A Comparative Risk Assessment and Risk Management Plan for Health Risks to Chippewa Indians Exposed to Mercury Contamination in the St. Louis River Estuary and Northern Wisconsin

A report

submitted by

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ABSTRACT

The Chippewa Indians of northern Wisconsin and northeastern Minnesota were surveyed recently to determine if indicators of health risks from methylmercury poisoning through consumption of contaminated fish were present among the tribal population. Methylmercury is a known neurotoxin at high blood levels (> 400 µg/l) and is suspected to cause neurologic symptoms at substantially lower levels in adults and infants. The levels of methylmercury in fish in the Study Area have been discovered to be high (> 1 ppm, the U.S. Food and Drug Administration standard), and Chippewa Indians rely heavily on fishing the local waters for subsistence and income. Using monitoring data from State and Tribal studies, together with health effects and risk assessment data from numerous sources, this report has examined the health risks to the Study population and arrived at the following conclusions:

1) pregnant women should forego consumption of large predatory fish, such as walleye;

2) the current approach to communicate risk to the Chippewa Tribes is inadequate and should be modified; and

3) additional research is required to reduce uncertainties relating to uptake, cycling and methylation of mercury.

List of Abbreviations

ADD - Average Daily Dose

ANC - Acid Neutralizing Capacity

AOC - Area Of Concern

ATSDR - Agency for Toxic Substances and Disease Registry

BW - Body Weight

CAA - Clean Air Act

CDC - Center for Disease Control

CERCLA - Comprehensive Environmental Response Compensation and Liability Act

C_m - Concentration of chemical m

CNS - Central Nervous System

COC - Chemical of Concern

CR - Consumption Rate

CWA - Clean Water Act

DOC - Dissolved Organic Carbon

D_{ref} - Reference Dose

E_m - Effective ingested dose of chemical m

EPA - Environmental Protection Agency

EPC - Exposure Point Concentration

FDA - Food and Drug Administration

g - gram

GIS - Geographic Information System

GLIFWC - Great Lakes Indian Fish and Wildlife Commission

GLNPO - Great Lakes National Program Office

GLWQA - Great Lakes Water Quality Agreement

HHS - Health and Human Services

Hg^0 - Elemental mercury

Hg(II) - Divalent inorganic mercury

HgS - Mercuric Sulfide

HQ - Hazard Quotient

IHS - Indian Health Service

IJC - International Joint Commission

IRIS - Integrated Risk Information System

Kg - Kilogram

LOAEL - Lowest Observable Adverse Effect Level

MDH - Minnesota Department of Health

MeHg - Methylmercury

Mg - Milligram

MPCA - Minnesota Pollution Control Agency

MWC - Municipal Waste Combustor

ng - nanogram

NOAEL - No Observable Adverse Effect Level

Pb - lead

PCB - Polychlorinated Biphenyl

List of Abbreviations (continued)

pH -	log of the hydrogen ion concentration
ppb -	parts per billion
ppm -	parts per million
RCRA -	Resource Conservation and Recovery Act
RfD -	Reference Dose
s -	standard deviation
SMSA -	Standard Metropolitan Statistical Area
SRS -	Surveillance and Research Staff
SV -	Screening Value
TOC -	Total Organic Carbon
TSCA -	Toxic Substances Control Act
WDNR -	Wisconsin Department of Natural Resources
WLSSD -	Western Lake Superior Sanitary Department
X_m -	Relative absorption coefficient

EXECUTIVE SUMMARY

This report evaluates whether the families of Native American fishers who engage in spearfishing of walleye at inland lakes in northeastern Minnesota and northern Wisconsin are at higher risk than the general public in the Great Lakes region from mercury toxicity through fish consumption.

The report examines the results of two health studies performed between 1989 and 1994 within the Study Area. Using health effects research and risk assessment methodology, the report concludes that the Chippewa Indians surveyed are subject to moderate levels of risk from methylmercury poisoning, with fetal exposures resulting in very high risk.

These results are corroborated with supporting data from environmental studies and research projects, including those conducted by the U.S. Environmental Protection Agency, State and Tribal governments, and academic institutions. Environmental correlates, such as water chemistry, are addressed as tools to focus future monitoring and research efforts. The use of a Geographical Information System allowed visual representation within distinct spatial boundaries of environmental contamination, for both educational and analytical purposes.

Recommendations are provided to mitigate risks to the Study population and similar populations with respect to risk communications, environmental monitoring, and biogeochemical research. These recommendations are intended for use by Federal and State governments in determining the most viable and efficient strategies for improving current mercury risk reduction programs with respect to populations at risk, such as the ones included herein.

CHAPTER 1.0

BACKGROUND AND HISTORY

1.1 Overview of the Problem

It is helpful to examine the sources and scientific mechanisms of mercury transport in the environment in order to understand its complex interactions. Mercury is present naturally in the earth's crust, occurring in rock and soil at the surface of the earth at an average concentration of 50 parts per billion (ppb)[1]. Mercury is released to the environment as a result of a variety of human and naturally-occurring activities.

Mercury is found in all environmental media: air, water, sediment, biota and soil. This is critical in complex ecosystems such as the Great Lakes. Pollutants that enter the Great Lakes ecosystem remain there for long periods of time. The long retention times, low biological productivity, and low suspended solids all contribute to the persistence of toxic pollutants, including mercury, in the Great Lakes. Also, mercury often re-enters the water column through resuspension of bottom sediments, through dredging, or as a result of storm events. This results in recycling of mercury through the food chain. Mercury is methylated through chemical and biological action (both aerobic and anaerobic), producing methylmercury, and tends to bioaccumulate in both plankton and fish, becoming concentrated at levels that are much higher than those in the water of the lakes and rivers.

Mercury is used as pigment in the paint industry and in bleaching in the wood pulp and paper industries. These applications contribute to discharge of waste mercury into waterways, in addition to atmospheric emissions. Electrical power generation and waste incineration account for most of the atmospheric deposition in the Great Lakes region, due, in part, to the adsorption of mercury onto carbon and fly ash components.[2,3]

Mercury is released from these industrial processes mainly in its inorganic form, as divalent mercury (Hg^{++}). Once in the aquatic environment, mercury forms strong aqueous complexes with sulfides and precipitates as HgS. However, the majority of mercury in edible fish tissue is in the form of methylmercury (MeHg). Methylation of mercury occurs in sediments under anaerobic and aerobic conditions through methyl-group donating bacteria.[4] Increased methylation rates have been found to be highly correlated with low acid neutralizing capacity (ANC) and low pH in waterbodies.[5] These conditions are often present in the Upper Midwest region of the U.S., in part due to the low alkalinity of the noncalcareous tills upon which the Great Lakes lie.[6]

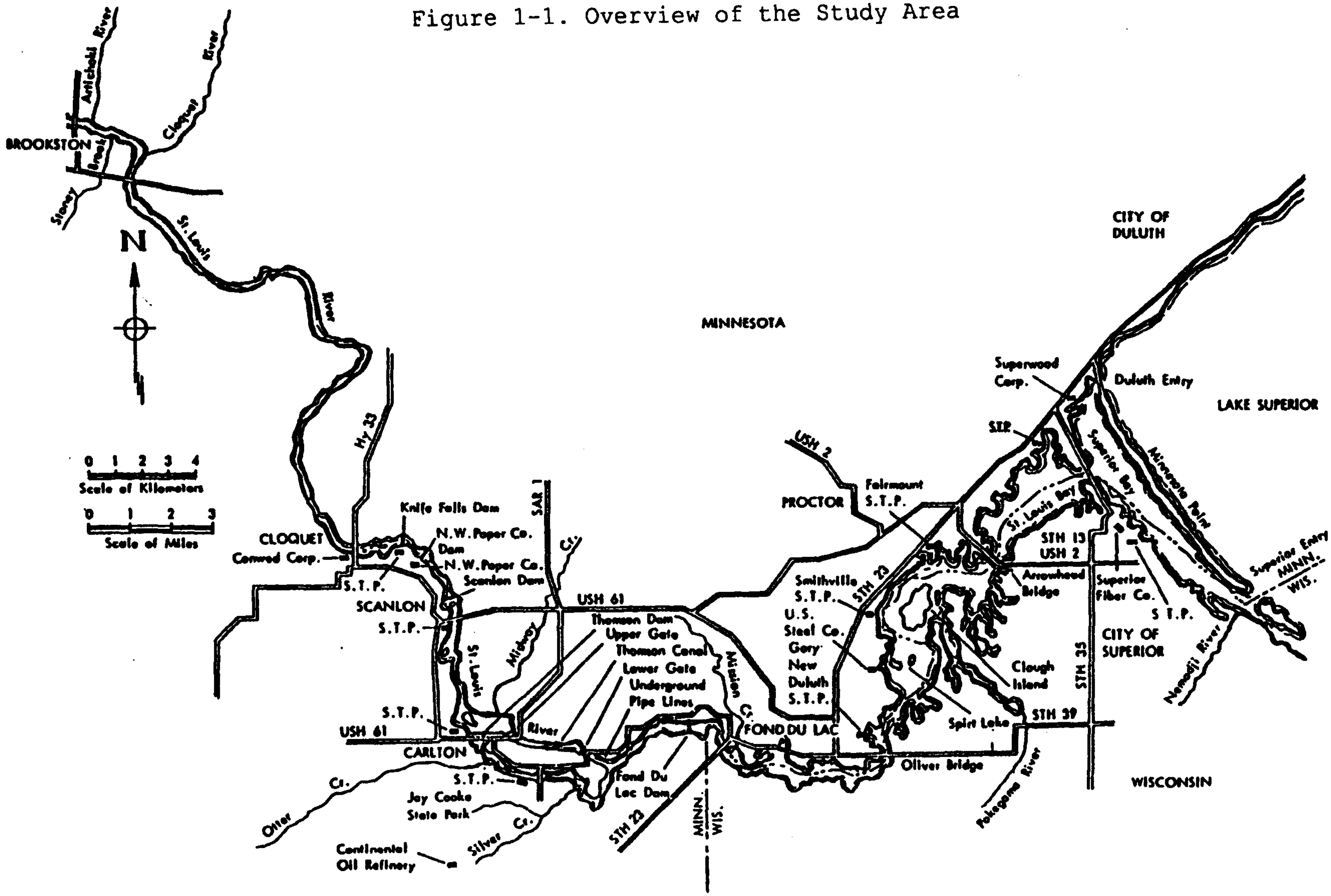
Acknowledging these physical conditions, the U.S. government has devoted considerable resources toward monitoring mercury contamination in water, sediment, and biota through collection of samples. The remote inland lakes of the Upper Midwest have been monitored routinely for mercury contamination by the States since the 1970's. This effort has included fish sampling, particularly the top predators such as walleye and northern pike.

The Great Lakes and their tributaries are monitored by several U.S. Federal agencies for contamination in water, air, sediment, and biota. Of particular interest are the 43 designated "Areas of Concern." These are the most heavily contaminated localities that have been adjudged, by cumulative risk potential, to merit increased attention.

One such area is the St. Louis River Estuary, which flows from Western Lake Superior along the border between Minnesota and Wisconsin. Due to its proximity to the Fond du Lac Indian Reservation, this area was examined for potential adverse health effects by the Federal Agency for Toxic Substances and Disease Registry (ATSDR). The impact of mercury emissions from the Western Lake Superior Sanitary Department (WLSSD) incinerator site and other urban point sources, coupled with terrestrial runoff from erosion of recently cleared forest embankments, led to targeting of this area for this study.

