Fish Advisory Evaluation:

PFOS in Fish from Lakes Meridian, Sammamish, and Washington

2022

Washington State Department of Health

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Executive Summary

In 2018, the Washington State Department of Ecology (Ecology) collected freshwater fish from Lakes Meridian, Sammamish, and Washington and analyzed for 15 per and poly fluoroalkyl substances (PFAS). The Washington State Department of Health (DOH) has evaluated the fish tissue data to determine possible health implications and whether contaminant concentrations warrant changes to and/or issuance of fish advisories on Lakes Meridian, Sammamish, and Washington. Based on perfluorooctane sulfonate (PFOS) fish tissue concentrations and an average-sized adult (70 kg or 154 lbs) eating an eight-ounce meal, DOH provides the following recommendations:

Location/Species	Calculated Meals Per Month	Recommended Meals Per Month	Basis
Lake Meridian			
Brown bullhead	12	No Advisory	This evaluation
Kokanee	2	2	This evaluation
Largemouth bass	1	1	This evaluation
Northern pikeminnow	0	Do Not Eat	Statewide advisory
Smallmouth bass	0	Do Not Eat	This evaluation
Yellow perch	1	1	This evaluation
Lake Sammamish			
Brown bullhead	13	No Advisory	This evaluation
Largemouth bass	0	Do Not Eat	This evaluation
Northern pikeminnow	0	Do Not Eat	Statewide advisory
Smallmouth bass	2	2	Statewide advisory
Yellow perch	1	1	This evaluation
Lake Washington			
Brown bullhead	5	4	This evaluation
Common carp	0	Do Not Eat	Prior Lake WA advisory
Cut-throat trout	0	Do Not Eat	This evaluation
Largemouth bass	0	Do Not Eat	This evaluation
Northern pikeminnow	0	Do Not Eat	Prior Lake WA advisory
Pumpkinseed	19	No advisory	Prior Lake WA advisory
Rainbow trout	19	No advisory	Prior Lake WA advisory
Smallmouth bass	0	Do Not Eat	This evaluation
Sockeye salmon	20	No advisory	Prior Lake WA advisory
Yellow perch	1	1	This evaluation

Background

The Washington State Department of Health (DOH) works to protect and improve the health of people in Washington State. Part of this mission is to reduce or eliminate exposures to health hazards in the environment, including contaminants found in fish. Starting in 2008, the Washington State Department of Ecology (Ecology) has sampled freshwater and fish tissue in order to survey levels of per and poly fluoroalkyl substances (PFAS) in rivers and lakes across the state. A 2008 survey analyzed 15 composite fish samples of 11 different species collected from seven freshwater bodies throughout the state. Only four PFAS were detected and quantified. Perfluorooctane sulfonate (PFOS) was detected in 40% of fillet samples (6 out of 15). In 2008, Ecology collected fish from throughout the state as part of a screening survey for PFAS in Washington rivers and lakes (Ecology, 2010). PFOS was the primary compound observed and the highest concentrations were in samples from urban waters. In 2016, Ecology measured PFAS in various species of freshwater fish from 11 water bodies in Washington (Ecology, 2017) as part of the follow-up study to the 2008 survey. PFOS was still the dominant compound in all fillet samples, making up 62 – 100% of the total concentration of PFAS detected. The levels were highest in fish collected from urban waterbodies. This is consistent with global environmental surveys indicating PFAS concentrations are highest in urban watersheds due to increased anthropogenic inputs (Kurwadkar et. al. 2021).

To characterize PFAS levels in fish for DOH fish advisories, Ecology collected additional fish in 2018 from Lake Meridian, Lake Sammamish, and Lake Washington (Ecology 2022). Specifically, five fish species: brown bullhead (*Ameiurus nebulosus*), yellow perch (*Perca flavescens*), largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieu*), and kokanee (*Oncorhynchus nerka*) from Lake Meridian; three fish species: brown bullhead, yellow perch, largemouth bass from Lake Sammamish; and five fish species: brown bullhead, yellow perch, largemouth bass, smallmouth bass, and cutthroat trout (*Oncorhynchus clarkii*) from Lake Washington. DOH evaluated the fish tissue data provided by Ecology to determine possible health implications and whether PFAS concentrations warrant changes to existing fish advisories and/or the issuance of new fish advisories on Lakes Meridian, Sammamish, and Washington.

