Derivation of Screening Values for Contaminants in Fish Tissue

Ministry of Water, Land & Resource Stewardship

Water Protection & Sustainability Branch

BRITISH COLUMBIA

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Cover Photo: Whitetail Lake at Whitetail Lake Recreation Site, East Kootenays B.C.

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ABBREVIATIONS

AF	Allocation factor
B.C.	British Columbia
BW	Body weight
CCME	Canadian Council of Ministers of the Environment
C_{Foodi}	Concentration of contaminant in food *i*
D_2	Years of exposure to contaminant
ENV	British Columbia Ministry of Environment / Environment & Climate Change Strategy
HLTH	British Columbia Ministry of Health
IR	Ingestion rate
LE	Life expectancy
OSF	Oral slope factor
RAF_{orali}	Relative absorption factor from the gastrointestinal tract for contaminant *i*
RL	Risk level
SV	Screening value
TDI	Tolerable daily intake
TRV	Toxicological reference value
USEPA	United States Environmental Protection Agency
WLRS	British Columbia Ministry of Water, Land and Resource Stewardship

1. INTRODUCTION

The Purpose of This Document

The Ministry of Water, Land and Resource Stewardship (WLRS) works with the Ministry of Health (HLTH) to develop benchmarks to protect human health from harmful substances when eating fish. A risk-based approach is recommended to develop human consumption benchmarks for bioaccumulative substances in fish and shellfish tissue (ENV 2014). This document outlines the derivation method for calculating a human consumption screening value (SV) for contaminants of concern in fish tissue, inclusive of shellfish tissue.

What is a Screening Value?

Screening values are threshold benchmarks against which contaminant concentrations in fish tissue can be compared and assessed for potential risks to human health. If an SV is exceeded and people have been exposed to the contaminant by eating fish, informed decisions can be made regarding next steps. This may be especially relevant to Indigenous populations that typically consume more fish than non-Indigenous people. In this document, fish refers to country foods, that is, all foods sourced outside of retail food systems. These include any food that is trapped, fished, hunted, harvested, or grown for subsistence or medicinal purposes, outside of the retail food chain (Health Canada 2018). Screening values help balance the benefits and risks of fish consumption as fish is a great source of minerals, vitamins, and omega-3 polyunsaturated fatty acids (HealthLinkBC 2022).

The SV method is considered appropriate for protecting fish consumer health for the following reasons:

- it provides a direct link between risk level and fish consumption rate (i.e., between dose and response)
- it generally leads to conservative estimates of increased risk
- it is designed for protection of consumers of locally caught fish, including sport and subsistence fishers who are at potentially greater risk than the general adult population because they tend to consume greater quantities of fish and repeatedly fish at the same locations (Reinert et al. 1991)
- it considers other sources of exposure to the contaminant by adjustment of the allocation factor (AF)

Why Do We Need Screening Values?

In B.C., fish are harvested and consumed for personal, recreational, subsistence, and cultural purposes. Chemical contaminants may be problematic in fish tissue that is consumed, largely due to bioaccumulation. Bioaccumulation is the increase of a contaminant in an organism compared to the contaminant concentration in water or sediments, resulting from the organism's exposure to the contaminant through respiration, dermal absorption, and/or food ingestion (Wright and Welbourn 2002). Bioaccumulation can result in biomagnification, which occurs when an organism's internal contaminant concentration exceeds that of the food ingested. The biomagnification of toxic chemicals in aquatic environments can lead to increased contaminant levels in top predators, such as large predatory fish (Wright and Welbourn 2002) and may become a human health concern if these organisms are consumed.

Contaminant bioaccumulation and biomagnification depends on several factors including the concentration and properties of the chemical (i.e., speciation), ambient conditions (e.g., water hardness, temperature, salinity), and the type of exposure (CCME 1999). Since the bioaccumulation process is complex, it is recognized that some degree of uncertainty exists in contaminant concentrations considered safe for human consumption. In response to the potential bioaccumulation of contaminants in B.C. waters, the use of SVs for fish tissue is important in aquatic environment monitoring programs to help assess risks to human health.