The area which is the focus of this report is described as follows: the St. Louis River runs through northeastern Minnesota from Floodwood (Figure 1-1) through the towns of Brookston, Cloquet, and Scanlon on its way to St. Louis Bay and Lake Superior at Duluth. A 22-mile portion of the St. Louis River from above Brookston to Cloquet comprises the Northern boundary of the Fond du Lac Reservation.[7] Some Fond du Lac band members fish these and other rivers and reservoirs in the area heavily during the fishing

Figure 1-1. Overview of the Study Area



Source: Minnesota Pollution Control Agency and Wisconsin Department of Natural Resources. The St. Louis River System Remedial Action Plan, Stage One. MPCA, Duluth MN and WDNR, Superior WI. 1992.

season, which is from May until October. Because of mercury levels in walleye and other top predator species (e.g., northern pike and lake bass), the Minnesota Department of Health (MDH) has issued a fish consumption advisory suggesting that no more than one fish meal a week be consumed for these fish species taken from the St. Louis River between Floodwood and Scanlon.[8]

Walleye over 18 inches long from the St. Louis River have consistently contained over 0.5 mg/kg mercury, based on ongoing testing since 1983.[9] The St. Louis River walleye fishery is characterized by an abundant spawning population in the Fond du Lac area in the spring. After spawning, the adult walleye disperse downstream throughout the estuary to Lake Superior. Dispersal takes place at an extremely variable rate, with some walleye spending long periods of time in the St. Louis estuary and others moving throughout western Lake Superior. The St. Louis River walleye population makes up the bulk of the western Lake Superior walleye fishery. For this reason, and because of confirming test results, the Wisconsin fish advisory has been extended to include walleye in the Wisconsin portion of Lake Superior.[10]

Many lakes in northern Wisconsin, although often pristine in appearance, have been discovered to be mercury-contaminated.[11] The Wisconsin Department of Natural Resources (DNR) has been finding that about one-third of the lakes it tests in northern Wisconsin have game fish contaminated with mercury above the state level of 0.5 ppm[12], warranting issuance of a fish consumption advisory for the lake.[13]

Mercury contamination has been documented in many lakes in remote regions of Wisconsin. Although these lakes lie in landscapes with little or no human development, they contain fish with mercury levels that pose health risks for human consumption[14], and their sediments show stratigraphic evidence of increasing mercury inputs within the last 100 to 200 years.[15]

1.2 Potential for Mercury Exposure

The bioavailability of mercury compounds in the water column and in the sediments governs their accumulation by a variety of organisms, including plankton, fish, and benthic macro-invertebrates. Bioavailability is the result of a combination of phenomena: physicochemical characteristics of the biotopes (abiotic factors, amount of suspended matter, and geochemical properties of sediments), and specific features of contamination conditions (inorganic and organic forms of mercury, chemical speciation reactions with dissolved and particulate ligands, and biotransformation processes).[16]

The presence of mercury in fish tissue presents a threat to human health. In response to this threat, all States contiguous to the Great Lakes have issued fishing advisories throughout the basin. As of fall 1993, 164 fish advisories were in effect for the Great Lakes system.[17]

Mercury contamination of fish in Minnesota was first investigated in 1969. This followed reports of fish contamination from direct industrial discharges to surface waters in Sweden.[18]

High mercury concentrations in fish from northern Minnesota lakes were noted in 1971.[19] Later, elevated water and sediment concentrations were discovered in these same areas. Early efforts to control mercury loadings centered on control of point source discharges to rivers, as was the case nationally. Significant mercury contamination was found in the lower St. Louis River (Figure 1-1), prompting efforts to identify and reduce its sources within the State. However, major sources such as utilities and municipal waste combustors were left uncontrolled due to economic and political considerations.[20] Furthermore, the contamination frequently crossed political boundaries, requiring regional management due to overlapping jurisdictions.

Atmospheric deposition of mercury has been cited as a source of mercury to many of these waters. An example is the St. Louis River Estuary, near Duluth, Minnesota. One of the significant sources of mercury in the estuary was hypothesized by Glass et al. as coming from airborne deposition.[21] This source was evaluated in 1988 by monitoring mercury concentrations in rain and snow and in ambient air near Lester Park in eastern Duluth. The results of the ambient air measurements showed average mercury concentrations of 22 ng/l[22], as compared with the water quality criterion of 2 ng/l established for Wisconsin waters[23]. This is in the high end of the range found by Lindqvist and Rodhe[24], 5 to 30 ng/l in precipitation over continents around the globe. Although air concentrations consist mainly (>80 to 90 percent) of volatile mercury, Hg^0, it is the less abundant water-soluble forms that are washed out by precipitation.[25] Therefore, low direct correlation results would be expected between precipitation and air concentrations. The summation over one year of measurements by Glass et al. indicates that approximately 14 ng per square meter of total mercury was deposited as wet deposition in the estuary. This precipitation loading rate applied equally over the 4700-hectare surface area of the St. Louis River estuary yields about 660 grams of mercury per year or 1.8 grams of mercury per day.[26]

The mean annual wet deposition value and standard deviation for six precipitation monitoring sites representing Minnesota are 8.2 ± 2.7 µg Hg/m^2.[27] Using these values times the surface area of the state correspondingly yields 1800 ± 600 kg of Hg deposited by wet deposition during 1990.[28] This value does not reflect additional quantities from dry deposition, generally assumed to be less than half of the wet deposition magnitude.[29]

Because mercury deposition in precipitation is intrinsically dependent on weather that is highly variable from year to year, it is risky to characterize the phenomena based on one or two years of observations. Further study of mercury in precipitation with regard to geographic patterns, precipitation rates, seasonal variations, related ions, and deposition inventory is therefore needed to assess the long-term applicability of these findings.[30]

Studies from Minnesota and surrounding areas show a tripling in sediment concentration of mercury since the 1840s. In one such study, Henning analyzed at least ten cores from each of four lakes across the noncalcareous region of northeastern Minnesota, which has lakes with lower pH values due to lower alkalinity, and found that sediment concentrations increased by factors of 3.4 to 3.9.[31] Detailed lead-210 dating allowed the estimation of the timing of increases and deposition rates. The increases in Hg deposition occurred in two periods, the first immediately after settlement (1860-1890), and the second between 1920 and 1950.[32] Modern deposition rates of 18-26 mg/m^2 per year were estimated to be 3.2 to 3.6 times those during presettlement. Based on a North American average deposition rate of 15 mg/m^2 per year[33], Henning concluded that direct atmospheric deposition to lake surfaces could account for 60 to 80 percent of the measured rate of mercury contribution to the lakes.[34]

The greatest permanent ecological damage to the St. Louis River estuary probably occurred when extensive areas of wetlands were filled for docks and industrial uses on the waterfront. Water flow patterns were changed by building the Duluth Ship Canal, harbor dredging, and the construction of dams and reservoirs upstream to generate power. These projects decreased water turnover time (flushing rates), changed flow patterns, caused oxygen consuming materials to accumulate, and formed barriers to fish migration. The direct discharge of waste products, wood processing wastes including sawdust, and sewage clogged and covered fish-spawning areas. Paper mill, fiber board, and municipal wastes were directly discharged into the river, estuary, and lake, consuming life-sustaining oxygen from miles of river (and harbor) and adding toxic and odor-forming chemicals, including mercury, to the aquatic environment.

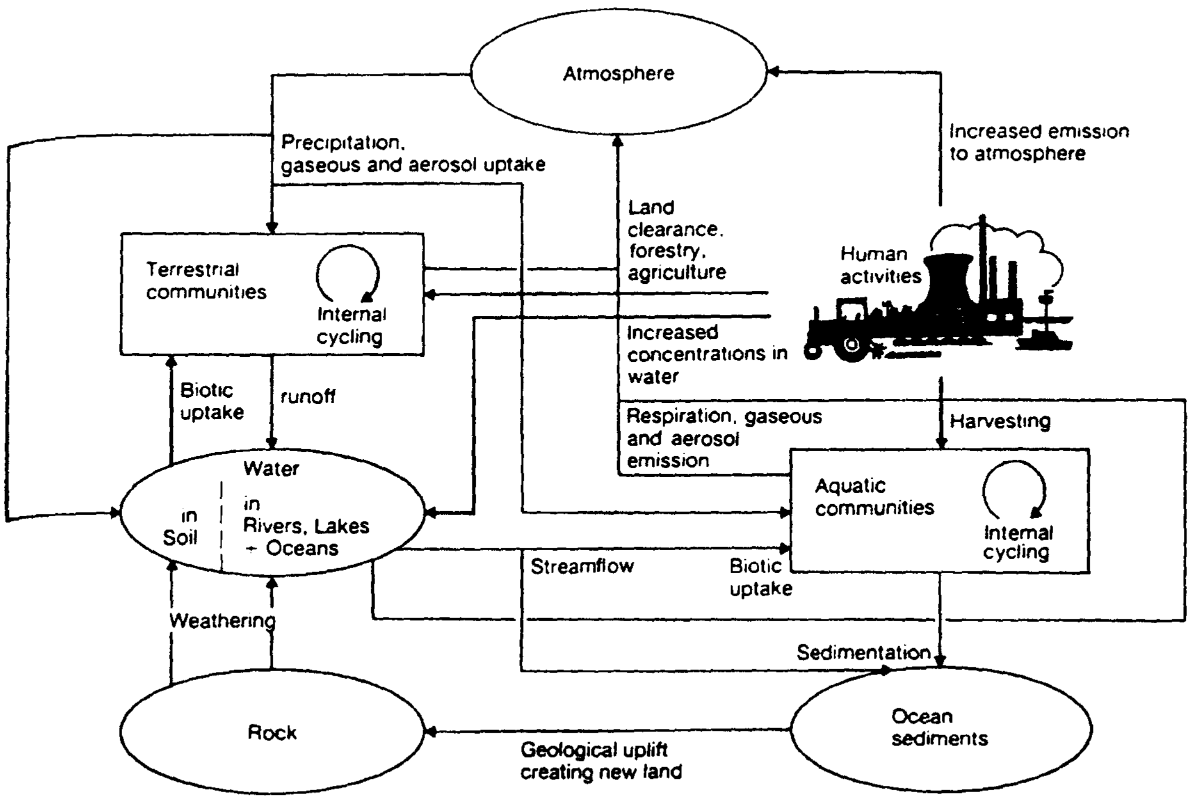
1.3 Cycling,Methylation and Mercury in the Environment

Whole-basin mercury fluxes, determined from lake-wide arrays of dated sediment cores at seven inland lakes within the Study Area, indicate that the annual deposition of atmospheric mercury has increased from 3.7 to 12.5 micrograms per square meter since 1850 and that 25 percent of atmospheric mercury deposition to the terrestrial catchment is transported to the Lake.[35] It is evident that this transfer of mercury from airborne sources to the terrestrial environment and finally to the aquatic environment can be significant in increasing mercury concentrations in the biotic food chains.[36] A schematic description of the mercury cycle is shown in Figure 1-2.

In the environment, mercury is in equilibrium among its different chemical forms. The most toxic and bioaccumulating of these is monomethylmercury (II), a water-soluble ion that binds strongly to protein in the central nervous system and other tissues.[37] Mercury and its various forms and compounds are capable of cycling through various environmental compartments. The permanence, toxicity, volatility, and ability of this element to change forms and cycle through the hydrosphere make mercury one of the more complex environmental contaminants.[38]

Atmospheric deposition of mercury to lakes occurs largely as inorganic mercury,[39]. Within oxygenated waters, Hg^{++} will form complexes with inorganic ligands (e.g., Cl^- and OH^-), bind with

Figure 1-2. Mercury Cycle



Source: Minnesota Pollution Control Agency, Swain, Edward, ed., "Mercury Control Activities in Minnesota: Laws, Rules, and Initiatives (Draft)," St. Paul, MN, 1993.

dissolved organic carbon (DOC), or adsorb to particulate matter.[40] Mercuric (Hg^{++}) ion can be reduced microbially to form elemental mercury [Hg^0]. Most waters are oversaturated with respect to the solubility of atmospheric Hg^0, and Hg^0 is volatilized to the atmosphere.[41] Within anoxic zones, mercury forms strong aqueous complexes with sulfide and precipitates as HgS. Within anaerobic environments or within anoxic zones in aerobic environments, Hg^{++} can be converted to methylmercury by microorganisms in sediment.

The methylmercury available for bioaccumulation in a lake is the balance between methylation and losses of methylmercury. Methylmercury can be converted to dimethylmercury, which is readily released to the atmosphere, or by demethylation to elemental mercury. Each of these processes is a function of environmental conditions, including pH, oxidation-reduction potential, temperature, oxygen, and organic substrate concentration.[42]

Mercury exists in water in a variety of forms. These forms can be distributed between particles, including silts and plankton, and the water phase, depending upon environmental processes and water quality conditions. Distribution of mercury forms between particles and solution can indicate its relative availability, since particulate mercury can be less active than mercury in solution.[43] Because most forms of mercury are hydrophobic and sorb to particulate matter, free mercury concentration in surface waters is usually very low.[44]

Sediments are recognized as pollutant sinks and reservoirs of contaminants that can be mobilized and bioaccumulated by aquatic organisms. Contaminants can attach to sediment particles, which are then ingested by organisms. The contaminants in sediment can also partition or dissolve into porewater surrounding sediment particles. This release of contaminants can be exacerbated by dredging, large streamflow events, ship traffic, and the effect of lake seiches.[45]

Sediment pH is usually 6.9 to 7.5, but in anoxic sediments pH and redox potential are lowered.[46] When initially anoxic sediments are exposed to oxygenated water, a significant portion (20 percent to over 90 percent) of the pyrite-bound metals (i.e., trace metals that are coprecipitated with and adsorbed on aqueous Fe (III) or FeS_2) can be released in a day or less.[47] Mercury, in particular, has a tendency to form pyrites and, therefore, is released and often exceeds the concentration of its potentially bioavailable fraction. After oxidation, metals may again be released. It is concluded that pyritization-depyritization of trace metals is an important process in controlling bioavailability.[48]

The prevailing evidence also suggests that sediments are the principal source areas for the methylation of mercury.[49] Micro-organisms living in sediments uptake inorganic mercury, biotransform it and incorporate methylmercury into their cell structures. These microorganisms are, in turn, ingested by macroinvertebrates residing in the sediment. Unless accumulated inorganic mercury in sediments is removed or rendered unavailable to organisms, its persistence makes it available for conversion to methylmercury for years to come.[50]

The mercury cycle in aquatic systems is detailed because of the myriad of chemical species and pathways. Understanding of the biogeochemistry of mercury has increased markedly over the past ten years, with the development of ultra-trace protocols for the sampling and analysis of mercury.[51]