Assessment Methodology

The assessment is based on a comparison of reported mean chemical concentrations with a corresponding screening level (SL). SLs are used as threshold values against which tissue residue levels of a contaminant in seafood can be compared. SLs were calculated based on non-carcinogenic effects of the chemical contaminant for both the general (SL = 1.8 µg/kg) and high (SL = 0.6 µg/kg) fish consumer groups. The method we use is discussed in detail in Volume 1 of EPA's Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories (EPA 2000a). The general equation to derive a screening level is as follows.

Non-carcinogens:

$$Screening\ Level\ (SL_{nc}) = \frac{RfD\ x\ BW\ x\ UCF}{CR} \times RSC$$

Where: SL_{nc} = chemical specific non-cancer screening concentration (mg/kg)

BW = average body weight of adult (70 kg) or childbearing age woman (60 kg)

UCF = unit conversion factor ($1x10^3$ g/kg)

RfD = chemical specific oral reference dose (mg/kg-day)

CR = consumption rate (g/day)

RSC = relative source contribution (unitless)

Consumption Rate

For this evaluation, DOH calculated SLs based on consumption rates of 8 and 23 meals per month, one meal is defined as one 8-oz. serving (6-oz. cooked). This is equivalent to 59.7 and 175 grams of fish per day, respectively. The eight meal per month consumption rate corresponds to advice from the Dietary Guidelines for Americans, recommending that people consume 8 to 12-oz of fish per week due to the health benefits from consuming seafood (Dietary Guidelines 2020). It is also the rate at which or below that DOH may issue an advisory. Twenty-three meals per month consumption rate corresponds to a value that Ecology proposed in setting Federal Clean Water Act (CWA) Standards, it is used by the state of Oregon for compliance with the CWA, and is further supported by the Columbia River Inter-Tribal Fish Commission (CRITFC). Twenty-three meals a month is approximately the 95^{th} percentile consumption rate of its tribal members (CRITFC 1994). While DOH does not give meal restrictions on fish consumption rates greater than two meals per week (eight meals per month), DOH provides calculated meal recommendations for all available contaminant concentrations measured in a given species for individuals who exceed this general population consumption rate and have additional questions or concerns.

PFOS Reference Dose

Noncancer health effects associated with exposure to PFOS include a variety of adverse health effects observed in animal and human studies. Among the most sensitive of these health effects is immune suppression (Dong et al. 2009, Dong et al. 2011, Peden-Adams et al. 2008, Xheng et al. 2009, Guruge et al. 2009). A systematic review by the National Toxicology Program (NTP) for evidence of immune toxicity from epidemiological studies and studies in experimental animals concluded that PFOS met the criteria of a “presumed immune hazard” in humans (NTP 2016). This was based on high confidence that PFOS is immunotoxic in rodents and moderate evidence of immunotoxicity in humans. Therefore, DOH has chosen to use the RfD of 3×10^{-6} mg/kg-day, from the current State Action Level in drinking water based on Dong et. al. 2011, as the noncancer toxicity value for use in the derivation of the risk-based fish consumption guidelines for PFOS.

Relative Source Contribution

Relative Source Contribution (RSC) used in establishing fish advisories is meant to account for non-fish sources of exposure to non-carcinogens. Multiple exposure pathways exist for PFOS including drinking water, other foods, occupational exposures, and consumer products. In establishing drinking water criteria for PFOS, DOH has adopted a drinking water RSC of 0.2 (DOH 2021) and apportioned 80% (0.8) to all other potential sources of exposure to PFOS. Fish and shellfish consumption is considered to be the primary PFOS dietary exposure route (EFSA 2020). Here DOH chose to assign an RSC of 50% (0.5) to use when apportioning PFOS exposure from fish consumption, and the remaining 30% (0.3) from other unknown potential dietary and environmental sources.