How to Use a Screening Value

Screening values provide recommended safe contaminant levels in fish tissue based on conservative estimates of human fish consumption rates; they do not provide advice regarding consumption amount limits or constitute a fishing advisory. Measured contaminant levels in fish tissue are compared to SVs as an indicator of human health risk.

Screening values inform water quality assessments and Water Quality Objectives policy co-development with Indigenous peoples, supporting the protection of traditional Indigenous values.

The exceedance of an SV in areas where fish is consumed may indicate that further investigation to assess human health risk at a particular site is warranted (ENV 2021b). Aquatic sampling and monitoring considerations and protocols are provided in ENV (2016) and Health Canada (2021a).

2. SCREENING VALUE CALCULATIONS: VARIABLES AND ASSUMPTIONS

The calculation of an SV considers: the *human receptors* (subsistence fishers, recreational fishers, etc.); *exposure* to the contaminant (how much fish the human receptors consume); and the contaminant's *toxicity* (what is known about the contaminant and how it affects different human receptors).

Human Receptors: Age and Body Weight

Human receptors, or people eating fish, are generally categorized in this document as: subsistence fishers, recreational fishers, low-level (general B.C. population) fishers, pregnant or breastfeeding women, children, and toddlers.

Table 1 outlines the general human receptor body weights (BW) for SV calculations. The mean adult human BW in Canada is 70.7 kg and is the default BW used in SV calculations for adults (Health Canada 2021a). It is recognized updated information may be available for receptor characteristics in Canada so site-specific investigations should determine the most appropriate information. For example, body weight can be customized to the human receptor population in an area if data are available.

Table 1. General Canadian body weights, by gender and age, used in screening value calculations (Health Canada 2021a).

Human Receptor Population	Age (years)	Body Weight (kg)
Adult (males and females combined)	≥ 20	70.7
Teen (males and females combined)	12 to < 20	59.7
Child (males and females combined)	5 to < 12	32.9
Toddler	6 months to < 5	16.5

Exposure: Fish Ingestions Rates

Human receptor populations are differentiated by their fish ingestion rate (IR) (Table 2). The IRs of fish tissue consumed by subsistence fishers (220 g/day) and recreational fishers (111 g/day) correspond to Health Canada's consumption rates for Indigenous Groups in Canada and the general population, respectively (Richardson 1997) and are meant to provide an estimate of local fish consumption habits. The subsistence fisher IR is not specific to any Indigenous peoples fish consumption habit; therefore, IRs should be obtained from the Indigenous community where possible to accurately assess risk and establish sufficiently protective SVs (HLTH 2022). The low-level consumption IR of 21 g/day reflects Health Canada's (2011) recommended two servings of fish per week. The IR for a child (90 g/day) and toddler (56 g/day) represents that of the general Canadian population. Teen, child, and toddler subsistence fisher IRs are also included in Table 2 (Richardson 1997). Although dated (1970-72), these IRs represent the best Canadian data currently available (Health Canada 2018).

Table 2. General ages and associated fish ingestion rates for Canadian and Indigenous populations (Richardson 1997).

Human Receptor Category	Age (years)	Fish Ingestion Rate (g/day)
Subsistence fisher	≥ 20	220
Recreational fisher	≥ 20	111
Low-level fisher	≥ 20	21
Pregnant or breastfeeding woman	≥ 20	111
Teen	12 - 19	104 200 (Indigenous fish consumer)
Child	5 - 11	90 170 (Indigenous fish consumer)
Toddler	7 months to 4	56 95 (Indigenous fish consumer)

Toxicity: Toxicological Reference Values

Toxicological reference values (TRVs) are prescribed by Health Canada and other agencies (i.e., United States Environmental Protection Agency [USEPA] and the World Health Organization), to characterize risks associated with exposure to environmental contaminants. For carcinogenic contaminants, the TRV is called an oral slope factor (OSF) which represents an upper bound estimate of the slope between exposure (ingestion of contaminated fish) and the occurrence of cancer (Health Canada 2021b). For noncarcinogenic contaminants, the TRV is called the tolerable daily intake (TDI); the daily dose deemed to be tolerable or acceptable (i.e., safe), based on the assumption that a threshold dose exists below the level which toxic effects occur. Health Canada (2021b) provides TDIs for a wide variety of contaminants. For some contaminants of concern, the TDI chosen for an SV calculation will depend on the age of the human receptor.

