PCB Potential in San Francisco Bay Fish: A risk assessment of lipid-normalized PCB concentration potentials in popularly consumed fish from the San Francisco Bay.

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This risk assessment explores which fish species are of greatest and least concern to eat with respect to polychlorinated biphenyl (PCB) contamination in the San Francisco (SF) Bay. PCBs are hydrophobic and tend to accumulate in lipid-rich fish tissue (fatty flesh). PCBs also tend to accumulate in sediments. Margin-dwelling fish likely have higher exposure to PCBs than fish that inhabit open water. To characterize the risk posed by various species, lipid-normalized PCB concentrations in edible tissue are compared to the percentage of anglers in the SF Bay area who consume leopard shark, brown smoothhound shark, halibut, black perch, striped bass, sturgeon, jacksmelt, shiner surfperch, walleye surfperch, brown rockfish, white croaker, and salmon. Species of greatest concern have both high PCB concentration and high consumption.

Consumption data is based on interviews with anglers who consumed SF Bay fish, conducted by the San Francisco Estuary Institute (SFEI) (Lee et al 2001). This study analyzed the fish consumption of anglers as a representative of the general SF population consumption of Bay fish. PCB water concentration is based on the SFEI Regional Monitoring Program (RMP) list of 40 congeners, which is recommended as the most appropriate index for the sum of PCBs (Davis et al 2014). From 2010 to 2018, the mean PCB water concentration (C_w) was 0.0219 μg/L. To compare species, accounting for variations in lipid content, lipid-normalized PCB concentrations were calculated using equations 1 and 2 with variables defined in Table 1, Appendix A. An average Bioaccumulation Factor (BAF) of 2,000,000 was assumed for all species (Blaisdell et al 2012). Lipid composition data comes from a SFEI report on sport fish contaminant concentrations (Sun et al 2014).

Based on the results of the lipid-normal characterization, all of the species have a PCB tissue concentration potential higher than the FDA mandate of 2 ppm (equivalent to 0.05 g PCB/kg tissue for an average fish with 4% lipid composition). The species with the highest PCB potential (greater than 4 g PCB/kg tissue) are the leopard shark, brown smoothhound shark, halibut and black perch. The species a slightly lower PCB potential (between 0.2 and 4 g PCB/kg tissue) are the striped bass, brown rockfish, sturgeon, jacksmelt, shiner surfperch and walleye surfperch. The species with the lowest lipid-normalized PCB concentration potential (less than 0.2 g PCB/kg tissue) are the white croaker and salmon. Fish that are consumed more frequently are more concerning than others, e.g. the highly consumed striped bass is more concerning than the less consumed leopard shark, by increasing the risk of exposure to PCBs in fish tissue. Lipid normalization is best performed when the octanol-water partition coefficient is below 5 and PCBs range between a $\log K_{ow}$ 4.10 to 9.60 so further analysis of the fish PCB tissue concentrations is necessary for further conclusions (Zhang et al 2013). In addition, species specific bioaccumulation factors will need to be determined for further comparison of lipid PCBs. Consumers of SF Bay fish should consider factors like lipid concentration and habitat to make safer consumption decisions. Consumers should also stay up to date on the California Office of Environmental Health Hazard Assessment (OEHHA) fish advisories.

San Francisco Bay

PCB POTENTIAL IN FISH

A risk assessment of lipid-normalized PCB concentration potentials in popularly consumed fish from the San Francisco Bay.

