Spokane County, Washington (µg/kg)

MEL ID Number	Sample ID		Zinc		Cadmium		Lead		Mercury		PCB 1016		PCB 1221		PCB 1232		PCB 1242		PCB 1248		PCB 1254		PCB 1260		% lipid
15-8303	LLL-LMB	1	7430		100	U	100	U	108		11	u	11	u	11	u	11	u	11	j	24		12		0.41
15-8304	LLL-LMB	2	9460		100	U	100	U	86.4		11	u	11	u	11	u	11	u	18		33		13		0.62
15-8305	LLL-LMB	3	9100		100	U	100	U	65.4		11	u	11	u	11	u	11	u	14		31		12		0.32
13-8289	LLL-LRS	1	9400	J	100	U	100	U			11	u	11	u	11	u	11	u	16		34		13		1.48
13-8290	LLL-LRS	2	15000		100	U	100	U			11	u	11	u	11	u	11	u	26		44		30		1.86
13-8288	LLL-LRS	3	10200		100	U	100	U			11	u	11	u	11	u	11	u	34		53		25		1.92
13-8281	LLL-LRS	W1									27	u	27	u	27	u	27	u	63		160		170		2.54
13-8282	LLL-LRS	W3	32200		420		500				27	u	27	u	27	u	27	u	41		180	nj	100		4.1
13-8296	LLL-SMB	1									11	u	11	u	11	u	11	u	11	u	17	nj	14		0.23
13-8295	LLL-SMB	2									11	u	11	u	11	u	11	u	11	u	11	u	11	u	0.09
13-8294	LLL-SMB	3	7610		100	U	100	U			11	u	11	u	11	u	11	u	11	u	22		11	j	0.17
13-8297	LLL-YPC	1									10	u	10	u	10	u	10	u	10	u	10	u	10	u	0.13
14-8298	LLL-YPC	2	9110		100	U	100	U			11	u	11	u	11	u	11	u	11	u	11	u	11	u	0.17
14-8299	LLL-YPC	3									10	u	10	u	10	u	10	u	10	u	10	u	10	u	0.18

LMB = Largemouth bass LRS = Largescale sucker SMB = Smallmouth bass YPC = Yellow perch

U = not detected j = estimated value

ug/kg = micrograms per kilogram; also known as parts per billion (ppb).

Table B3. Polychlorinated Biphenyl Dioxin Toxic Equivalents (PCB-TEQs) for June 2001 Samples of Upper Long Lake Fish, Spokane County, Washington (ng/kg)

IUPAC NO.	**ULL-LRS-1**	**ULL-LRS-2**	**ULL-LRS-3**	**ULL-LRS-3 (dup)**	**ULL-LMB-1**	**ULL-LMB-2**	**ULL-LMB-3**	**ULL-MHF-1**	**ULL-MHF-2**	**ULL-MHF-3**
	13-8280	13-8287	13-8286	13-8286	15-8307	15-8311	15-8306	15-8308	15-8309	15-8310
77	0.007	0.011	0.005	0.006	0.019	0.007	0.008	0.010	0.009	0.012
81	0.000063	0.000029	0.000045	0.000008	0.000012	0.000010	0.000028	0.000010	0.000011	0.000010
105	0.254	0.309	0.380	0.310	0.220	0.111	0.111	0.236	0.174	0.211
114	0.118	0.144	0.149	0.151	0.091	0.049	0.050	0.100	0.076	0.085
118	0.827	0.895	1.040	0.987	0.508	0.257	0.284	0.643	0.478	0.542
123	0.018	0.025	0.023	0.022	0.012	0.007	0.007	0.012	0.009	0.011
126	1.120	1.170	1.390	1.420	1.390	0.696	0.851	0.872	0.630	0.752
156	0.389	0.408	0.474	0.463	0.231	0.121	0.142	0.366	0.283	0.300
157 [a]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
167	0.004	0.003	0.004	0.004	0.002	0.001	0.001	0.003	0.002	0.002
169	0.038	0.035	0.042	0.033	0.014	0.008	0.013	0.026	0.020	0.022
189	0.006	0.005	0.007	0.007	0.003	0.001	0.002	0.004	0.004	0.004
Total	2.78	3.00	3.51	3.40	2.49	1.26	1.47	2.27	1.68	1.94
Sum $_{105,114,118,126,156}$	**2.71**	**2.93**	**3.43**	**3.33**	**2.44**	**1.23**	**1.44**	**2.22**	**1.64**	**1.89**
Contribution $_{105,114,118,126,156}$	**97%**	**97%**	**98%**	**98%**	**98%**	**98%**	**98%**	**98%**	**97%**	**97%**

LRS = Largescale sucker LMB = Largemouth bass MHF = Mountain whitefish ng/kg = nanograms per kilogram; also known as parts per trillion (ppt).