3. GENERAL EQUATIONS FOR CALCULATING SCREENING VALUES IN B.C.

Screening values are calculated using Health Canada's (2021a) recommended general equation (Equation 1) for calculating the ingested contaminant dose via consumption of contaminated food.

$$Dose = \frac{(\sum(C_{Foodi} \times IR_{Foodi} \times RAF_{Orali} \times D_i)) \times D_2}{BW \times 365 \times LE} \qquad \text{(Equation 1)}$$

Where:

- *Dose* = predicted intake of contaminant (µg/kg BW/day)
- C_{Foodi} = concentration of contaminant in food *i* (µg/kg)
- IR_{Foodi} = human receptor ingestion rate for food *i* (g/day)
- RAF_{Orali} = relative absorption factor from the gastrointestinal tract for contaminant *i* (unitless)
- D_i = days per year during which consumption of food *i* will occur
- D_2 = total years exposed to site (only used for assessment of carcinogens)
- *BW* = mean body weight of human receptor (kg)
- 365 = total days per year (constant)
- LE = life expectancy (only used for assessment of carcinogens)

Assumptions:

- Fish are consumed daily throughout the year: D_i = 365 days
- RAF_{Orali} = 1. Unless site-specific data have been collected, oral exposures should be assumed to have a relative absorption of 100% (Health Canada 2021b)

Carcinogenic Screening Value Example: Arsenic

Carcinogenic SVs depend on the cancer risk, mean human receptor BW, OSF, life expectancy, exposure pathway (orally for fish ingestion), human IR of fish, and the total years exposed to the contaminant (USEPA 2000, Health Canada 2021a). The acceptable risk level (RL) for cancer in B.C. is 1 in 100,000 persons exposed (ENV 2021b). Life expectancy and the total years of exposure to the contaminant are 80 years (Health Canada 2021a).

The carcinogen example calculation shown below is for ingestion of arsenic by a low-level adult fish consumer. Using Equation 1 for calculating the ingested contaminant dose via consumption of contaminated food, Equation 1 was rearranged to solve for C_{Foodi} (Equation 2). It is assumed food ingestion occurs every day of the year, therefore D_1 and 365 cancel each other out.

$$C_{Foodi} = \frac{Dose \times BW \times LE}{IR_{Foodi} \times RAF_{Orali} \times D_2} \qquad \text{(Equation 2)}$$

The same assumptions listed for Equation 1 apply here, as well as:

- LE = 80 years (Health Canada 2021a)
- D_2 = 80 years (Health Canada 2021a)

C_{Foodi} is equal to the SV_c when a maximum acceptable risk level and *OSF* are substituted for the *Dose*. Equation 2 becomes Equation 3 by substituting in the variables SV_C for C_{Foodi} and *RL*/*OSF* for the *Dose*.

$$SV_c = \frac{\frac{RL}{OSF} \times BW \times LE}{IR_{Foodi} \times RAF_{Orali} \times D_2} \qquad \text{(Equation 3)}$$

Where:

- SV_c = Screening value for carcinogenic effects of arsenic (µg/g) (wet weight or dry weight). Based on edible portions of tissue. Wet weight to dry weight conversion based on 75% moisture content.
- *RL* = Risk level = 1/100,000
- OSF = Oral slope factor for arsenic = 0.0018 (µg/kg BW/day)$^{-1}$ (equal to µg/kg-day)$^{-1}$ (Health Canada 2021b)
- *BW* = body weight = 70.7 kg
- *LE* = life expectancy = 80 years
- IR_{Foodi} = ingestion rate of fish by humans = 21 g/day
- RAF_{Orali} = relative absorption factor from the gastrointestinal tract for arsenic = 100%
- D_2 = total years exposed to site = 80 years

$$SV_{As} = \frac{\dfrac{0.00001}{0.0018\ \frac{\mu\text{g}}{\text{kg}}\text{day}} \times 70.7\ kg \times 80\ yrs}{21\,\frac{g}{day} \times 1 \times 80\ yrs}$$

$$SV_{As} = 0.019\ \mu\text{g/g wet weight}$$

This example SV indicates that concentrations of arsenic over 0.019 µg/g wet weight in fish tissue have the potential to pose a carcinogenic risk to low-level adult fish consumers.