Level of Concern

Highest PCB Potential

> 4 g PCB / kg tissue

Brown Smoothhound Shark

Leopard Shark

Halibut

Black Perch

Intermediate PCB Potential

0.2 to 4 g PCB / kg tissue

Sturgeon

Brown Rockfish

Walleye Surfperch

Jacksmelt

Shiner Surfperch

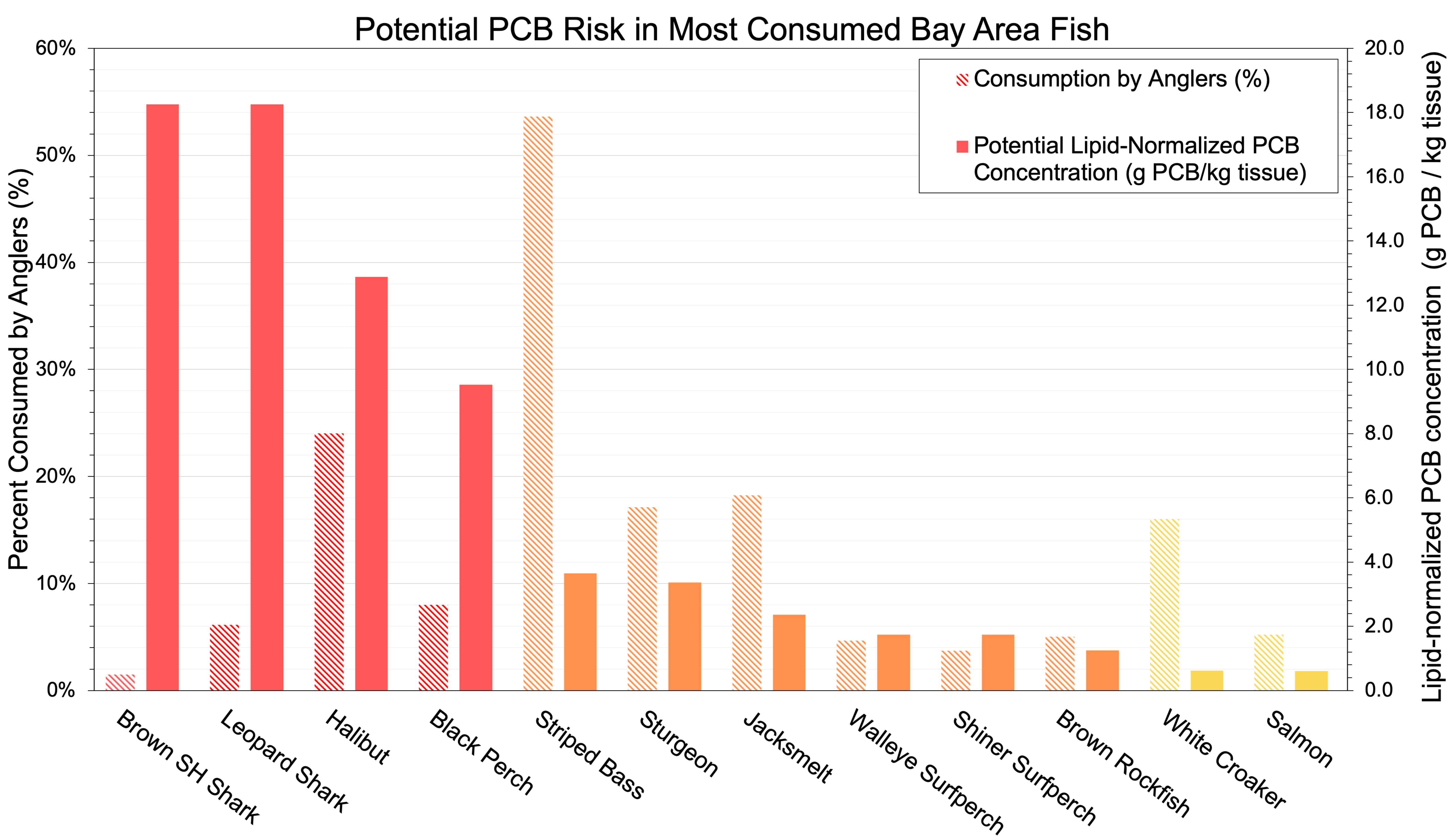
Striped Bass

Lowest PCB Potential

< 0.2 g PCB / kg tissue

Salmon

White Croaker



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Appendix A: Equations and data used for lipid-normalized PCB concentration in fish tissue.

Equations used:

$$(1) \qquad C_t = BAF * C_w$$

$$(2) \qquad C = C_t / f$$

Table 1. Lipid-Normalized PCB Concentration Calculation Variables

Description	**Variable**	**Value**	**Units**	**Source**
Average PCB Bioaccumulation Factor for Edible Fish Tissue	BAF	2,000,000	L / kg	OEHHA
PCB Concentration in Bay Water, 2000 - 2018 Average	C_w	0.0219	µg PCB / L water	RMP CD3
PCB Concentration in Fish Tissue, Calculated	C_t	43,800	µg PCB / kg tissue (wet weight)	BAF x C_w
Fraction of Lipid Content	f	Varies by species	kg lipid / kg tissue (wet weight)	SFEI
PCB Concentration in Fish (Lipid-Normalized)	C	Varies by species	µg PCB / kg tissue (wet weight)	OEHHA