1.4 Health Effects

In the general population, diet is the major pathway of mercury exposure, primarily through fish consumption, as a result of food web biomagnification. Methylmercury is absorbed by the gills of fish as water passes over them or by accumulation through the food chain.[52] Methylmercury enters aquatic food chains starting with small organisms such as plankton, and eventually attains its highest concentration in large, predatory fish that ingest fish and other organisms that have accumulated mercury in their tissues. Methylmercury is poorly, if at all, eliminated from fish so that it accumulates throughout the lifetime of the fish. Thus, the highest concentrations are found in the longest-lived, top predatory fish such as walleye.[53]

Humans who eat these fish are at risk of mercury toxicity. For adults, except at extremely high doses, all the signs and symptoms of methylmercury poisoning are due to selective damage to the nervous system.[54] The brain is the primary target, and even within this organ, selective or focal damage is the dominant characteristic.[55]

Fetuses, infants, and children are at increased risk of adverse effects of methylmercury (MeHg). MeHg readily crosses the placenta and blood-brain barrier during the prenatal stage, when the nervous system is most sensitive to mercury poisoning. Because MeHg is eliminated in breast milk, nursing infants can also be exposed through this route.[56]

Studies of MeHg concentrations in the blood of newborn infants show a significant correlation with maternal blood levels. In MeHg poisonings, unlike the focal damage in adults, the damage to the fetal nervous system is widespread and probably involves derangement of brain developmental processes such as neuronal migration and neuronal cell division[57], leading to altered brain architecture, heterotrophic cells, and decreased brain size.2] [58]

Methylmercury has been shown both *in vitro* and *in vivo* to depolymerize nerve cell microtubules.[59] Microtubules are the first subcellular structure to be affected at the lowest concentrations of methylmercury.[60] Microtubules play an essential role in both cell division and in neuronal migration. Thus, methylmercury is damaging that component of neuronal cells that is essential for two basic processes in the developing brain, cell division and cell migration.[61]

Quantitative information on the greater susceptibility of the fetus became available following study of an incident of methylmercury poisoning in Iraq in the early 1970's.[62] Whereas the practical threshold in the adult dose response was in the range of 50 to 100 µg Hg/g hair, the prenatal threshold was in the range of

10 to 20 µg Hg/g hair.[63] Despite the uncertainties in the estimates of these threshold values, these dose-response data indicated that the fetus may be 5 to 10 times more sensitive than the adult to brain damage from methylmercury.[64]

Organomercury compounds are readily absorbed by inhalation, dermal contact, and ingestion. MeHg is distributed uniformly to all tissues, although it concentrates more in the blood and brain than elemental mercury or mercury ions do. About 90 percent of MeHg is found in the red blood cells, where it is metabolized to mercury ions at a slow rate. The major route of MeHg excretion (about 90 percent) is through bile into the feces; urinary excretion accounts for most of the remaining 10 percent. The biologic half-life of MeHg is about 50 to 70 days in humans.[65] Effects of mercury toxicity manifest primarily in the central nervous system (CNS), where methylmercury accumulates after exposure. The duration, intensity, and route of exposure, as well as the form of mercury, influence which systems are affected.[66]

Blood mercury results alone can be difficult to interpret if there is only sporadic or rare exposure to methylmercury. Such exposure is unlikely to result in a steady state in the blood. Thus, significant concentrations in the blood can be missed if exposure ceases several weeks before the time a sample is obtained.[67] In addition, a sharp peak will be seen in blood mercury concentration during the 20 to 30 hours following exposure in a person not chronically exposed; the peak will level off as the mercury is distributed to tissues.[68] Because of these potential problems when blood is used as the only biologic medium to assess exposure, analysis of hair is often used to obtain an indication of past exposure. Mercury concentration in hair is proportional to that in blood at the time of hair formation.[69] Mercury in the hair closest to the scalp represents the most recent exposure, with each centimeter of hair representing approximately one month's growth. Therefore, segmental analysis of hair provides valuable additional information on past exposure.[70]

1.5 Tribal Issues

At the present time, there are six bands of Chippewa Indians, spread throughout northern Wisconsin, who fish many of these contaminated lakes.

The Chippewa people were part of a huge group of Indians, the "Anishinabe" or "Human Beings," who lived along the St. Lawrence River. They arrived in the Great Lakes region in the 1400's, and settled along the southern and western shores of Lake Superior.[71] The Chippewa people, or "Keepers of the Faith," became known as "Ojibwa" after people noticed that their mocassins were sewn differently from those of other Woodland Indians. The seam at the top of Chippewa moccasins was gathered. "Ojibwa" was the word used to describe this stitch. Europeans, who had a difficult time pronouncing Indian words, said "Chippewa" when they tried to say "Ojibwa." This is how the Anishinabe were named the Ojibwa, which was later said as Chippewa.[72] The Chippewa are composed of six bands: Bad River, Sokaogon (Mole Lake), Red Cliff, Lac Courte

Oreilles, St. Croix, and Lac du Flambeau.

1.5.1 Legal Issues

In the early 1980's, the Reagan administration agreed that Indian Tribes and their governing bodies should be recognized as sovereign entities and negotiated with on a government to government basis. One of the most important rights recognized by the Chippewa is the right to harvest the resources of the waters around their territories. Today, many successful commercial fisheries are being managed by Tribal members, in addition to providing subsistence to themselves and their families.

Prior to European settlers arriving in the region, their villages and campsites dotted the northern areas of Minnesota and Wisconsin. They had a long-standing system of traditional self-government. Called "Woodland Indians" because of their forested homeland and life-style, the Anishinabe relied on hunting, fishing and gathering for subsistence.[73]

With the onset of European settlement in the Upper Great Lakes region, many changes were brought upon the Anishinabe people. The white settlers were interested first in fur trade, and many Anishinabe acted as guides and trackers, being expert in their own woodlands. However, the newcomers later became more interested in land. They wanted the land for mines, timber, and growing settlements: towns, cities, ports, not just trading posts.

Sovereignty refers to the right of self-determination, or the ability to make independent decisions. When the European settlers first began to occupy the land, Tribes were negotiated with on a government-to-government basis.

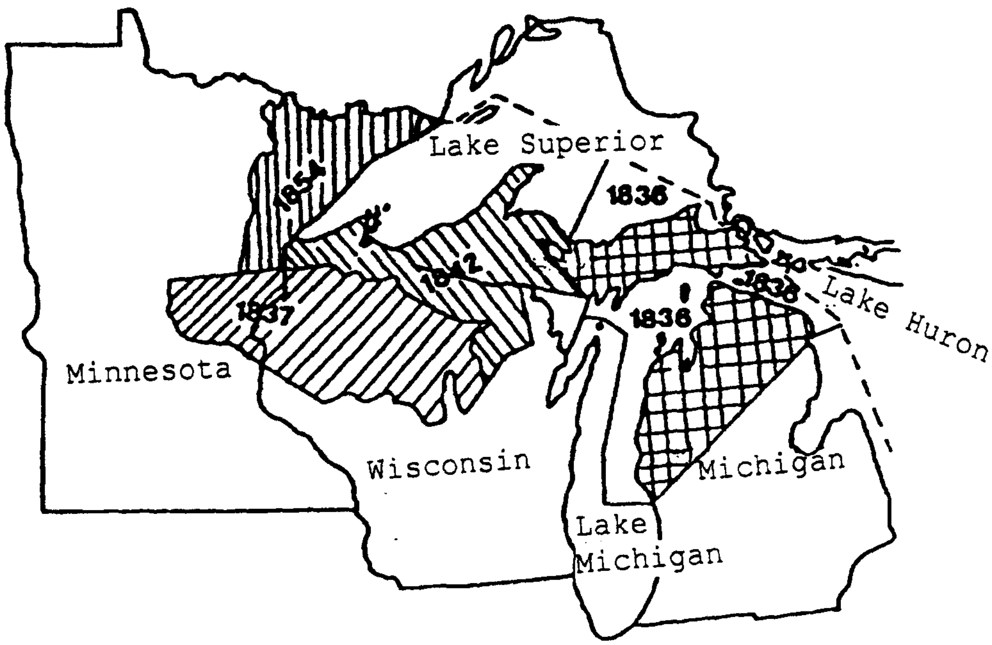
At the time of advancing settlement, however, the Anishinabe people held no real concept of land ownership. The notion of individuals "owning the land" was foreign to their culture, which considered land to belong to all living beings alike.

However, the U.S. government established boundaries for Tribal land in its first treaties with the Anishinabe. In treaties that followed, known as the cession treaties, the Anishinabe agreed to sell land to the U.S. Government as the demands of mining and timber interests pushed westward; however, they reserved the right to hunt, fish, and gather on the ceded lands. Cession treaties with the Anishinabe included: 1) the 1836 Treaty, which ceded parts of northern Michigan; 2) the 1837 Treaty, ceding territories in Minnesota and Wisconsin; 3) the 1842 Treaty, ceding the remaining land in northern Wisconsin; and 4) the 1854 Treaty, which ceded remaining land in northern Minnesota and established permanent reservation homelands for the Anishinabe bands.[14]

Since the 1854 Treaty, much of the land originally part of reservations no longer belongs to the bands. Various land deals drastically reduced reservations land bases. This left the bands with "checkerboard" reservations with non-Indian ownership of much of the land within the reservation boundaries (Figure 1-3).

Despite the devastating effects of rapid white settlement and exploitation of the resources, the bands today still maintain sovereignty and are considered "domestic, dependent nations." This means that while Tribes are no longer fully independent of the

Figure 1-3. Treaty Ceded Areas



Source: Great Lakes Indian Fish and Wildlife Commission. Guide to Understanding Chippewa Treaty Rights. GLIFWC Public Information Office. 1992, p. 3.

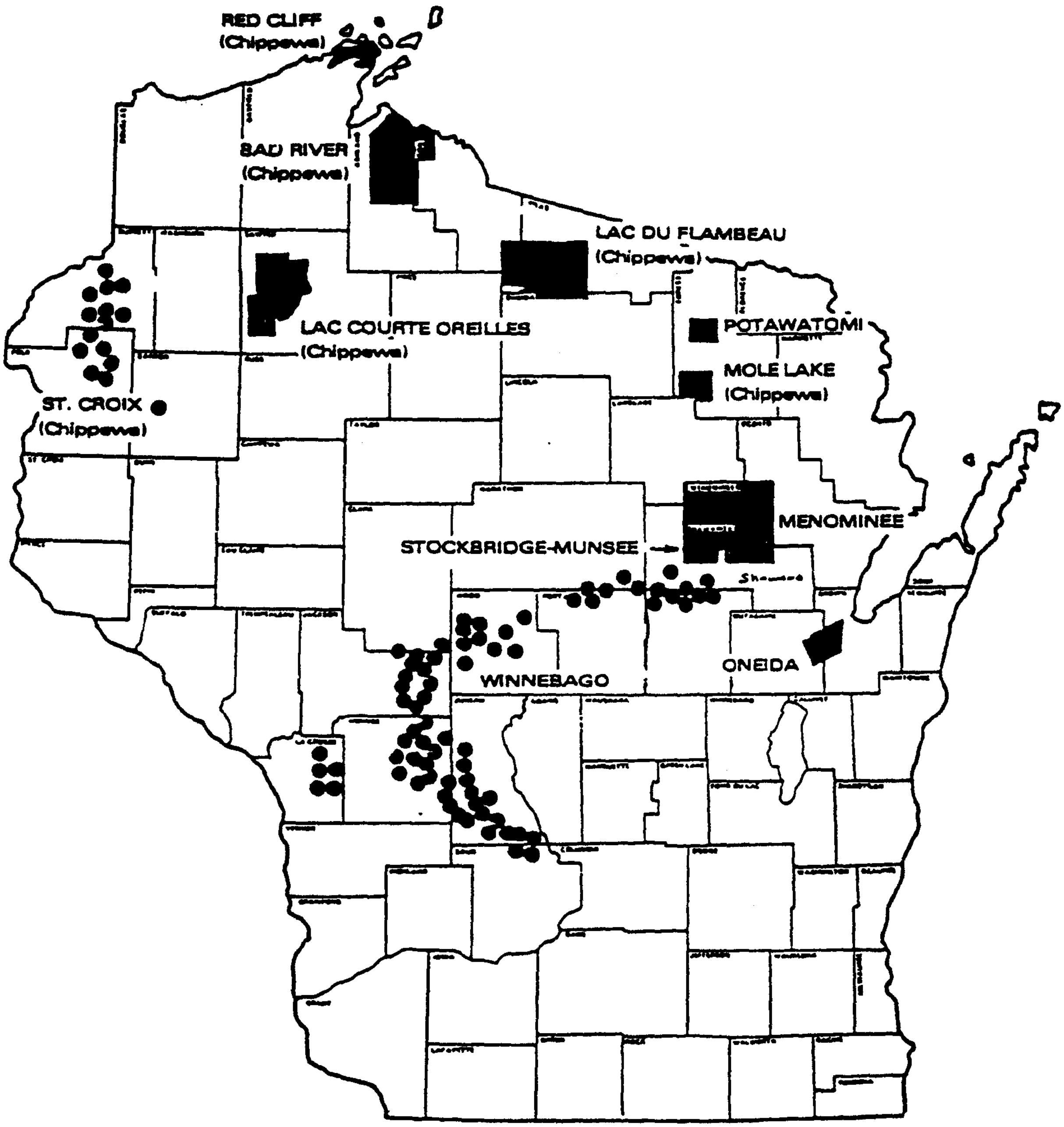
United States, they retain certain powers of sovereignty and self-determination.