NOTE: TEQs are calculated using one-half detection limit for congeners that were not detected. Toxic equivalency factors (TEFs) are those adopted by the WHO in 1998.

a = Congener 157 co-eluted with congener 156. Both of these congeners have the same toxic equivalency factor (0.0005) and, therefore, the TEQ given for congener 156 should provide an accurate estimate for both in the total TEQ value.

Table B4. Polychlorinated Biphenyl Dioxin Toxic Equivalents (PCB-TEQs) for June 2001 Samples of Lower Long Lake Fish, Spokane County, Washington (ng/kg)

IUPAC NO.	LLL-LRS-1	LLL-LRS-2	LLL-LRS-3	LLL-LRS-3 (dup)	LLL-LMB-1	LLL-LMB-2	LLL-LMB-3
	13-8289	13-8290	13-8288	13-8288	15-8303	15-8304	15-8305
77	0.007	0.007	0.011	0.010	0.008	0.011	0.014
81	0.000024	0.000023	0.000041	0.000026	0.000037	0.001210	0.000050
105	0.122	0.224	0.264	0.268	0.157	0.137	0.247
114	0.047	0.100	0.113	0.113	0.078	0.063	0.113
118	0.298	0.695	0.803	0.808	0.494	0.391	0.708
123	0.010	0.017	0.020	0.021	0.011	0.010	0.019
126	0.563	1.120	1.170	1.190	0.975	0.834	1.310
156	0.155	0.326	0.315	0.309	0.237	0.170	0.330
157	0.000	0.000	0.000	0.000	0.000	0.000	0.000
167	0.001	0.003	0.003	0.003	0.002	0.001	0.003
169	0.014	0.036	0.026	0.025	0.017	0.014	0.028
189	0.002	0.005	0.004	0.004	0.003	0.002	0.004
Total	1.2	2.5	2.7	2.8	2.0	1.6	2.8
Sum $_{105,114,118,126,156}$	**1.2**	**2.5**	**2.7**	**2.7**	**1.9**	**1.6**	**2.7**
Contribution $_{105,114,118,126,156}$	**97%**	**97%**	**98%**	**98%**	**98%**	**98%**	**98%**

LRS = Largescale sucker LMB = Largemouth bass NOTE: TEQs are calculated using ½ detection limit for congeners that were not detected. Toxic equivalency factors (TEFs) are those adopted by the WHO in 1998.a = Congener 157 co-eluted with congener 156. Both of these congeners have the same toxic equivalency factor (0.0005) and therefore, the TEQ given for congener 156 should provide an accurate estimate for both in the total TEQ value.ng/kg = nanograms per kilogram; also known as parts per trillion (ppt).

Appendix C: Total Polychlorinated Biphenyl Concentrations in Long Lake Fish, Spokane County, Washington

Species	Month/Year Sampled	Sample Type	Sample Size [a]	Total PCB Concentration [b] (ug/kg)
Largescale sucker	7/92	Whole	NA	724
	7/93	Whole	1 (C=5)	410
	8/94	Whole	1 (C=8)	820
	6/01-upper	Whole	3	265
	6/01-lower	Whole	2	357
	6/01-upper	Fillet	3 (C=10)	110
	6/01-lower	Fillet	3 (C=9)	92
Brown trout	8/94	Fillet	3 (C=3)	193
Crayfish	7/93	edible	1 (C=5)	<17
	8/94	edible	1 (C=3)	<9
Largemouth bass	8/92	Fillet	1	<75
	7/93	Fillet	1 (C=5)	97
	8/94	Fillet	1 (C=5)	94
		Fillet	1 (C=5)	104
	6/01-upper	Fillet	3 (C=10)	50
	6/01-lower	Fillet	3 (C=4)	56
Smallmouth bass	6/01-upper	Fillet	3 (C=5)	42
	6/01-lower	Fillet	3 (C=5)	31
Mountain whitefish	7/93	Fillet	1 (C=5)	780
	8/94	Fillet	1 (C=8)	150
		Fillet	1 (C=7)	118
		Fillet	1 (C=7)	71
	6/01-upper	Fillet	3 (C=6)	73

Species	Month/Year Sampled	Sample Type	Sample Size [a]	Total PCB Concentration [b] (ug/kg)
	6/01-lower	Fillet	NA	NA
Northern pikeminnow (Squawfish)	8/94	Fillet	1 (C=8)	300
		Fillet	1 (C=8)	206
		Fillet	1 (C=8)	200
White crappie	8/94	Fillet	1 (C=7)	98
Yellow perch	8/92	Fillet	1	<75
	7/93	Fillet	1 (C=5)	18
	8/94 [c]	Fillet	1 (C=8)	15
		Fillet	1 (C=8)	16
		Fillet	1 (C=8)	12
	6/01-upper	Fillet	3 (C=10)	< 11 for each Aroclor
	6/01-lower	Fillet	3 (C=11)	< 11 for each Aroclor

a = C denotes that the sample was a composite consisting of the designated number of individuals per sample.

b = Sum of Aroclors

c = Sum of Aroclors 1248, 1254 and 1260 using ½ detection limit for non-detected Aroclors.

ug/kg = micrograms per kilogram also known as parts per billion (ppb).