Spatial Correlation of Sediment PCB Concentration and Relative Lifetime Cancer Risk from Consumption of PCBs in Small Fish Tissue (Group 2, Question2):
By, Morgan DeAngelis and Haonan Wang

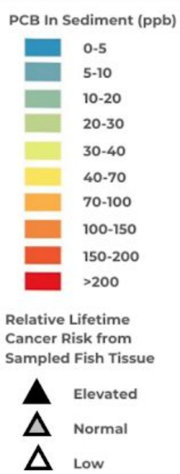
This section focuses on the correlation between fish tissue PCB concentrations and PCB concentrations in sediment within certain distances for different species. For the scope of this study, only the Sum of PCB 40 concentrations are used, as these represent the most reactive forms of PCB (1). This analysis focuses on only small fish species as they are more likely to stay within a smaller area for the duration of their lives. This allows for a more direct relationship to their geographic location (1). The Topsmelt and Mississippi Silverside are chosen as the representative species as they possess some of the largest datasets of fish tissue PCB concentrations on the SFEI database. Because these datasets only overlapped in 2010, only sediment PCB concentrations from 2010 are used. In order to assess and visualize the spatial relationship between sediment PCB concentration and fish tissue PCB concentration, a heat map from the SFEI report on PCBs in the San Francisco Bay (1) is adapted in this figure to show the sediment PCB concentrations as they vary across the bay. To determine the spatial correlation coefficient for each species, the sediment concentration legend from the SFEI heatmap is assigned numeric levels 1-10, 10 corresponding to the highest concentrations (>200 ppb). The corresponding numeric sediment concentration level is then determined for each tissue sample location and the correlation coefficients for each species was found using excel.