The U.S. Constitution defines the powers of different governments as they exist within the United States, including Federal government, State government, and Tribal government.[75]

The treaties of 1836, 1837, 1842 and 1954 are the primary treaties in which the Ojibwa ceded land. Although the Indians sold the land, they kept the **natural** right to harvest the resources.[76] Recently, a U.S. District Court Judge re-affirmed the Federally guaranteed rights of the Fond du Lac Chippewa to exercise treaty hunting, fishing, and gathering rights under the 1837 and 1854 treaties.[77]

Most bands, through the action of their respective Tribal Councils, have been managing the natural resources on their reservation lands for years. However, the affirmation of treaty rights extended the responsibility of Tribal Councils to off-reservation lands. The Councils are entrusted with ensuring both a meaningful exercise of rights for Tribal members and a continued abundance of off-reservation resources for future generations.[78] The treaty rights of the Chippewa are not individual rights, but Tribal rights. Thus, Tribal Councils are ultimately responsible for enacting ordinances that permit or restrict the use of those rights. In Wisconsin, the off-reservation treaty rights are jointly held by the six Chippewa Bands. These bands act cooperatively to make management decisions affecting the ceded territories (Figure 1-4).

Figure 1-4. Native American Settlements in Wisconsin



Source: U.S. Environmental Protection Agency, "Tribes at Risk," EPA Region 5, 1992, p. 3.

To assist the Chippewa with this large responsibility, the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) was formed in 1983. The GLIFWC is a non-profit Tribal organization which has exercised delegated governmental authority to its member Chippewa bands in the area of treaty hunting, fishing and gathering rights since 1983.[79] It has 11 member bands: six from Wisconsin, three from Minnesota, and two from Michigan. A representative from each band comprises the Board of Commissioners, the decision-making body of the GLIFWC.[80]

Tribal regulations are adopted for each fishing season, including commercial Great Lakes fishing, inland spring spearfishing, or other harvesting. Each year, the GLIFWC and the Wisconsin Department of Natural Resources (DNR) negotiate Tribal regulations for off-reservation harvesting, making their decisions based on biological information. The agreements prescribe regulations that become binding on each band's members when its Tribal Council passes the agreement as a Tribal ordinance.[81] Once passed by the Tribal Council, the regulations are enforced as Tribal law. GLIFWC's twelve wardens enforce the off-reservation treaty regulations in cooperation with DNR wardens. Each of Wisconsin's Chippewa bands has its own Tribal court system. This is the heart of Tribal self-regulation and self-determination and reflects the sovereign legal status of Tribes.[82]

1.5.2 Culture/Tradition

Some Tribal members have argued that mercury pollution constitutes an infringement on Indian social and economic rights to open and unrestricted usage of traditional fishing grounds. The need to avoid known contaminated waters and travel to other fishing locations has also increased the cost to the Tribes in time and effort required to obtain subsistence and commercial fish harvests. An analysis of spearfishing records from GLIFWC indicates that, from 1986 to 1991, about 25 percent of the walleye that the Chippewa speared were on Wisconsin's fish consumption health advisory, based on where they were caught.[83] This amounts to at least 27,404 fish, with at least 325 of these walleye (due to size) receiving the State's strongest warning: "Do not eat any quantities of these fish." The actual numbers may be much higher, since many of the lakes in which fish are speared have never been tested for mercury contamination.[84]

Several Federal and State agencies have attempted to work with local Indian community governments to resolve current problems and promote future welfare. The Federal government has attempted to discharge its responsibilities toward Indians via the Bureau of Indian Affairs, an agency within the Department of Interior; the Public Health Service, which functions within the Department of Health and Human Services; the Office of Economic Opportunity; and the Department of Housing and Urban Development. There is often no clear practical agreement within or among these offices as to a satisfactory definition of what their responsibilities are. General directives are issued regarding various policies and programs, but their implementation is normally left to the discretion of the area or subarea offices. As one moves up or down various bureaucratic levels, delegation and scope of authority are frequently nebulous and uncertain. The net result of this situation is that officials often find it difficult to carry out their duties effectively in the best interest of Indians concerned.[85]

An additional impediment to the effective support of Indian interests by Federal, State and local governments is the assumption that the nature of Indian life is adequately understood by all those who have contact with Indians, but especially by government officials. Common, but essentially false, assumptions by non-Indians are that poor Indians closely resemble poor whites, who live for the most part in rural areas, or that all Indians are alike with respect to aspirations, aptitudes, community and personal problems.[86] This view was repeated by several Tribal members during personal conversations.

1.5.3 Spearfishing Practice

Many non-Indians do not understand the importance of treaty rights like spearfishing. This stems from a lack of education about the original civilization of this land. "It defines who we are," said Walt Bresette, a Tribal member from the Red Cliff band of Chippewa located in northern Wisconsin, along the banks of Lake Superior. "It is essential to our identity. It's like what corn is to the farmer."[87]

A controversy has arisen in recent years regarding the practice of spearfishing in inland lakes, particularly in northeastern Minnesota and northern Wisconsin. This is an efficient method of harvesting game fish. The typical spearfisher can catch a fish every five minutes, whereas an experienced angler may catch an average of one every two hours, and an inexperienced angler one every ten hours. The concern with this practice is two-fold:

1) can the fishery be sustained given the increased harvesting efficiency afforded by the practice of spearfishing? and
2) what are the risks to the heavy consumers of these prized game fish due to toxic contamination?

The first question is beyond the scope of this report. The second question is of heavy interest due to a number of factors:

1) the degree of persistence of methylmercury in walleye;
2) the high degree of bioaccumulation of mercury in top predators, such as walleye, due to their position in the food chain;
3) the currently uncontrolled pollution that impacts on the use of sovereign Indian resources by Tribal members;
4) the heavy fish consumption patterns found in some Tribes, and
5) the presence of several correlating indicators with high methylation rates in these inland lakes. These include low acid-neutralizing capacity and low pH.

1.5.4 Heavy Fish Consumption

Average fish consumption in the United States by adults has been estimated to be 6.5 grams per day (g/d) (approximately 15.5 fish meals per year) by the USEPA Exposure Assessment Group (EAG), and 15 g/d (36 fish meals per year) in the Great Lakes Region by the USEPA Great Lakes Water Quality Initiative. Fiore, et al., studying Wisconsin residents who purchased fishing licenses, found an average consumption of 42 fish meals per year in this population.[88] All are lower than the average of 1.2 fish meals per week found by Peterson et al., 1991, for usual fish consumption by Chippewa Indians, but differences in study methodologies may account for observed differences.[89] Peterson found a seasonal variation in Chippewa fish consumption, with a predominance of local walleye consumption during and following their spearfishing season. As expected, there was a high correlation between blood mercury level and reported recent walleye consumption. The observed amount of blood mercury in adults for each walleye meal consumed is consistent with that reported in studies of other populations and in a human tracer study.[90]

Males and the unemployed had the highest fish consumption rates of the participants. Mean consumption of walleye during the previous two months was almost ten-fold higher than that of three other fish (i.e., large mouth bass, small mouth bass, and northern pike) that are sometimes contaminated with methylmercury.[91] Recent walleye consumption (at least one meal in the preceding two months) was reported by 72 percent of the population, whereas no other sportfish was reported by more than 25 percent.[92]

1.5.5 Socioeconomic Factors

According to a report of the U.S. Department of Health and

Human Services, Indian Health Service, about 27 percent of the upper Midwestern Indian population was below the poverty level in 1979, versus 12.4 percent of the U.S. (all races) population. Thirty one percent of the total U.S. Indian population was below the poverty line.[93] In 1989, forty seven percent of the total U.S. Indian on-reservation population was below the poverty level.[94] At the same time, thirty five percent of the Fond du Lac Reservation (Minnesota) members and forty seven percent of the Wisconsin Chippewa Reservation members were below the poverty level.[95]

In 1980, fifty seven percent of the upper Midwestern Indian male population, age 20 to 64 was employed, versus 80 percent nationwide for males of all races.[96] In 1989, the percentages remained the same.[97]

The average household size of the upper Midwestern Indian population was 3.44 in 1989, versus 2.75 for all races.[98] The data cited show a uniform trend toward lower socioeconomic conditions among the population of concern in terms of lower income and employment, as well as larger household size. Other indicators are similarly lower than average, including median years of school completed and percent of households with a telephone.[99]

1.6 Regulation

Federal environmental statutes authorize EPA to treat Indian Tribes in the same manner as States for purposes of environmental program authorization and grant awards. These statutes require that, to be recognized for such programs or grants, a Tribe must be

Federally recognized, have a governing body carrying out substantial duties and powers, and have adequate jurisdiction and capability to carry out the proposed activities. EPA has promulgated regulations for Tribal implementation of environmental laws.[100]

The following are the applicable Federal regulations that apply to mercury emissions and control.

Air: As of November 15, 1993 and every two years thereafter, EPA, in cooperation with the Department of Commerce, is required by Section 112(m) of the Clean Air Act Amendments of 1990 to report to Congress concerning the results of the Great Lakes monitoring studies for various contaminants, including mercury. EPA is also required to describe any revisions to Federal law necessary to ensure protection of human health and the environment of the Great Lakes System.[101] In particular, Congress directed EPA to develop a research agenda and schedule that would provide information on sources, transport, and fate and effects of mercury, including risks to human health and the environment.[102] Title III (Hazardous Air Pollutants) of the Amendments modifies Section 112 of the original Act and provides a list of hazardous air pollutants, including mercury, for control from major sources (those emitting 10 tons per year of a single pollutant or 25 tons per year aggregate). Lesser quantities of emissions may be considered for control by regulators based on their persistence in an ecosystem, bioconcentration factors, and health risk implications.[103]

A special report on mercury in air is being prepared by EPA.

This information will complement efforts by the electric utility industry to characterize mercury emissions as well as the environmental fate and transport of mercury, and to perform risk analyses. It is expected that EPA will rely heavily on this and other work when it prepares the Section 112 mercury study and a more comprehensive utility Hazardous Air Pollutant Study scheduled to be delivered to Congress in November 1995.[104]

Water: Another tier of regulatory requirements is embodied in State regulations. An example is Wisconsin Admin Code, N.R. 105, which specifies that surface waters not exceed a limit of 3 mg/l Hg^{+2} for the protection of aquatic organisms from acute effects; a limit of 0.002 mg/l for consumption by wild and domestic animals; and a level of 0.079 mg/l for the protection of human health.[105] By comparison, Minnesota rules, Chapter 7050, specifies that total mercury water column concentrations not exceed 2.4 mg/l for the class of waters designated for fisheries or recreational use.[106] These limits yield different standards on water quality.

The States also are responsible for promulgating fish consumption guidelines in the form of health advisories. These are strictly voluntary, similar to warning labels on cigarettes. The advisories are provided to everyone who purchases a fishing license. This procedure, unfortunately, does not cover Tribal members, who are exempt from the licensing requirement while fishing in reservation waters.

As of April 1991, the Wisconsin Department of Natural

Resources (WDNR) had surveyed sportfish from 720 lakes, rivers, and border waters; of these, 217 sites (30 percent) were listed in the fish consumption advisory because of elevated methylmercury levels in fish.[107] Walleye from lakes not listed in the advisory have methylmercury (MeHg) levels of about 0.3 ppm, whereas MeHg levels in walleye in listed lakes range from 0.5 to 4 ppm.[108] The 0.5 ppm value was chosen by the State as being more protective of the general population than the FDA action level of 1.0 ppm. While the fish advisory program has been monitoring MeHg levels in fish since 1982, exposure to humans resulting from fish consumption in Wisconsin, had not been examined until the Centers for Disease Control (CDC) conducted a study to assess the extent of exposure to methylmercury in the Chippewa Indians of this area.According to According to the International Joint Commission, a binational (U.S./Canada) study group devised in 1909 to develop a coordinated approach to controlling pollution in the Great Lakes basin, mercury in fish is of concern at the level of 0.5 ppm, based on GLWQA standards. The GLWQA requires that the U.S. and Canada, in cooperation with the Great Lakes States and the Province of Ontario, conduct research, surveillance, and monitoring, and implement pollution control measures to reduce atmospheric deposition of toxic substances, particularly persistent ones, to the Great Lakes Basin Ecosystem.[109] The GLWQA criteria methodology has two components or tiers.

Tier I: Specifies numeric limits for the maximum concentrations of chemicals that may be present in surface waters and not present a risk to human health.

Tier II: Specifies the methodology which must be used by Great Lakes States and Indian Tribes to determine appropriate water quality based permit limits when insufficient data exist for the development of Tier I criteria.

The two-tiered approach is intended to provide a uniform method for implementing existing requirements that waters be free of toxic pollutants in toxic amounts.[110]

Current EPA regulations under the Clean Water Act require States to include antidegradation requirements in their regulations that protect water quality. In the past, how these requirements were implemented has been up to each State and, consequently, there has been a wide degree of variation between States.