Calculating Meal Limits for Individual Chemical Exposures

When concentrations in fish tissue exceed screening levels considered to be protective, meal limits are calculated to inform consumers. In calculating screening levels, advice is targeted to the most sensitive population (e.g. women of childbearing age and young children). Calculating safe consumption rates based on the sensitive population would then also protect all other populations if the advice is followed.

In this assessment, DOH uses mean tissue concentrations to calculate meal recommendations. While median values are important for evaluating contaminant concentrations, the median value is insensitive to outliers, particularly at the high end. Non-detected values were assigned a value equal to one-half the corresponding detection limit. When evaluating contaminant data for use in deriving a fish advisory, DOH does not evaluate data with a detection frequency of less than ten percent.

Allowable meal limits are calculated based on non-cancer criteria, average body weight of an individual, and the known contaminant concentration in seafood. The equation used to calculate a safe consumption rate is shown below, with exposure parameters as defined in Table 1 (EPA 2000b).

Non-cancer meal equation:

$$Meal\ per\ month\ = \frac{RfD\ x\ BW\ x\ CF1\ x\ CF2}{MS\ x\ C}$$

Table 1. Exposure Parameters for Calculating PFOS Fish Meal Limits

Parameter	Value	Units	Comments
Reference Dose (RfD)	3×10^{-6}	mg/kg-day	PFOS
Body Weight (BW)	70	kg	70 kg adult
Conversion Factor (CF1)	30.44	days/month	
Conversion Factor (CF2)	1000	g/kg	
Meal Size (MS)	227	g	8 oz. meal
Concentration in fish (C)	Mean	mg/kg	Species specific

Single contaminant meal calculations are assessed using the most restrictive health criteria. Calculated meal limits are rounded up or down to fit one of the six meal rate categories used by DOH (no consumption, one, two, four, eight meals per month, or no advisory) to address ease of messaging (Table 2).

Table 2. PFOS meal limit categories based on fish tissue concentration ranges.

$[C]_{fish}$ (µg/kg)	# Meals
< 1.8	No Advisory
1.8 – 2.3	8 meals/month
2.4 – 4.7	4 meals/month
4.8 – 9.4	2 meals/month
9.5 – 28.2	1 meal/month
> 28.2	Do Not Eat

Calculating meal limits is the quantitative phase of developing a fish advisory. Other qualitative considerations include, but are not limited to, chemical background concentrations, the ability to reduce chemical concentrations through cleaning and cooking techniques (Great Lakes 1993), chemical concentrations in other food, known benefits of fish consumption, and ease of messaging.

Results

Ecology analyzed a total of 76 composite fillet samples (each composite consisting of 3-5 individual fish) collected from Lakes Meridian, Sammamish, and Washington. Laboratory results for PFOS are summarized below (Table 3). Data sets available through Ecology's Environmental Information Management database https://apps.ecology.wa.gov/eim/search/default.aspx.

PFOS was detected in and was the dominant PFAS compound in all samples analyzed, making up 70+% of the total PFAS concentration in all fish species except brown bullhead. PFOS remained the dominant compound in brown bullhead but with a lower percent contribution (<70%) of the total. The remaining PFAS detected were long-chain perfluoroalkyl carboxylates (PFCAs) and were present in much lower amounts than PFOS across the species. At the present time DOH is developing fish consumption guidance based upon PFOS concentrations, although this may change in the future as additional information comes available.

A summary of average PFOS concentrations for fish species at each location are in Table 3. PFOS levels were comparable among species across locations with the exception of brown bullhead which were slightly higher at Lake Washington compared to Lakes Meridian and Sammamish. PFOS levels were highest in smallmouth bass followed by largemouth bass and cut-throat trout. Cut-throat trout in Lake Washington and smallmouth bass and yellow perch in Lake Meridian had smaller sample sizes, however, PFOS concentrations were high enough to necessitate some guidance; especially with supporting concentrations observed in nearby lakes.

Table 3. Average PFOS concentrations per fish species per location.

