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# Modeling tribal exposures to methyl mercury from fish consumption

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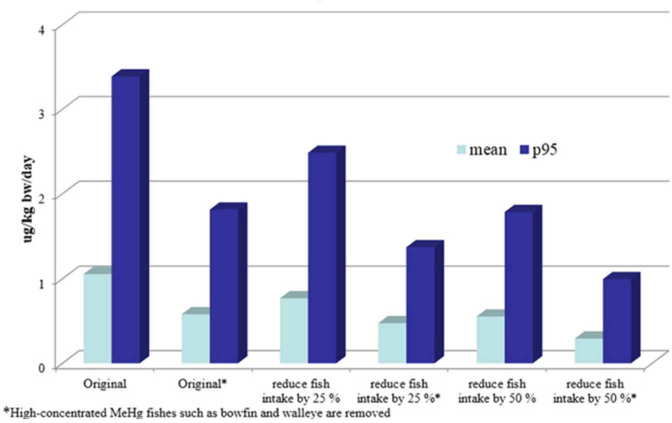
## HIGHLIGHTS

- The paper identifies key factors of methyl mercury (MeHg) exposure
- MeHg exposures from fish in tribes are much higher than the US general population
- ~50% of MeHg dietary exposures can be reduced just by avoiding some fishes with high MeHg

## GRAPHICAL ABSTRACT

Exposure sensitivity analyses reducing average fish intake for different scenarios: As much as ~50% of MeHg dietary exposures can be reduced just by replacing several species of fish with high MeHg concentration (e.g., walleye, bowfin), substituting species with lower concentrations.

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## ABSTRACT

Exposure assessment and risk management considerations for tribal fish consumption are different than for the general U.S. population because of higher fish intake from subsistence fishing and/or from unique cultural practices. This research summarizes analyses of available data and methodologies for estimating tribal fish consumption exposures to methyl mercury (MeHg). Large MeHg fish tissue data sets from the Environmental Protections Agency's (EPA's) Office of Water, USGS's EMMMA program, and other data sources, were integrated, analyzed, and combined with fish intake (consumption) data for exposure analyses using EPA's SHEDS-Dietary model. Results were mapped with GIS tools to depict spatial distributions of the MeHg in fish tissues and fish consumption exposure patterns. Contribution analyses indicates the major sources for those exposures, such as type and length of fish, geographical distribution (water bodies), and dietary exposure patterns. Sensitivity analyses identify the key variables and exposure pathways. Our results show that MeHg exposure of tribal populations from fish are about 3 to 10 times higher than the US general population and that exposure poses potential health risks. The estimated risks would be reduced as much as 50%, especially for high percentiles, just by avoiding consumption of fish species with higher MeHg concentrations such as walleye and bowfin, even without changing total fish intake. These exposure assessment methods and tools can help inform decisions regarding meal sizes and

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frequency, types of fish and water bodies to avoid, and other factors to minimize exposures and potential health risks from contaminated fish on tribal lands.



## 1. Introduction

Concerns of health risks from fish consumption are a priority tribal issue (Donatuto and Harper, 2008). Exposure assessment and risk management considerations for tribal fish consumption are different than for the general U.S. population because of higher fish intake from subsistence fishing and/or from unique cultural practices (USEPA, 2004; Donatuto and Harper, 2008). Tribal populations are vulnerable to methyl mercury (MeHg) which may lead to impairment of the developing central nervous system as well as pulmonary and nephrotic damage (Cohen et al., 2005). It is well documented that serious health effects of mercury resulted from high-level exposures in Minimata and Nigata, Japan (Irukayama et al., 1977) and in Iraq (Bakir et al., 1973). Though it is very unlikely for people in the general population to have those high-level exposures, the effects of exposure to low levels MeHg are well documented and include developmental deficits, particularly in children exposed prenatally (Grandjean et al., 1997; NRC, 2000). The toxic effects of MeHg are irreversible and severe enough that the potential risk to the United States population from consuming a variety of fish should be reviewed on a continuing basis (Mahaffeya and Merglerb, 1998). At the same time, it is important to note that eating fish has many health benefits (Daviglus et al., 2002; Mozaffarian and Rimm, 2006).

In aquatic environments, MeHg bio-accumulates up the food chain. Fish contain traces of MeHg; however, it accumulates more in certain types of fish, depending on what the fish eat, resulting in varying MeHg levels. Also, larger fish (swordfish, shark, king mackerel and tilefish) that eat smaller fish, have the highest levels of MeHg due to bio-accumulation. In general concentrations of MeHg vary ~2 orders of magnitude between species (Mahaffey et al., 2011). Only a few species of fish could have MeHg levels of 1 ppm or greater. This occurs most frequently in some large predator fish, such as shark and swordfish and in certain species of large tuna, typically sold as fresh steaks or sushi (Fletcher and Gelberg, 2013).