Locally, municipalities monitor and regulate water quality in compliance with Federal and State statutory requirements.

All media: As an example of measures the Federal government is taking to mitigate mercury contamination, the EPA began the 33/50 Program in January 1991 to encourage companies to prevent pollution during manufacturing rather than release wastes into the environment or transfer them to waste management facilities.[111] Participation is completely voluntary. The Program's objective is to cut release and off-site transfers of seventeen high-priority toxic chemical wastes, including mercury and its compounds, by 50 percent by the end of 1995. The program is measuring progress through reports to the toxics release inventory, required under SARA 313. Data from 1988 are being used as the baseline. Analysis of 1990 TRI data indicates a 20 percent reduction of total discharges of toxics. The State of Minnesota has a similar program, called Minnesota-50.[112]

1.7 Communications

Some of the factors that differentiate the Chippewa subpopulation from the Great Lakes angler population and cause a lack of official government communications include the following:

1) Reservation inhabitants are not required to obtain fishing licenses. This does not allow distribution of the fish consumption advisories and other State-provided materials normally issued upon licensing;
2) The Tribal members frequently inhabit remote areas, far from white neighbors and State/local government influence;
3) The Tribes share an inherent distrust of white government entities due to previous exploitation and broken promises;
4) The population has suffered from historic and continuing discrimination on the basis of race, as evidenced by personal discussions by Tribal members of anecdotal instances of racial harassment, threats and name-calling.

A central issue can be stated as follows: How can effective risk communications be conducted between non-Tribal and Tribal entities? In general, risk gets communicated when the target audience understands the probability of adverse effects from certain events. The risk of concern for the Tribes is neurologic damage from ingestion of methylmercury in fish.

The components of successful risk communications are:

1) credibility - how completely does the target audience believe what scientists and regulators report;
2) understanding - how well do they understand the risks and how they can control them;
3) motivation - how successful are authorities in translating credibility and understanding into action.

Credibility can be assessed by evaluating survey responses to questions regarding degree of agreement with scientists and regulators. This area has not been addressed in health studies reviewed in this report.

Knowledge of the health effects of methylmercury and its environmental persistence is widespread throughout Tribal communities, as a result of health fairs, fish consumption surveys, and the increased funding and research into this problem in recent years.

Motivation, although difficult to measure due to the presence of confounding variables, can be determined based on the trends toward fish consumption relative to amounts, types of fish, and choices of fish-harvesting locations.

1.8 Policy

The effort to reduce persistent toxic pollutant discharges into the Great Lakes began in the late 1980's, in response to requests by the Great Lakes States Governors, senior managers of State environmental agencies charged with protecting the Great Lakes basin, and numerous environmental and public interest groups concerned with the degradation of water quality in the Great Lakes. Congress endorsed the effort and in the Great Lakes Critical Programs Act of 1990 imposed deadlines for completion of the proposed and final water quality guidance.[113]

The Great Lakes Water Quality Initiative began as a voluntary EPA-State effort that included a Public Participation Group. It was co-chaired by the National Wildlife Federation and a representative from the paper industry. All meetings were open to the public.[114] The Great Lakes Water Quality Guidance, which was developed from the Great Lakes Water Quality Initiative, proposes human health criteria for 20 pollutants, including mercury. The guidance was developed though a cooperative process between the U.S. Environmental Protection Agency (EPA) and the States, Tribes, environmental groups, industries, and municipalities in the Great Lakes Basin.

The International Joint Commission, a binational U.S./Canadian planning and steering organization, has also designated mercury as a "Critical Pollutant" with the goal of virtual elimination. With the ban on the use of PCBs in the mid-1970s, declining PCB levels that are bioavailable to the ecosystem have elevated the prominence of mercury as a primary pollutant of concern in the Great Lakes basin.

1.9 Value of the Great Lakes

The Great Lakes are a national treasure and their ecosystems requires careful attention. The Great Lakes contain about 20 percent of the world's and 95 percent of the United States' fresh surface water. More than 40 million people live in the Basin (the drainage repository for adjacent territory), and more than 23 million people depend on the Lakes for drinking water (Figure 1-5). One quarter of U.S. industry is located in the basin and the Great Lakes provide many economic and recreational opportunities, such as swimming, fishing, and boating. The Great Lakes are an important shared resource of the United States and Canada.[115] The Great Lakes Basin also contains tens of thousands of inland lakes of varying sizes and depths. These, too, are valuable resources for the people of this region in terms of fishing and other forms of recreation. Some of these lakes drain to the Great Lakes. However, most of these inland lakes are isolated. To the Indian Tribes who inhabit the territories adjacent to or surrounding many of these lakes, they are more than a source of recreation; they are a means of sustaining life.

1.10 Mercury Trends in the Study Area

1.10.1 Increasing Atmospheric Deposition

In northeastern Minnesota, mercury concentrations in precipitation have been measured to investigate trends, relationships with other major cations and anions, and possible sources. The results for 1987-1990 showed that environmentally significant amounts of mercury are present in precipitation and air and are subsequently deposited, in both wet and dry form, into remote lake watersheds.[116] Volume-weighted concentrations of total mercury in precipitation averaged about 18 nanograms per liter (ng/l) with calculated annual mercury depositions near 15 milligrams per square meter (mg/m^2).[117] Mercury concentration in precipitation are positively correlated with conductivity and pH, and are negatively correlated with precipitation volume. Estimates of scavenging ratios suggest that most mercury in precipitation in continental regions, such as the Great Lakes region, is derived from washout of particulate mercury.[118] Because mercury in precipitation is intrinsically dependent on weather that is highly variable from year to year, it is risky to characterize the phenomena based on a few years of observations. Further study of mercury in precipitation with regard to geographic patterns, precipitation rates, seasonal variations, related ions, and deposition inventory is therefore needed to assess the long-term applicability of these findings.[119]

According to some researchers, including Swain from the Minnesota Pollution Control Agency, the ongoing atmospheric deposition and sediment leaching of mercury into the rivers and lakes of the St. Louis River watershed continue to increase the mercury levels in fish by 3 to 5 percent each year.[120] Other researchers, however, maintain that this increase may be due to bioaccumulation in fish.

The characteristics and distribution of mercury contamination in the St. Louis River were examined in a study conducted by Glass et al. in 1992. Mercury concentration was measured in sediments, suspended solids, plankton, and in the water column. Some of the conclusions reached by this study are as follows:

1) historical usage of mercury by the paper industry above the community of Fond du Lac contributed to contamination of the lower St. Louis River;
2) the use of mercury for iron analysis by a steel mill may have contributed to the sediment accumulation of mercury; and
3) the highest sediment concentrations of mercury were detected near the WLSSD discharge outfall.[121]

Non-point sources contribute sediments, nutrients, and toxic substances to the study area. Sedimentation rates have been accelerating since the turn of the century, as evidenced by paleolimnological analyses of sediment cores from the St. Louis estuary.[122] Modern rates have been estimated as high as 0.37 g dry sediment weight/cm^2/year.[123] The impact of non-point source pollution from land uses such as forestry and agricultural practices is not well documented in the study area.[124]

Some researchers (e.g., Schwartzkopf, Glass et al.) believe that poor land management in riparian areas (i.e., clear-cutting) causes release of significant amounts of mercury that was bound to organic matter through runoff.

1.10.2 Presence of Environmental Correlates

According to Carl Watras, a research supervisor at the University of Wisconsin Trout Lake Research Station at Minocqua, "The more acidic the lake, the more mercury you are going to find in the fish."[125] To investigate to a more systemic level, a strongly suspected cause of the acid-mercury relationship is the presence of naturally-existing bacteria that convert mercury into methylmercury. These bacteria, known as sulfur bacteria, thrive in acidic conditions which are common in the remote inland lakes of northern Wisconsin. Other correlating indicators include color, phosphorus and amount of forest litter.[126] State authorities look to the presence of these indicators in deciding which lakes to monitor for mercury.

1.10.3 Point Sources

The major point sources for mercury in both air and water in the study area include: Municipal Waste Combustors (MWCs), such as the Western Lake Superior Sanitary District (WLSSD); utilities, especially power plants; and industrial water discharge from pulp/paper mills and others. Only recently have MWCs been regulated, and the utilities have not yet been subject to control of mercury emissions.

1.10.4 Nonpoint Sources

Long-range atmospheric deposition appears to be the most significant nonpoint source in the St. Louis River Estuary. Others include natural emissions from weathering of rocks, and terrestrial runoff from erosion of soils containing mercury that was bound in organic matrices. Legislation is pending on measures to control these diffuse sources.

1.10.5 Findings Of Related Health Studies

The following is a summary of the findings of related health studies that have been conducted in the Study Area. These studies were used to complete the analysis for this report, and utilize the same populations as this report.

Dellinger (Wisconsin College of Medicine): The Dellinger study, entitled "An Assessment of a Human Population at Risk: The Impact of Consuming Contaminated Great Lakes Fish on Native American Communities,"[127] is a three-year project funded by the Agency for Toxic Substances and Disease Registry (ATSDR), to study fish consumption habits, body burdens and neurobehavioral effects of several Ojibwa Tribal bands who reside in the Lake Superior region. Questionnaires to determine fish consumption and risk perception were administered to four different reservation populations during the summer of 1993 by Dr. Dellinger. The results will be published, following peer review, later in 1994. Although no quantitative results were available, discussion of study methodology and general risk perception conclusions were helpful in evaluating the following two studies.

Amler (ATSDR): "Health Study to Assess Methylmercury Exposure Among Members of the Fond du Lac Band of Chippewa Indians in Northern Minnesota", a cross-sectional study designed to determine the association between fish consumption and concentrations of mercury in blood among members of the Fond du Lac Band of Chippewa Indians[128] was conducted in 1991 by ATSDR in conjunction with the Indian Health Service Bemidji Service Area, Bemidji, Minnesota. The contaminated medium of concern in this study was freshwater fish caught in waters of the St. Louis River. The same fish species (walleye) taken below Scanlon (Figure 1-1) in the St. Louis Bay showed mercury levels up to 1.2 mg/g.[129] In addition to fish, various environmental media have also been evaluated for mercury content. The highest value reported in water was 266 ng/g. Levels of mercury in river water taken from St. Louis Bay and Superior Bay estuary range from 2 ng/L above the estuary to 400 ng/L in the inner harbor region of Superior Bay.[130] River sediment samples from various sections of the St. Louis River downstream from Scanlon (i.e., below the Fond du Lac Reservation) contain mercury ranging from 0.03-0.8 mg/g (dry weight).[131]

According to the Amler study, fish consumption patterns vary greatly between individuals and cultures. Preliminary results of the Peterson mercury exposure study of six bands of Chippewa Indians in Wisconsin show that 65 (20.6 percent) of 315 participants ate 3 or more meal of fish per week, while 18 (5.7 percent) did not eat any fish.[132]

In the case of the Amler study, the investigators determined that the majority of Fond du Lac members who resided in the area were listed on the roster of the Min-no-aya-Win Clinic on the reservation, and this roster served as the source for identifying the study population.[133] This clinic is funded by the IHS and provides health care and social services for members of the Fond du Lac Band, other Indians in the area, and their family members. The selection of potential participants was limited to those persons on the roster who had used clinic services within the preceding five years and whose home addresses were on-reservation or in the adjacent towns of Sawyer, Cloquet, or Brookston.[134]

During Phase 1: Fish Consumption Survey and Census, telephone and personal interviews with 454 people were conducted by ATSDR to determine the frequency with which band members ate locally caught fish during the summer months. This survey was also used to delineate the population by age and sex and to identify pregnant women who would be invited to participate in Phase 2 of the study: Interviews and Biological Sampling. During this phase, trained nurses and technicians collected blood and hair specimens from the participants.[135]

During Phase 2: The final population of the ATSDR study consisted of 108 persons reported in the first phase to have eaten fish meals once or more per week, and 145 persons reported to have eaten fish meals less often.[136] This resulted in a total study population of 253 participants in Phase 2. The participants were divided into a "high" consuming group and a "low" consuming group based on the results.

Of the eight women who were reported that they were pregnant, four participated in Phase 2.[137] During the interview in Phase 2, an additional seven women were identified as being pregnant, resulting in a total of 11 pregnant women participating in Phase 2.[138] Total mercury concentrations in the blood specimens obtained from the 11 pregnant women ranged from 0.6 to 2.4 µg/L.[139] Of the 11 women, four reported that they were aware of the fishing advisory, and three of the four reported that they had changed their fish consumption habits as a result of the fishing advisory.[140]

The value of the ATSDR study to this report was based on the analysis of results of the questionnaires, which substantiated the conclusions of this report by independent comparison with the next report discussed.