Location/Species	Composite Sample Size	% Detected	Mean $[C]_{fish}$ (µg/kg)
Lake Meridian			
Brown bullhead	5	100%	1.2
Kokanee	3	100%	7.3
Largemouth bass	4	100%	24.2
Smallmouth bass	2	100%	62.1
Yellow perch	2	100%	10.8
Lake Sammamish			
Brown bullhead	5	100%	1.1
Largemouth bass	5	100%	37.8
Yellow perch	5	100%	15.4
Lake Washington			
Brown bullhead	15	100%	2.6
Cut-throat trout	2	100%	34.0
Largemouth bass	13	100%	31.4
Smallmouth bass	3	100%	93.8
Yellow perch	12	100%	13.2

Recommendations

General Fish Consumption Advice

Eat fish, fish are good for you. DOH encourages all Washingtonians to eat at least eight to twelve ounces of fish per week in accordance with The Dietary Guidelines for Americans (2020). The purpose of a fish advisory is not to discourage or restrict fish consumption but to inform people about risks associated with consumption of fish species at specific locations. Our advice helps people avoid fish high in contaminants in favor of fish lower in contaminants. People may eat more than eight ounces of fish weekly; however frequent consumers should consider taking steps to reduce exposure to contaminants in the fish that they eat. Some general guidance is as follows:

- Eat a variety of fish that are low in contaminants according to guidance provided by DOH (http://www.doh.wa.gov/fish/) and local health agencies.
- Consume younger, smaller fish (within legal limits). These fish typically contain lower levels of accumulative contaminants than older, larger fish.
- When cleaning fish, remove the skin, fat, and internal organs before cooking; this will help to reduce the amount of some contaminants.
- Grill, bake, or broil fish so that fat drips off while cooking.
- Young children and small adults should eat proportionally smaller meal sizes (Table 4).

Table 4. Adjustment of fish meal size based on the body weight of the consumer.

Weight (lbs)	Mass (kg)	Meal Size (oz)	Meal Size (g)
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

Waterbody Specific Guidance

DOH provides the following recommendations within table 5. Included are meal recommendations for PFOS, calculated utilizing the non-cancer meal equation described above, as well as pre-existing guidance for each waterbody from two prior fish advisories: a statewide advisory for mercury and a Lake Washinton advisory for polychlorinated biphenyls in fish tissue.

Table 5. Lake Meridian, Lake Sammamish, and Lake Washington recommended meals per month per species.

Location/Species	Calculated Meals Per Month	Recommended Meals Per Month	Basis
Lake Meridian			
Brown bullhead	12	No Advisory	This evaluation
Kokanee	2	2	This evaluation
Largemouth bass	1	1	This evaluation
Northern pikeminnow	0	Do Not Eat	Statewide advisory
Smallmouth bass	0	Do Not Eat	This evaluation
Yellow perch	1	1	This evaluation
Lake Sammamish			
Brown bullhead	13	No Advisory	This evaluation
Largemouth bass	0	Do Not Eat	This evaluation
Northern pikeminnow	0	Do Not Eat	Statewide advisory
Smallmouth bass	2	2	Statewide advisory
Yellow perch	1	1	This evaluation
Lake Washington			
Brown bullhead	5	4	This evaluation
Common carp	0	Do Not Eat	Prior Lake WA advisory
Cut-throat trout	0	Do Not Eat	This evaluation
Largemouth bass	0	Do Not Eat	This evaluation
Northern pikeminnow	0	Do Not Eat	Prior Lake WA advisory
Pumpkinseed	19	No advisory	Prior Lake WA advisory
Rainbow trout	19	No advisory	Prior Lake WA advisory
Smallmouth bass	0	Do Not Eat	This evaluation
Sockeye salmon	20	No advisory	Prior Lake WA advisory
Yellow perch	1	1	This evaluation

Benefits of fish consumption

Fish is considered a healthy food, known to be high in protein, low in saturated fats and rich in other nutrients such as vitamin D, iodine, and selenium. Health benefits of eating fish are well documented and linked to the reduction of cardiovascular disease, osteoporosis, and partial reduction of certain types of cancer. These major chronic diseases afflict much of the U.S. population. Advisories can be protective yet acknowledge benefits of eating fish, by recommending decreased consumption of fish known to have high concentrations of contaminants in favor of fish that are lower in contaminants.