Appendix D. Calculation of Health Risk Estimates

The human health risks associated with exposure to PCBs in Spokane River fish were evaluated for both cancer and noncancer endpoints using the equations below and the exposure parameters provided in Table D1.

Equation D1

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

Equation D2

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

Equation D3

$$\text{Hazard Quotient} = \frac{Dose_{noncancer}}{MRL}$$

Equation D4

$$\text{Cancer Risk} = Dose_{cancer} \times \text{Cancer Potency Factor}$$

Table D1. Exposure Assumptions

Parameter	Value	Unit	Comments
Concentration (C) - Average	see Tables 1,2 and 3	ug/kg	Mean
Concentration (C) – High-end			Maximum detected value.
Conversion Factor$_1$ (CF_1)	0.001	mg/ug	Converts contaminant concentration from micrograms (ug) to milligrams (mg)
Ingestion Rate (IR) - Average	42	g/day	DOH Lake Roosevelt angler survey
Ingestion Rate (IR) - High-end	90		
Conversion Factor$_2$ (CF_2)	0.001	kg/g	Converts mass of fish from grams (g) to kilograms (kg)
Exposure Frequency (EF)	365	days/year	Assumes daily exposure consistent with units of ingestion rate given in g/day.
Exposure Duration (ED)	30	years	High-end estimate of residence time.
Body Weight (BW) *	70	kg	Adult mean body weight (Immune endpoint)
	60		Adult female mean body weight (Developmental endpoint)
Averaging Time$_{noncancer}$ (AT)	10950	days	30 years
Averaging Time$_{cancer}$ (AT)	25550	days	70 years
Minimal Risk Level (MRL) or Oral Reference Dose (RfD)	Contaminant-specific	mg/kg/day	Source: ATSDR, EPA
Cancer Potency Factor	Contaminant-specific	mg/kg-day^{-1}	Source: EPA

***Note:** A body weight of 60 kg was used when calculating doses for mercury and combined doses of mercury and PCBs. The PCB chronic MRL of 0.00002 mg/kg-day was also replaced in this calculation by the intermediate MRL for developmental effects of 0.00003 mg/kg-day.

Table D2. Health Risk Calculations from Exposure to Total Polychlorinated Biphenyls in Fish Sampled in 2001 from Long Lake, Spokane County, Washington

Location	Species	Tissue	# of Samples	Hazard Quotient		Cancer Risk	
				Average	High-end	Average	High-end
Upper Long Lake	Largemouth bass	Fillet	3	1.5	4.6	3E-05	8E-05
	Largescale sucker	Fillet	3	3.3	8.5	6E-05	1E-04
		Whole[a]	3	7.9	21.6	1E-04	2E-04
	Mountain whitefish	Fillet	3	2.2	5.7	4E-05	1E-04
	Smallmouth bass	Fillet	3	1.3	3.5	2E-05	6E-05
	Yellow perch	Fillet	3	**0.5**	1.1	8E-06	2E-05
Lower Long Lake	Largemouth bass	Fillet	3	1.7	4.1	3E-05	7E-05
	Largescale sucker	Fillet	3	2.8	7.2	5E-05	1E-04
		Whole[a]	2	10.7	25.3	2E-04	4E-04
	Smallmouth bass	Fillet	3	**0.9**	2.5	2E-05	4E-05
	Yellow perch	Fillet	3	**0.5**	1.1	8E-06	2E-05
Lower and Upper Long Lake	Largemouth bass	Fillet	6	1.6	4.6	3E-05	8E-05
	Largescale sucker	Fillet	6	3.0	8.5	5E-05	1E-04
		Whole	5	9.0	25.3	2E-04	4E-04
	Smallmouth bass	Fillet	6	1.1	3.5	2E-05	6E-05
	Yellow perch	Fillet	6	**0.5**	1.1	8E-06	2E-05

Numbers in **bold** are those that do not exceed a hazard quotient of 1.