Peterson (CDC): "Fish Consumption Patterns and Blood Mercury Levels in Wisconsin Chippewa Indians", a similar study (Peterson, 1994), which focused on Chippewa Indians in Wisconsin, found lower rates of fish consumption than expected. Participants in Peterson's study reported that they consumed an average of 1.2 fish meals per week.[141] This level of fish consumption was higher than the average in the Fond du Lac study. This may be due to several factors. Perhaps most importantly, the populations studied used different methods to catch fish and the two studies (Amler and Peterson) were performed at different times of the year from each other.[142] The Wisconsin Chippewa population obtained much of its fish through spearfishing, and data were collected during May, just after the peak in spearfishing. In contrast, data were collected during August for the Fond du Lac study. This month was selected because members of the Fond du Lac Band fish throughout the summer months, and few, if any, reportedly participate in spearfishing in the Fond du Lac area. It is not surprising that fish consumption would be somewhat greater in a population which obtains much of its fish through spearfishing, given the high harvest versus other methods.[143]

The value of the CDC report to this analysis was based on utilization of the mean fish consumption rates, as well as validation of conclusions by comparison with the ATSDR study.

CHAPTER 2.0

METHODOLOGY

2.1 Introduction

This report evaluates whether the families of Native American fishers who engage in spearfishing of walleye at inland lakes in northeastern Minnesota and northern Wisconsin are at significantly higher risk of illness from mercury through fish consumption than the general public in the Great Lakes region. In order to test this hypothesis, data on mercury concentrations in walleye were compiled from several independent databases to represent both "average" and "worst case" values within the study area. The sources of these data include both State and Tribal samplings over the period 1978-1993, with most of the data collected in the later years.

This report evaluated health studies conducted by others, compiled the data from all available sources, and applied an exposure analysis to determine whether there has been excessive risk to Chippewa who consume large amounts of fish from the lakes in the study area.

The "mean" values were obtained by taking an arithmetic mean of all data for each waterbody referenced.

The "worst case" values were obtained by establishing a starting point of 1.0 ppm (based on the least restrictive regulatory action level invoked for this area) and selecting all values that exceed that threshold. These values are displayed individually to provide an indication of where some of the "hot spots" exist within the study area. These may also be used for further research, in order to evaluate the causative factors behind these high concentrations.

An ancillary and supporting objective is to determine how to conduct effective (i.e., believable, trustworthy and action-provoking) risk communications with the Tribes at greatest risk. The considerations that support these objectives include:

1) Concerns expressed by the author's mentoring organization (EPA) and also universally by the environmental community in the Great Lakes region regarding the potentially adverse health effects of persistent toxic bioaccummulative substances, such as mercury;
2) Physical evidence of increasing mercury contamination in fish;
3) Suspected heavy fish consumption by the Chippewa in this region based on custom, tradition and practices such as spearfishing; and
4) The author's Indian ancestry and desire to learn about the Tribes of the Great Lakes Basin for personal cultural growth.

Literature searches reinforced the premises behind these factors. Subsequent personal discussions with Tribal representatives regarding concerns about point sources of pollution and reports of contamination at inland lakes remote from local sources led to the framework of this investigation. Greater familiarization with the high degree of bioconcentration in certain predatory species, popularity and accessibility of selected species, and the need to narrow the scope of this investigation led to selecting the study of walleye exclusively. The magnitude of data available from State, Federal and Tribal sources produced a need for geographic definition of the study area, and the study concentrated on Tribal spearfishing for walleye in remote inland lakes of northern Wisconsin. Then, it was decided to compare the risk factors associated with this type of activity, such as heavy fish consumption, with the risk factors for the band of Fond du Lac Indians (who are subject to expose to local urban point source emitters of mercury) at the St. Louis River Estuary.

2.2 Study Methods

Data Gathering: This study initially used library research and contacts with researchers and government officials who have dealt with this topic in some form.

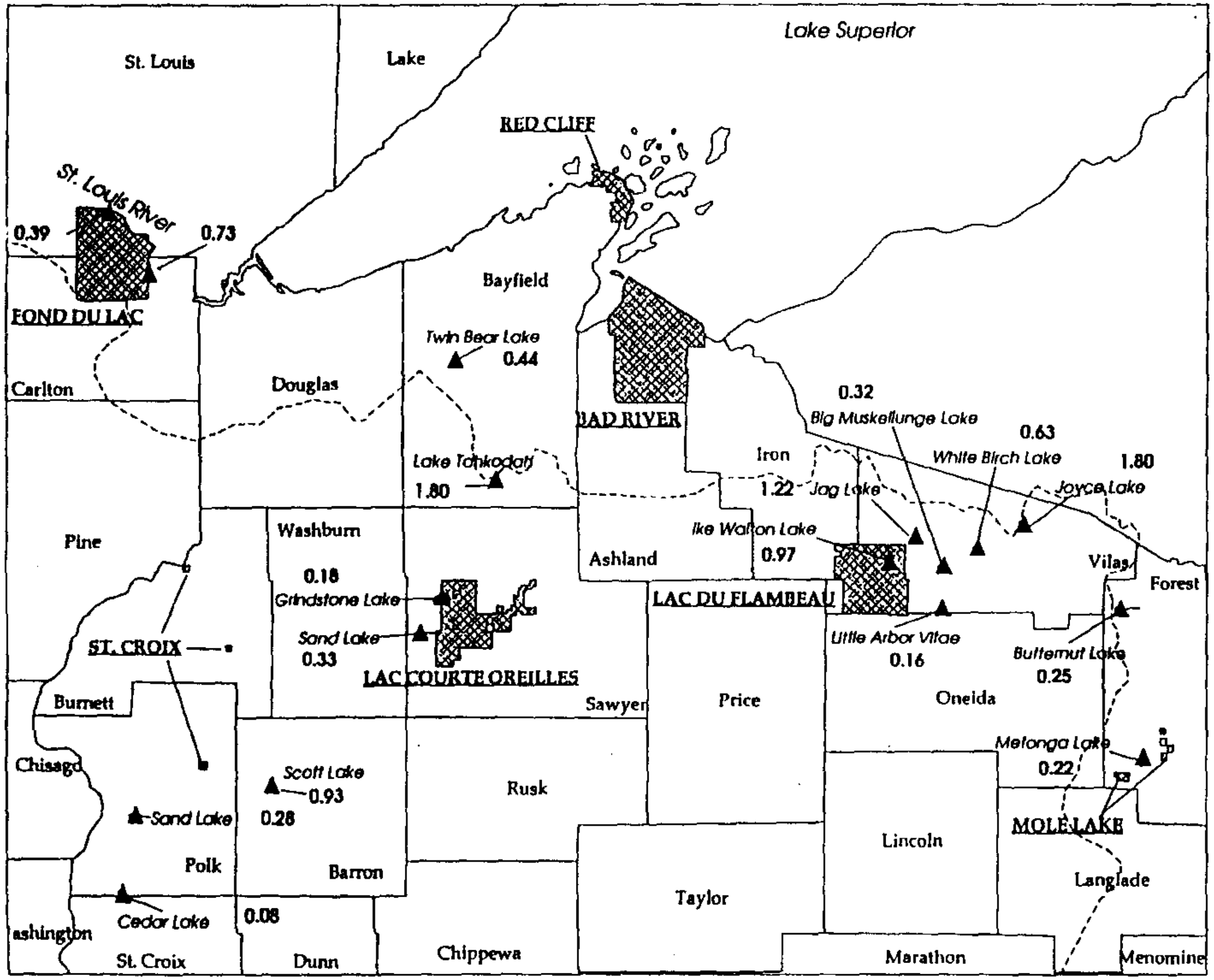
The EPA Region 5 library was utilized to review the following: targeted searches of several data services, including Dialog(R) and Crosstalk(R); inter-library searches and loans; and personal assistance by library reference personnel. Local, public and university libraries were also utilized to obtain specific periodicals and books not available at EPA.

EPA Staff Interaction: This topic was suggested by Mr. Paul Horvatin, the Chief of the Surveillance and Research (SRS) branch of EPA's Great Lakes National Program Office (GLNPO). Members of the SRS staff provided focus and technical validation to each iteration of proposals submitted. In particular, the SRS staff chemist provided contacts based on attendance at the recent Global International Conference on Mercury; the SRS staff biologists were consulted repeatedly on fish monitoring and contamination issues, the regional health scientist was consulted on health issues and provided feedback; various multi-media specialists were utilized as resources, including the Regional Mercury Contamination Workshop; and various GLNPO environmental scientists were consulted for information regarding cycling and other environmental characteristics of mercury. The Director of GLNPO contributed constructive criticism of the scope and direction of this report on a frequent basis following transition from the proposal to draft stage. These comments were discussed with the assigned academic advisor prior to disposition.

Additionally, liaison with the EPA Environmental Research Laboratory at Duluth resulted in numerous documents regarding environmental mercury research in northeastern Minnesota.

Finally, the Geographic Information System specialist in GLNPO prepared computer-generated plots of data supplied by the author. As an example, Figure 2-1 is a GIS plot of mercury concentration in walleye at lakes and rivers in the Study Area. It also includes census data to indicate the number of potential receptors within the Native study population. The mean total mercury concentrations in walleye at inland waterbodies of northern Wisconsin and

Average Mercury Concentrations in Walley at Inland Waterbodies of Northern Wiscon: and Northeastern Minnesota



Mercury concentrations in Walleye - ppm (dry weight)

Hg values are shown in bold.
- River/Lake
- Chippewa Indian Reservation
- Great Lakes Basin
- County

Scale: 1 in = 28.59 mi

1990 Census Data for Indian Women of Child Bearing Age (15-44) and Indian Children (age 0-14)

County	State	INDFEM	INDCHI	FEMCHI	TOT_INPOP
Bayfield	Wisconsin	299	419	718	919
Douglas	Wisconsin	122	183	305	545
Forest	Wisconsin	87	142	229	394
Sawyer	Wisconsin	336	509	845	1385
Vilas	Wisconsin	287	459	746	1200
Carlton	Minnesota	235	304	539	725
Itasca	Minnesota	323	401	724	907
St. Louis	Minnesota	928	1009	1937	2075
Duluth-Superior SMSA	MN/WI	881	1133	2014	3355

Source: *Map Product Generated using MapInfo 2.1.1 March 30, 1994*

northeastern Minnesota, within the study area, in proximity to seven Chippewa reservations were plotted via a Geographic Information System, as shown in Figure 2-1. The plot was developed by inputting worst case mercury concentrations in walleye, and using the geographic database to correlate these values with the locations of the associated waterbodies. The plot may be used as an educational or research aid in identifying the spatial or geographic extent of mercury contamination in walleye, coupled with the illustration of the locations of potentially at-risk populations of Chippewa Indians.

Discussion with Tribal Agencies: The EPA Regional Indian work group facilitated early contacts with the Tribal agencies. The Water Division Coordinator provided opportunities for direct contact with Tribal leaders and members, including face-to-face interviews at the Native American Fish and Wildlife Society Conference held in Green Bay, Wisconsin. The Great Lakes Indian Fish and Wildlife Commission provided coordination and documentation regarding walleye spearfishing. The Fond du Lac Band Natural Resource Manager also provided data used for the study.

Use of Information from Other Agencies and Organizations: The groups identified in Table 2-1 were consulted, and provided information on the topics identified in the table.

Table 2-1. Summary of Interaction with Other Agencies

Agency Contacted	**Information Obtained**	**Purpose/Usage**
Lake Superior Research Institute	St. Louis River Remedial Action Plan	Illustrate extent of mercury contamination and effort to remediate.
Wisconsin Dept of Natural Resources	Environmental Correlates, Fish Advisory Info	Indicate key variables correlated with high fish concentrations.
Minnesota Pollution Control Agency	Fish Contaminant Data, Trends	Provide location of high concentrations and trend information.
Cornell University	Risk Communications Survey Data	Determine key factors with respect to risk communications.
University of Michigan	Environmental Equity Issues	Gain familiarization with equity issues of minority anglers.
U.S. Fish & Wildlife Service	Fish Monitoring Data	Determine the extent of fish monitoring in the study area.
U.S. Geologic Survey	Water Quality Data	Ascertain mercury concentrations in water within the study area.
Wisconsin College of Medicine	Red Cliff Band Health Study	Review study dealing with mercury risks to an indigenous Tribe in the Lake Superior basin.
U.S. Agency for Toxic Substances and Disease Control	Fond du Lac Health Study and Related Correspondence	Examine methodology and conclusions of health study for incorporation into report.
U. S. Centers for Disease Control	Northern Wisconsin Chippewa Health Study Discussion	Examine methodology and conclusions of health study for incorporation into report.

Sources: Personal Telephone Conversations with the following people between August 1993 and April 1995: Professor J. A. Dellinger, Lake Superior Research Institute; Mr. J. Amrhein, Wisconsin Department of Natural Resources; Mr. Mark Briggs, Minnesota Pollution Control Agency; Professor B. Knuth, Cornell University; Professor P. West, University of Michigan; Mr. J. Wiener, U.S. Fish and Wildlife Service; Professor G. Glass, University of Minnesota - Duluth (for U. S. Geologic Survey); Dr. J. A. Dellinger, Wisconsin College of Medicine; Dr. R. Amler, Agency for Toxic Substances and Disease Registry; and Dr. D. Peterson, Centers for Disease Control.

CHAPTER 3.0

RESULTS

3.1 Minnesota

Table 3-1 displays the mean mercury concentrations in walleye from various studies conducted from 1980 through 1992.