Fish is the primary dietary source of two long chain n-3 polyunsaturated fatty acids (n-3 PUFAs), eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). N-3 PUFAs are essential components of membranes in all cells of the body are vitally important for normal development of the brain and retinal tissues and for maintenance of normal neurotransmission and connectivity (Wenstrom 2014). Much of the research examining the possible adverse health effects of diets deficient in n-3PUFAs has focused on cardiovascular risks among older adults or developmental outcomes associated with perinatal exposure. An example of these benefits from fish consumption includes an associated with improvement of blood lipid profiles, decreased risk of heart disease, and lowered blood pressure (IOM 2006, Mozaffarian and Rimm 2006) and enhanced eye and brain development in early life (Fleith and Clandinin 2005). Other evidence of the beneficial health effects has shown improvement in rheumatoid arthritis (Kremer 2000), prevention of macular degeneration (SanGiovanni et al. 2007), lower risk of colitis (Hudert et al. 2006) and type 2 diabetes (Barre 2007), and improvements in neurologic and psychological disorders such as depression, schizophrenia, and Parkinson disease (Calon and Cole 2007).

Fish oil enriched with n-3 PUFAs has therapeutic value in treating a wide variety of inflammation-associated disorders. Infants whose mothers were supplemented with EPA and DHA during pregnancy were shown to have a decreased risk of food allergies and IgE-associated eczema (Furuhjelm et al. 2009) and decreased incidence of asthma (Olsen et al. 2008). Fish oil is associated with modulation of the immune function (Yagoob 2010), reductions subclinical inflammation (Souza et al. 2020) and has been associated with a boost of humoral (B cell) response to antigens, the lessening of and prevention of immune mediated inflammatory processes, and the development of immune functions in early infancy (Shaikh el al. 2012, Whelan et al. 2016, Calder 2017). Fish oil or more specifically, a metabolite of DHA administered to mice that were then subsequently challenged with influenza antigen vaccination showed an increase in both IgM and IgG antibody production as well as greater resistance to infection (Ramon 2014). Marine fatty acids (EPA and DHA) give rise to anti-inflammatory and inflammation resolving mediators called resolvins, protectins, and maresins and inhibition of activation pro-inflammatory transcription factors (Calder 2015).

Non consumptive benefits of fish

Fish is not only an important source of nutrition, the act of catching, preparing, and eating fish are important cultural and family practices that contribute to health and well-being. Fish is an important cultural food in Washington State that defines a recreational as well as a spiritual way of life in the Pacific Northwest. In Native American tribal communities, fish and other seafood are important to food security, community cohesion, ceremonies, and cultural practices that promote individual and community health and well-being (Donatuto et. al. 2011). Recreational fishing may also contribute to health and well-being in numerous ways such as spending time in nature (White et. al. 2019), experiencing mental relaxation that combats stress and anxiety (Craig et. al. 2020), spending quality time with family and friends and practicing long-held traditions (Brown et. al. 2012).

Further, removal of fish from the diet of subsistence consumers may have serious health, social and economic consequences. Such populations are encouraged to consume a variety of fish species, to fish from locations with low contamination, and to follow recommended preparation and cooking methods.

Consideration of risk vs benefits

The health benefits of eating fish are not able to be assigned a value quantitatively for use in calculating a fish consumption advisory but they can be used qualitatively in advisory decisions. DOH has considered the health benefits of fish consumption in the selection of the RfD used for evaluating PFOS risk in fish tissue. Epidemiologic studies have indicated immunotoxicity (i.e. reduced vaccine antibodies in children) at very low levels of PFOS exposure and an interim reference dose (RfD) from the EPA reflects these lower levels (EPA 2022). However, the interim RfD would produce screening values that are lower than current methodological detection limits for fish tissue. Additionally, as described above fish consumption provides a number of health and immune benefits that cannot be included in a theoretical risk calculation. Therefore, DOH chose to use the RfD of 3×10^{-6} mg/kg-day from the current State Action Level in drinking water based on Dong et. al. 2011.

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