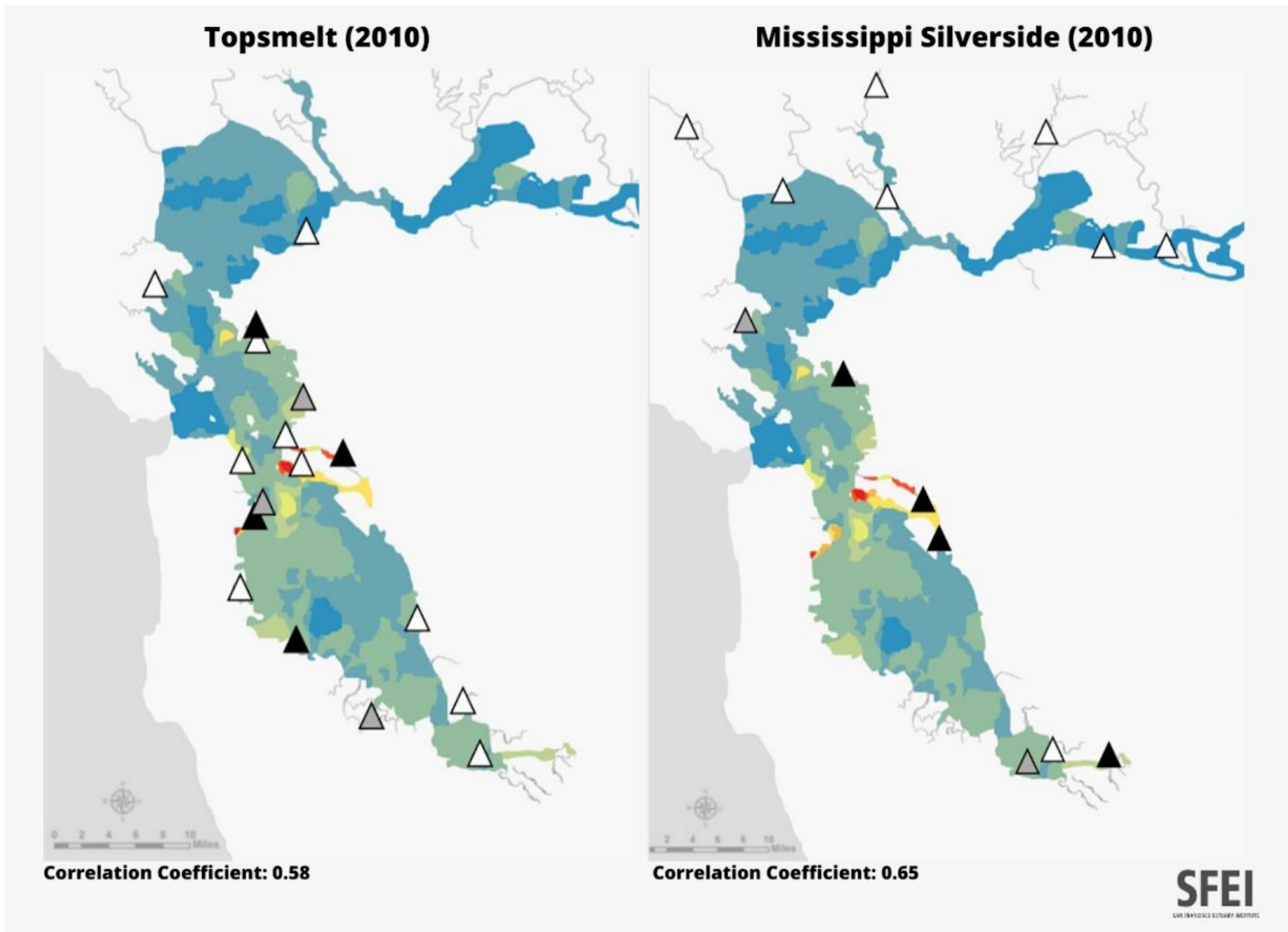
Next, in order to visualize the variation of PCB concentrations in fish tissue, the Bootstrap and Monte Carlo Risk Assessment methods are used to determine distinct levels of lifetime cancer risk. The bootstrap method is first used to expand our initial datasets of 14 (Silverside) and 17 (Topsmelt) to “resampled” data sets of 100 samples each in order to determine a more representative mean and standard deviation for a larger scale. Next, this new mean and standard deviation are used in the monte carlo method (see Equation 1 in appendix) in order to determine a distribution of possible lifetime cancer risks representative of our data. The cooked fish PCB concentration was determined to be 75% of raw fish tissue PCB concentration (2). The daily ingestion rate 0.0433 kg is from EPA’s *Estimated Fish Consumption Rates for the U.S (4). Population and Selected Subpopulations*. We assume that the general public would consume fish twice per week, which generates an exposure frequency of 104 days/year. Exposure duration is assumed to be 78.54 years from World Bank’s Life Expectancy plot (3). The average body weight is assumed to be 65kg. The cancer slope factor of 2 $mg/kg \cdot day^{-1}$ is taken from EPA’s *Quantitative Estimate of Carcinogenic Risk from Oral Exposure (5).*

The classification “Elevated” is assumed to be any risk above the 50th percentile, “Normal” is defined as any risk between the 75th and 50th percentiles, and “Low” is defined as any risk below the 75th percentile. The lifetime cancer risk for each of the original fish tissue samples is then sorted into these classifications and shown on the figure map.

Being able to see the relationship between sediment PCB concentration and lifetime cancer risk associated with the ingestion of fish tissue from that area allows the viewer to more clearly understand the potential human health impact corresponding to PCB soil contamination.

Spatial Correlation of Sediment PCB Concentration and Relative Lifetime Cancer Risk from Consumption of PCBs in Small Fish Tissue





Appendix

Equation 1: Cancer risk estimation

$$Risk_i = C \cdot \frac{IR_i \cdot EF_i \cdot ED_i}{BW_i \cdot AT} \cdot SF$$

$$Risk = Estimated\ possibility\ for\ getting\ cancer$$
$$C = PCB\ concentration\ in\ cooked\ fish\ tissue\ (mg/kg)$$
$$IR_i = Average\ ingestion\ rate\ of\ fish\ for\ general\ public\ (kg/day)$$
$$EF_i = Exposure\ Frequency\ (days/year)$$
$$ED_i = Exposure\ Duration\ (years)$$
$$BW_i = Average\ body\ weight\ for\ general\ public\ (kg)$$
$$AT = Averaged\ Time\ (days)$$
$$SF = Cancer\ slope\ factor\ (mg/kg \cdot day^{-1})$$

Reference

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