Table 3-2 displays the "worst case" mercury concentrations in walleye from these same studies. Worst case is defined as greater than 1.0 ppm.

The mean mercury concentration in walleye for the Minnesota sampling, as calculated from data shown in Table 3-1, is 0.623 ppm, with a standard deviation of 0.248. The mean value was obtained by summing the concentrations for all tested fish caught in Minnesota waters from all databases referenced, and then dividing by the total number of samples (note that those concentrations less than the detection limit of 0.020 ppm were considered to be 0.010 ppm in one database,[144] but otherwise included all actual values with no instances of non-detects indicated). The mean value is based on a population of 427 fish, at least 90 percent of which were collected since 1987. The worst case found for Minnesota, as noted in Table 3-2, was 1.32 ppm in 24 walleye caught between 1987 and 1992 in Northeastern Minnesota. This is lower than many of the values found in Wisconsin waters (mean of 0.75 ppm with a standard deviation of 0.298, and individual s values of each database ranging from 0.174 to 0.298).

The Amler[145] survey of fish consumption patterns for the Fond

Table 3-1. Fish (Walleye) Mercury Concentrations (Mean)

Study	When Taken	Location	Preparation	No. Fish in Sample	Avg Wt (lb)	Avg Length (in)	Avg Hg Conc (µg/g)
Amler[146]	1987	St. Louis River near Brookston, MN	whole	5	1.2	14.2	0.39
Schwartzkopf[147]	1991-1992	Fond du Lac Res., MN	fillet (skin-on)	4	unk	15.4	0.73
Minn. Fish Contam Monitoring Prog.[148]	1987-1992	Minn. Region 2 (north of Fond du Lac Res.)	fillet (skin-on)	318	unk	19.5	0.74
Minn. Fish Contam Monitoring Prog.[149]	1987-1992	Minn. Region 3 (Fond du Lac Res. and south)	fillet (skin-on)	58	unk	19.5	0.36
Glass, EST Vol. 24[150]	1980-1987	NE Minn (Region 2)	fillet (skin-on)	42	0.27	15.35	0.39
						MEAN	0.53
Lac du Flambeau Tribal Natural Resource Program[151]	1991-1992	Lac du Flambeau Res.: Ike Walton Lake, WI	fillet (skin-on)	21	1.2	15.8	0.97
Wisc. DNR[152]	1985	St. Louis R. near Superior	fillet (skin-on)	9	1.4	25.6	0.97
Gerstenberger[153]	1990-1991	No. Wisc. (near Chippewa Indian Res.)	fillet (skin-off)	55	unk	18.11	0.50
WDNR Tech. Bull. #163[154]	1985-1986	No. Wisc. (near Chippewa Indian Res.)	fillet (skin-on)	68	0.46	18.24	0.56
						MEAN	0.75
						OVERALL MEAN	0.62

Table 3-2. Fish (Walleye) Mercury Concentrations (Worst Case)[1]

Study	When Sample Taken	Location	Preparation	No. Fish in Sample	Wt (lb)	Length (in)	Hg Conc (µg/g)
Minn. D.H. 1987 in ATSDR Memo Aug 89 to EPA (reported in Amler)[155]	1987	St. Louis Bay near Scanlon MN	whole	1	unk	unk	1.2
Minnesota Fish Contaminant Monitoring Prog. 1993 Data Doc. (Rough Draft)[156]	1987-1992	Minn. Region 2 (north of Fond du Lac Res.)	fillet (skin-on)	24	unk	26.6	1.32
G. Glass et al., EST Vol. 24, No. 11, 1990, p. 1069[157]	1980-1987	Crane Lake, NE Minn (Region 2)	fillet (skin-on)	1	unk	15.35	1.06
						MEAN	1.19
Wisc. DNR Report S539MERC rcvd informally 3 Feb 94 from J. Amrhein[158] [2]	1985	St. Louis R. near Superior	fillet (skin-on)	1	3.63	27.0	1.4
Wisc. DNR Report S539MERC rcvd informally 3 Feb 94 from J. Amrhein[159]	1985	St. Louis R. near Superior	fillet (skin-on)	1	4.31	27.2	1.2
Wisc. DNR Report S539MERC rcvd informally 3 Feb 94 from J. Amrhein[160]	1987	Island Lake (in L. Superior basin)	fillet (skin-on)	1	0.91	18.7	1.3
Wisc. DNR Report S539MERC rcvd informally 3 Feb 94 from J. Amrhein[161]	1987	Island Lake (in L. Superior basin)	fillet (skin-on)	1	1.12	21.0	1.3
Wisc. DNR Report S539MERC rcvd informally 3 Feb 94 from J. Amrhein[162]	1987	Island Lake (in L. Superior basin)	fillet (skin-on)	1	1.12	21.0	1.3
Wisc. DNR Report S539MERC rcvd informally 3 Feb 94 from J. Amrhein[163]	1984	Superior Harbor	fillet (skin-on)	1	1.20	20.5	1.2
Wisc. DNR Report S539MERC rcvd informally 3 Feb 94 from J. Amrhein[164]	1984	Superior Harbor	fillet (skin-on)	1	1.70	22.0	1.1

[1] "Worst Case" is defined as Hg Conc > 1.0 ppm.

[2] Total of 17 samples with conc. > 1.0 ppm out of total of 298 samples taken between 1979 and 1992 (about 5.7%).

Study	When Sample Taken	Location	Preparation	No. Fish in Sample	Wt (lb)	Length (in)	Hg Conc (µg/g)
Wisc. DNR Report S539MERC rcvd informally 3 Feb 94 from J. Amrhein[165]	1985	Lyman Lake (in L. Superior basin)	fillet (skin-on)	1	2.25	24.2	1.7
Wisc. DNR Report S539MERC rcvd informally 3 Feb 94 from J. Amrhein[166]	1986	Lyman Lake (in L. Superior basin)	fillet (skin-on)	1	2.90	25.4	2.1
Wisc. DNR Report S539MERC rcvd informally 3 Feb 94 from J. Amrhein[167]	1986	Lyman Lake (in L. Superior basin)	fillet (skin-on)	1	9	20.9	1.2
Wisc. DNR Report S539MERC rcvd informally 3 Feb 94 from J. Amrhein[168]	1986	Lyman Lake (in L. Superior basin)	fillet (skin-on)	1	1.48	20.8	1.1
Wisc. DNR Report S539MERC rcvd informally 3 Feb 94 from J. Amrhein[169]	1986	Minnesuing Lake (in L. Superior basin)	fillet (skin-on)	1	0.78	17.6	1.1
Wisc. DNR Report S539MERC rcvd informally 3 Feb 94 from J. Amrhein[170]	1983	Siskiwit Lake (in L. Superior basin)	fillet (skin-on)	1	2.90	25.5	1.4
Wisc. DNR Report S539MERC rcvd informally 3 Feb 94 from J. Amrhein[171]	1986	St. Louis R. 22 mi. above Fond du Lac Res.	fillet (skin-on)	1	8	21.6	1.1
Wisc. DNR Report S539MERC rcvd informally 3 Feb 94 from J. Amrhein[172]	1986	Tahkodah Lake (in L. Sup. basin)	fillet (skin-on)	1	1.28	21.2	1.9
Wisc. DNR Report S539MERC rcvd informally 3 Feb 94 from J. Amrhein[173]	1986	Tahkodah Lake (in L. Sup. basin)	fillet (skin-on)	1	0.65	17.9	1.8
Wisc. DNR Report S539MERC rcvd informally 3 Feb 94 from J. Amrhein[174]	1986	Tahkodah Lake (in L. Sup. basin)	fillet (skin-on)	1	1.36	21.9	1.7
Wisc. DNR Report S539MERC rcvd informally 3 Feb 94 from J. Amrhein[175]	1992	Black River	fillet (skin-on)	1	0.22	15.0	1.3

Table 3-2. (Continued)

Study	When Sample Taken	Location	Preparation	No. Fish in Sample	Wt (lb)	Length (in)	Hg Conc (µg/g)
WDNR Tech. Bull. #163: Mercury Levels in Walleyes from Wisc. Lakes[176] [3]	1985-1986	Joyce Lake	fillet (skin-on)	1	1.45	20.9	1.80
WDNR Tech. Bull. #163: Mercury Levels in Walleyes from Wisc. Lakes[177]	1985-1986	Jag Lake	fillet (skin-on)	1	2.05	25.1	2.20
WDNR Tech. Bull. #163: Mercury Levels in Walleyes from Wisc. Lakes[178]	1985-1986	Jag Lake	fillet (skin-on)	1	2.05	2	1.7
WDNR Tech. Bull. #163: Mercury Levels in Walleyes from Wisc. Lakes[179]	1985-1986	Jag Lake	fillet (skin-on)	1	1.90	23.0	ND
WDNR Tech. Bull. #163: Mercury Levels in Walleyes from Wisc. Lakes[180]	1985-1986	Jag Lake	fillet (skin-on)	1	1.90	23.0	ND
WDNR Tech. Bull. #163: Mercury Levels in Walleyes from Wisc. Lakes[181]	1985-1986	Jag Lake	fillet (skin-on)	1	1.30	20.7	1.20
WDNR Tech. Bull. #163: Mercury Levels in Walleyes from Wisc. Lakes[182]	1985-1986	Scott Lake	fillet (skin-on)	1	1.14	19.0	1.10
WDNR Tech. Bull. #163: Mercury Levels in Walleyes from Wisc. Lakes[183]	1985-1986	Tahkodah Lake	fillet (skin-on)	1	1.28	21.2	1.90
WDNR Tech. Bull. #163: Mercury Levels in Walleyes from Wisc. Lakes[184]	1985-1986	Tahkodah Lake	fillet (skin-on)	1	0.65	17.9	1.80

[3]Total of 11 out of 68 samples.

Table 3-2. (Continued)

Study	When Sample Taken	Location	Preparation	No. Fish in Sample	Wt (lb)	Length (in)	Hg Conc (ug/g)
WDNR Tech. Bull. #163: Mercury Levels in Walleyes from Wisc. Lakes[185]	1985-1986	Tahkodah Lake	fillet (skin-on)	1	1.36	21.9	1.70
WDNR Tech. Bull. #163: Mercury Levels in Walleyes from Wisc. Lakes[186]	1985-1986	Tahkodah Lake	fillet (skin-on)	1	3	21.2	1.30
						MEAN	1.48
						OVERALL MEAN	1.33

Table 3-1 displays the mean fish mercury concentrations from several data sources within the study area, as referenced. Table 3-2 displays the data compiled from the various sources listed and was utilized to develop "worst case" total mercury concentrations in walleye. "Worst case" is defined as total mercury concentrations of greater than 1.0 ppm. These data represent almost six percent of the total samples, and are mainly found in Wisconsin.

du Lac Band of Chippewa Indians within this study area indicates that about ten percent of the respondents consume one or more fish meals per week on average. The worst case (fishermen only) showed about 18 percent in the same category. As serving size data were not provided, another study of Chippewa diet was utilized, showing that the average daily intake for Wisconsin Indians, which is probably similar to the Fond du Lac Band by proximity and tradition) was 39 g/d.[197] This level is about five times greater than the current EPA average for the total U.S. population.

3.2 Wisconsin

The mean mercury concentration in walleye for the Wisconsin sampling, as calculated from data in Table 3-1, is 0.75 ppm. This is based on a population of 143 fish, collected between 1985 and 1992, with a standard deviation of 0.298. The worst case found was 2.2 ppm found a walleye from Jag Lake in northcentral Wisconsin, followed closely by fish from Lyman Lake in Douglas County in northwestern Wisconsin, with 2.1 ppm, and nearby Tahkodah Lake, in adjacent Bayfield County, with 1.7 - 1.9 ppm. All three of these lakes are within the Lake Superior basin, and each are in close proximity to one of the Chippewa Tribes.

The Peterson survey of fish consumption related fish meals to serving size on the basis of 15 g/day being equivalent to about 36 fish meals a year. This is about two and one-quarter times the value of 6.5 g/day currently used by EPA as an average for the American public in their Exposure Assessment Handbook.[198]

Peterson's estimate of 1.2 fish meals per week of usual fish consumption by the Chippewa translates to 26 g/day, which is four times the EPA default value. The worst case discovered by Peterson was during April and May, which correlates directly with the spearfishing season.

Peterson also drew blood from anglers who completed consumption questionnaires and discovered the following: 64 persons (20 percent) had blood mercury levels in excess of 5 mg/L (the upper limit of normal in non-exposed populations according to the Centers for Disease Control), and the highest value was 33 mg/L. Fish consumption was higher in males and the unemployed. Blood mercury levels were highly associated with recent walleye consumption ($p=0.001$).[189]

3.3 Exposure Assessment Background

A Screening Value (SV) is an EPA developed Exposure model used by States to develop Fish Advisories. Screening values are defined as concentrations of target analytes in fish tissue that are of public health concern. They are used as standards against which levels of contamination in similar tissue collected from fish in the ambient environment can be compared.[190] Exceedance of these SVs should be taken as an indication that more intensive site-specific monitoring and/or evaluation of human health risk should be conducted. Risk-based screening values (SVs) are derived from the EPA general model for calculating the effective ingested dose of a chemical m (Em)[191]:

$E_m = (C_m \times CR \times X_m)/BW$ (3-1)

where

E_m= Effective ingested dose of chemical m in the population of concern averaged over a 70-yr lifetime (mg/kg/d)

C_m= Concentration of chemical in the edible portion of the species of interest (mg/kg;ppm)

CR= Average daily consumption rate of the species of interest by the general population or subpopulation of concern averaged over a 70-yr lifetime (kg/d) (note that this term includes both frequency and duration)

X_m= Relative absorption coefficient, or the ratio of human absorption efficiency to test animal absorption efficiency for chemical m (dimensionless)

BW= Average body weight of the general population or subpopulation of concern (kg).