Reliable estimates of MeHg exposures from fish consumption, and the major contributors, can inform decisions of tribal populations and the general US population regarding types and quantities of fish that are both safe to eat and nutritionally beneficial. Fish MeHg concentrations can be highly variable, even within the same species. Therefore, it is important to have a large dataset of MeHg in fish tissues and reliable fish consumption data. The EPA's Stochastic Human Exposure and Dose Simulation model (SHEDS) has been well evaluated with biomarkers for arsenic, MeHg, chlorpyrifos, and pyrethroids (Xue et al., 2010; Xue et al., 2012a, 2014a, 2014b). It has gone through external peer review by EPA's Federal Insecticide Fungicide, Rodenticide Act Scientific Advisory Panel and has been used to support regulatory decisions on organophosphate, carbamates, pyrethroids, chromated copper arsenate (CCA) and others (SAP, 2007; SAP, 2010).

Xue et al. (Xue et al., 2012a, 2012b) using the SHEDS-Dietary model with national data, reinforced and expanded upon previous observations that dietary exposure via fish consumption is an important route for MeHg intake by the general population, and especially for racial/ethnic groups with higher fish consumption such as tribes. That paper concluded that probabilistic dietary modeling approaches could be applied for local populations (e.g., tribes) and other chemicals and foods, if data are available, and that many research and data needs remain for local-scale assessments involving fish consumption exposures/risks (Xue et al., 2012a). Because that study used national rather than tribal-specific fish consumption and residue data, and Americans Indians are grouped with Asians, Pacific Islanders, and multiracial groups (APNM) in the National Health and Nutritional Examination Survey (NHANES), it is difficult to draw tribal-specific conclusions or suggest specific risk reduction recommendations. Future research recommendations included 1) collecting detailed consumption and residue data at the local scale to identify the specific type of fish consumed and the concentrations of MeHg in those fish for specific community or tribal assessments; and 2) conducting dietary exposure analyses to answer questions of interest related to risk mitigation (e.g., identification of key fish contributing to local exposures; maximum meal sizes relevant to reference doses).

Questions being addressed by the research presented in this paper include the following:

- What fish tissue data sets and tribal fish consumption data sets are available for exposure modeling?
- What are major factors for fish contamination and exposures?
- How can tribes minimize exposures and potential health risks from contaminated fish on tribal lands, while maintaining current dietary practices?
- How can exposure assessment tools inform those decisions?

## 2. Methods

EPA's SHEDS-Dietary, an important module of EPA's SHEDS-Multimedia model, was used for the analysis. SHEDS-Dietary can generate population percentiles of dietary exposure predictions by source and age-gender group; quantify contribution to total exposure predictions by food, commodity, and chemical; and be used for eating occasion, sensitivity, and uncertainty analyses. In general terms, this model combines information about food and drinking water consumption data for each reported eating occasion with corresponding chemical residue/concentration data to estimate human dietary exposures. SHEDS-Dietary can use the NHANES/WWEIA dietary consumption data (1999–2010), along with EPA/USDA recipe translation files (FCID; Food Commodity Intake Database), and available food and water concentration data and detailed methods can refer to the earlier publications (Xue et al., 2010; Xue et al., 2012a).

To conduct the exposure analyses, we compiled and analyzed available fish tissue data sets and tribal fish consumption data from key studies as listed below. We then mapped fish tissue concentrations and analyzed for key exposure factors. We also compared tribal fish consumption data to NHANES consumption data and then used those data as inputs to the EPA SHEDS model (http://www.epa.gov/heasd/research/sheds/user_information.html). With the SHEDS model, we conducted sensitivity analyses to better understand the impact of modifying fish intake for different species.

National fish tissue data sets used here were the following: EPA National Listing of Fish Advisories (NLFA); EPA National Lake Fish Tissue Study; EPA National Rivers and Streams Study; EPA National MeHg Survey; and USGS EMMA (Environmental Mercury Mapping, Modeling and Analysis). State/local fish tissue data sets used were as follows: Washington State, tribally-provided data, including Columbia River Inter-Tribal Fish Commission (CRITFC) (EPA Region 10), Winnebago Tribe Kelly Pond (EPA Region 7), and Pyramid Lake (EPA Region 9).

Tribal fish consumption surveys used in this analysis were the following:

- A fish consumption survey of the Umatilla, Nez Perce, Yakama, and Warm Springs Tribes of the Columbia River Basin (CRITFC, 1994)
- A fish consumption survey of the Tulalip and Squaxin Island Tribes of the Puget Sound Region (Toy, 1996)