Table D3. Hazard Quotients and Hazard Index Results from Exposure to Both Total Polychlorinated Biphenyls and Mercury in Fish Sampled in 2001 from Long Lake, Spokane County, Washington

Location	**Species**	**Tissue**	**# of Samples**	**PCB Hazard Quotient (immune)**		**PCB Hazard Quotient (developmental)**		**Mercury Hazard Quotient**		**Hazard Index (developmental)**	
				Average	High-end	Average	High-end	Average	High-end	Average	High-end
Upper Long Lake	Largemouth bass	Fillet	3	1.5	4.6	1.2	3.6	0.7	1.7	1.9	5.3
Lower Long Lake	Largemouth bass	Fillet	3	1.7	4.1	1.3	3.2	0.6	1.6	1.9	5.1
Upper and Lower Long Lake	Largemouth bass	Fillet	6	1.6	4.6	1.2	3.5	0.7	1.7	1.9	5.2

Table D4. Health Risk Calculations from Exposure to Polychlorinated Biphenyl Dioxin Toxic Equivalents (PCB-TEQs) in Fish Sampled in 2001 from Long Lake, Spokane County, Washington

Location	**Species**	**Tissue**	**# of Samples**	**Hazard Quotient**		**Cancer Risk**	
				Average	High-end	Average	High-end
Upper Long Lake	Largemouth bass	Fillet	3	1.0	3.1	7E-05	2E-04
	Largescale sucker	Fillet	3	1.8	4.4	1E-04	3E-04
	Mountain whitefish	Fillet	3	1.1	2.9	7E-05	1E-04
Lower Long Lake	Largemouth bass	Fillet	3	1.2	3.5	8E-05	2E-04
	Largescale sucker	Fillet	3	1.3	3.5	8E-05	2E-04
Lower and Upper Long Lake	Largemouth bass	Fillet	6	1.1	3.5	7E-05	2E-04
	Largescale sucker	Fillet	6	1.5	4.4	1E-04	3E-04

Table D5. Total Polychlorinated Biphenyl (PCB) Concentrations in Largescale Sucker and Mountain Whitefish from Long Lake and the Upper Spokane River, Spokane County, Washington [a] (ug/kg)

	1999												2001					
	Stateline			**Plante Ferry**			**Greene Street**			**Seven Mile** Bridge			**Upper Long Lake**			**Lower Long Lake**		
Fish Species	W	C	HQ	W	C	HQ	W	C	HQ	W	C	HQ	W	C	HQ	W	C	HQ
Largescale sucker (fillets w/skin)	1019	101	3	917	148	4	935	192	6	934	147	4	627	110	3	829	92	3
Largescale sucker (whole)	1052	120	4	870	283	9	790	445	13	915	680	20	984	265	8	911	357	11
Mountain whitefish (fillets with skin)	NA	NA	NA	NA	NA	NA	427	339	10	411	642	19	169	73	2	NA	NA	NA

W = mean weight C = concentration HQ = hazard quotient

a = Whole largescale sucker samples taken from the four upper river locations in 1999 are single composites of five fish. Upper river fillet sample results from 1999 are means of 5 individuals. The 2001 Long Lake whole largescale sucker results represent the mean of 3 individuals for the upper lake and 2 individuals for the lower lake. The 2001 Long Lake fillet sample results are means of the 3 composites per species.

ug/kg = micrograms per kilogram; also known as parts per billion (ppb).

Table D6. Results of Different Calculation Methods for Total Polychlorinated Biphenyls (PCBs) in Fish from Long Lake, Spokane County, Washington

Location	Species	Tissue	Samples	# per composite	Mean Total PCBs (ug/kg)					
					Sum of congeners w/ ND = 0	Sum of congeners w/ ND = DL	Homologues	1248, 1254 and 1260 Only [a]	All Aroclors w/ ND = ½ DL	All Aroclors w/ ND = 0
Upper Long Lake	Largemouth bass	Fillet	3	10	57.9	57.9	57.9	50.0	71.3	50.0
	Largescale sucker	Fillet	3	10	143.1	143.1	143	110.0	143.3	110.0
		Whole	3	NA	NA	NA	NA	264.7	328.0	264.7
	Mountain whitefish	Fillet	3	6	78.1	78.1	78.1	73.0	95.0	73.0
	Smallmouth bass	Fillet	3	5	NA	NA	NA	42.0	64.0	42.0
	Yellow perch	Fillet	3	10	NA	NA	NA	16.5	38.5	0.0
Lower Long Lake	Largemouth bass	Fillet	3	4	78.8	78.8	78.7	56.0	78.0	56.0
	Largescale sucker	Fillet	3	9	112.2	112.2	112.2	91.7	113.7	91.7
		Whole	2	NA	NA	NA	NA	357.0	411.0	357.0
	Smallmouth bass	Fillet	3	5	NA	NA	NA	30.5	61.7	21.3
	Yellow perch	Fillet	3	11	NA	NA	NA	15.5	51.7	0

ND = non-detect DL = detection limit ug/kg = micrograms per kilogram also known as parts per billion (ppb).

a = Sum of Aroclor 1248, 1254 and 1260 using ½ detection limit for non-detects.

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