Noncarcinogen Screening Value Example: Methylmercury

Noncarcinogenic SVs are calculated with the TDI of the specific contaminant (Health Canada 2021b), human IR of fish, exposure pathway (orally for fish ingestion), and the mean human receptor BW.

An AF is recommended to account for other sources of contaminant exposure (not just fish consumption). Exposure or risk should not assume predetermined allocations of exposure between environmental media. An AF of 0.2 is typically used to develop risk-based SVs for specific exposure media (soil/sediment, surface/groundwater, air, food, consumer products) for contaminated sites, such as the risk-based numerical standards in the Contaminated Sites Regulation (ENV 2021a). With respect to tissue SVs, 0.2 reflects the percentage of contaminant exposure assumed to come from country foods (in this case, wild fish). Using an AF of 0.2 may lower the SVs below background concentrations and discourage fish consumption. It is recommended that SV calculations start with an AF of 0.2, and if there are no other exposure pathways (or limited exposure pathways) the AF can be adjusted accordingly with sufficient scientific justification or rationale. This would require a detailed analysis of the proportion of risk contributed by each media (e.g., drinking water, soil, food, inhalation).

The noncarcinogen example calculation provided below is for the ingestion of methylmercury (MeHg) by an Indigenous toddler fish consumer. Health Canada has two methylmercury TDI values; one specific to women of child-bearing age, infants and children < 12 years, and one for non-sensitive adults of the general population. The example uses Equation 1 for calculating the ingested contaminant dose via consumption of contaminated food.

Equation 1 is rearranged to solve for C_{Foodi} (Equation 4). The equation is simplified as the D_2 and LE variables are not used in the noncarcinogen calculation. Equation 1 is simplified further as it is assumed that food ingestion occurs every day of the year, therefore D_1 and 365 cancel each other out.

$$C_{Foodi} = \frac{Dose \times BW}{IR_{Foodi} \times RAF_{Orali}} \quad \text{(Equation 4)}$$

C_{Foodi} is equal to SV_n when the appropriate TDI is substituted for the $Dose$. Substituting the variables SV_n for C_{Foodi} and TDI (the safe or acceptable contaminant dose) for the $Dose$ gives Equation 5. An AF is added to consider other sources of contaminant exposure.

$$SV_n = \frac{TDI \times BW \times AF}{IR_{Foodi} \times RAF_{Orali}} \quad \text{(Equation 5)}$$

Where:

- SV_n = screening value for noncarcinogenic effects of methylmercury (µg/g) (wet weight or dry weight). Based on edible portions of tissue. Wet weight to dry weight conversion based on 75% moisture content.
- *TDI* = tolerable daily intake for methylmercury= 0.2 µg/kg BW/day (Health Canada 2021b)
- *BW* = body weight = 16.5 kg
- AF = allocation factor = 20%
- IR_{Foodi} = ingestion rate = 95 g/day
- RAF_{Orali} = relative absorption factor from the gastrointestinal tract for MeHg = 100%

$$SV_{MeHg} = \frac{0.2\ \frac{\mathrm{\mu g}}{\mathrm{kg}}\mathrm{day}\ \times 16.5\ \mathrm{kg} \times 0.2}{95\,\frac{g}{day}\ \times 1}$$

$$SV_{MeHg} = 0.007\ \mathrm{\mu g/g}\ \text{wet weight}$$

This example SV indicates that concentrations of methylmercury over 0.007 µg/g wet weight in fish tissue have the potential to pose a risk to Indigenous toddler fish consumers.

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