The following equation is used to calculate the SV for noncarcinogens[192]:

$SVn = (RfD \times BW)/CR$ (3-2)

where

SVn= Screening value for a noncarcinogen (mg/kg; ppm)

RfD= Oral reference dose (mg/kg/d)

Default Values:

BW= 70 kg, average adult body weight

CR= 6.5 g/d (0.0065 kg/d), EPA estimate of average consumption of fish and shellfish from estuarine and fresh waters by the general adult population[193] (note that this value is approximately four times smaller than the CR calculated [Appendix 1] for the subpopulation of interest, the Chippewa, but was selected to provide an indication of the difference between the exposure levels of the two populations)

For methylmercury:

RfD = 3×10^{-4} mg/kg/d (per EPA Integrated Risk Information System database)[194]

SV (as calculated per Eq. 4-2) = ($3x10^{-4}$ mg/kg/d x 70 kg)/.0065 kg/d = 3.23 mg/kg = 3.23 ppm

The 6.5-g/d CR value that is used by EPA to establish water quality criteria is currently under review by the EPA office of Water.[195] This CR, which represents a consumption rate for the average fish consumer in the general adult population (45 FR231, Part I), may not be appropriate for sport and subsistence fishermen who generally consume larger quantities of fish.[196]

The first effects in people associated with long-term daily ingestion of MeHg are estimated to occur in the most sensitive adults at a dose of about 3 to 7 mg/kg/day[197].

The EPA's reference dose of 0.3 mg/kg/day (IRIS, February, 1994) is based on the appearance of paresthesia, but includes an uncertainty factor of 10. Thus, an intake of 0.3 mg/kg/day would prevent blood mercury concentration from reaching a level associated with paresthesia.[198] To reach an intake of 0.3 mg/kg/day, fish fillets containing 0.3 mg/g mercury would have to be consumed at a rate of 1 g/kg/day. For a 70 kg individual, this is a consumption rate of 70 g/kg/day.[199]

Based on a similar approach, provisional tolerable weekly intake of 0.3 mg total mercury per person, of which no more than 0.2 mg should be MeHg, was established by a joint Food and Agricultural Organization/World Health Organization Expert Committee on Food Additives.[200] These guidelines provide a margin of safety to prevent exposure at levels that may result in adverse health effects.

It is necessary to describe the consumption rate of the subpopulation accurately in order to set protective SVs. For example, the fish consumption rate of 140 g/d, based on an EPA estimate of the average consumption of fish and shellfish from marine, estuarine, and fresh waters by the **90th percentile of recreational fishermen** (i.e., subsistence fishermen)[201], may underestimate the consumption rate for some subsistence populations, including Native Americans. To illustrate this, the following is a recalculation of the SV using the CR derived from survey data contained in this report for the Chippewa within the study area:[202,203]

$$SV_c = (3 \times 10^{-4} \text{ mg/kg/d} \times 70 \text{ kg})/0.003888 \text{ kg/d} = 5.4 \text{ ppm} \qquad (3-3)$$

The concentration of mercury in individual fish, even for humans consuming only small amounts (10 to 20 g of fish per day), can markedly affect the intake of methylmercury.[204] The consumption of 200 g of fish containing 500 mg mercury/kg will result in the intake of 100 mg mercury (predominately methylmercury). The RfD for MeHg currently available in the EPA Integrated Risk Information System (IRIS) database[205], 3×10^{-4} mg/kg/d, has been recently lowered by EPA, in accordance with the current EPA approved risk assessment findings, by a factor of 5 to a value of 6×10^{-5} mg/kg/d.[206] The EPA is reevaluating the RfD for MeHg and is especially concerned about evidence that the fetus is at increased risk of adverse neurological effects from exposure to MeHg, and that pregnant women may also be at increased risk of these and other defects.[207] In the general adult population, blood MeHg concentrations of 200 mg/l, corresponding to approximately 50 mg/g in hair, have been associated with a five percent risk of parasthesia; whereas for the fetus, a five percent risk of neurological and developmental abnormalities is associated with peak Hg concentrations of 10 to 20 mg/g in the maternal hair.[208] These findings suggest a possible fivefold increase in fetal sensitivity to MeHg exposure. Consequently, the EPA chose to apply an uncertainty factor of 5 to the 1993 IRIS RfD for MeHg.[209]

3.4 Exposure Assessment Calculations

In the Exposure Assessment, potential receptors, exposure routes, and exposure point concentrations of total mercury are identified. Ninety percent of the mercury ingested will be assumed to be in the form of methylmercury[210]. For this Risk Assessment, the exposure analysis is conducted using the standard USEPA Risk Assessment Method.[211] For purposes of this analysis, the EPA Method is simplified by considering only one pathway of concern, ingestion through fish consumption, and only one chemical of concern, methylmercury. The difference between this calculation and the SV calculation is that the Risk Assessment Method uses averaging time and duration to determine an index of the degree of health risk from chronic and acute exposure to the chemical of concern.

Following this Method, weighting factors are determined by estimating three variables:

1) the chemical concentration at the point of exposure;
2) the characteristics of the exposed population (e.g., frequency of exposure, duration, age, and body weight of exposed individuals); and
3) the time period over which the exposure is averaged.

The general form of the equation used to determine exposure is:

$$\text{Intake} = (C \times CR \times AF \times EFD)/(BW \times AT) \qquad (3\text{-}4)$$

where

Intake - dose of chemical ingested or absorbed at the point of exposure, in mg/kg/day;

C - chemical concentration in fish (average) contacted over the exposure period, in mg/kg;

CR - contact rate, the amount of contaminated medium contacted per unit time or event, in kg fish/week (or day);

AF - availability factor, a value derived from experimental data that estimates the amount of methylmercury absorbed by the receptor after exposure (unitless);

EFD - exposure frequency and duration, how long and how often exposure occurs, in days;

BW - body weight, the average body weight of exposed individuals (for adult males, 70 kg is used; for adult females, 50 kg; for children, 20 kg; and for the fetus, 2 kg is used for this exposure); and

AT - averaging time, period over which exposure is averaged, in days.[212]

The numerical values for these variables are presented in Appendix A, Part IV.

3.5 Risk Characterization Results

The risk characterization step of Risk Assessment involves comparing the intake of chemicals calculated under the exposure scenarios to the Reference Dose. See Appendix 1 for supporting calculations.

To determine the mean intake of total mercury for an adult male in the study area within Minnesota, the mean values derived for each variable can be substituted for the following assumptions:

1) the population chooses to fish in waterbodies where "mean" concentrations of total mercury of 0.623 µg/g in walleye are found in this Study Area;
2) the consumption rate of 38.33 g/d is the average, based on deriving the mean of survey data from separate health surveys of Fond du Lac and northern Wisconsin Chippewa;
3) the availability factor is 0.9, based on discussion with a EPA Region 5 risk assessment specialist[213];
4) the frequency is based on chronic daily lifetime exposure (70 years), considering much of the fish caught in season is eaten daily or frozen, when too much is caught to consume at once;
5) the duration of the exposure is considered to be lifetime (70 years);
6) the body weight is 70 kg, based on EPA guidance;
7) the averaging time is a lifetime (70 years).

For "worst case" concentrations, the resultant $Intake_{MA}$ (Male Adult) is 0.726 mg/kg/day.

The risk characterization is calculated by dividing the Intake by the Reference Dose, which yields a Hazard Quotient as follows:

$$HQ = \quad Intake/D_{ref} \tag{3-5}$$

As shown in Appendix A, Part V, the resultant calculation based on mean concentrations for the fetus yields: HQ_{fetus} = 36.33. For "worst case" concentrations, the result is: HQ_{fetus} = 84.71.

The values for the adult male and adult female are also calculated. For a 50 kg woman or adolescent with the same intake, the Intake would be 1.4 times (70/50) higher than an adult male's, or approximately 1.016 mg/kg/day. Application of Equation 3-4 results in a Hazard Quotient for a Female Adult of HQ_{FA} = 3.4.

For fetal exposure, it is assumed, based on discussion with the office of an EPA Region 5 risk assessment specialist[214], that 100 percent of the intake is passed through the placenta to the 2 kg fetus, resulting in an Intake 25 times higher than the woman's (50/2), or 25.4 mg/kg/day. This results in a HQ = 84.7.

Since a HQ greater than one indicates some risk of adverse health effects, these results can be characterized as moderately risky for adults and severely risky for fetuses. As with the Screening Value (SV), the HQ is directly proportional to body weight. Children (assumed around 20 kg) are at 2.5 times the risk calculated for women/adolescents and 3.5 times the risk for men, assuming equally high consumption rates of mercury-contaminated fish.

These HQ calculations are based on exposure to mean concentrations of total mercury in walleye in the Study Area. If the maximum (worst case) concentrations are used, the exposure would be higher.

3.6 Geographic Information System Plot

A GIS plot was developed by U.S.EPA Great Lakes National Program Office to provide the Tribes and government agencies with an indication of where higher walleye mercury concentrations have been detected. They can then examine the priorities assigned to these waterbodies in order to evaluate potential risks associated with consuming fish.

The data indicate that the Fond du Lac band is exposed to lower mercury concentrations than several of the Wisconsin bands. In contrast, Lake Tahkodah, near Bad River reservation, and Joyce Lake, near Lac du Flambeau reservation, have walleye with "worst case" mercury concentrations of 1.8 ppm (based on three samples), which is almost four times the level triggering State fish consumption advisories.

The table included with Figure 2-1 shows the numbers of sensitive receptors in each County, based on 1990 census data. The columns are defined as follows: INDFEM = Indian Females of childbearing age (15 to 44); INDCHI = Indian Children (0 to 14); FEMCHI = Total of INDFEM + INDCHI (number of sensitive receptors); TOT_INPOP = Total Indian Population.

The Indian population totals for Minnesota and Wisconsin are nearly equal, with the Duluth-Superior SMSA having a large proportion of the total Indian population within the study area.

3.7 Reference Values

Table 3-3 contains advised mercury reference values and illustrates protection levels employed by various jurisdictions. This table displays the reference values utilized by the agencies listed for the protection of human health, as stratified for adults and sensitive receptors. As calculated in the Exposure Assessment portion of this study, the use of the Wisconsin Adult Protection Reference Values result in the Hazard Quotients shown in Table 3-4. Therefore, the lower rates listed in Table 3-3 for Fetus/Mother/Child Protection by the States should be adopted by the Federal government as well.

Table 3-3. Summary of Advised Mercury Reference Values for Humans Related to Fish Consumption and Derived From Various Advisories[1]

Group	**Adult Protection Reference Values (µg Hg/kg/day)**	**Fetus/Mother/Child Protection Reference Values (µg Hg/kg/day)**
World Health Organization	0.43	-
U.S Environmental Protection Agency	0.3	0.3
Wisconsin Division of Health	0.5	0.125
Minnesota Department of Health	1.0	0.2
Michigan Department of Health	0.22-0.69	0.061-0.18
U.S. Food and Drug Administration	1.0	1.0

1 Partially derived from: U.S. Environmental Protection Agency, "Mercury in the Great Lakes: Management and Strategy," Environmental Research Laboratory/Duluth, 1992, p. 9.

Table 3-4. Hazard Quotients Calculated for Humans Related to Fish Consumption in the Wisconsin[4] and Minnesota[5] Study Areas

Group	Wisconsin Hazard Quotient	Minnesota Hazard Quotient
Adult Males	0.83	2.4
Adult Females	1.17	3.4
Fetuses	96.83	84.71

[4] These HQs are derived from the "worst case" concentrations from Wisconsin waters only.

[5] These HQs are derived from the "worst case" concentrations from Minnesota waters only.

CHAPTER 4.0

DISCUSSION

4.1 Health Risk Measures/Indicators

Measurements of methylmercury (MeHg) in edible tissues of fish, along with dietary information on fish intake, allow estimates of both the mean and, more importantly, the range of human intake of methylmercury. Pharmacokinetic models are used to estimate the predicted levels in indicator media, such as blood, for any given daily intake of MeHg. Thus, a range of daily intakes may be converted to a range of levels in blood or other indicator media.[215]

Dose-response relationships that compare levels in indicator media to frequency of observed toxic effects in humans are used to estimate the risk to a population having a specified range of daily intakes. If the fraction of the population at risk is deemed too high, the regulatory agency will reduce the allowable levels in fish to a value giving an acceptable risk to the population.[216]

The dose-response estimate for noncarcinogens is the reference dose (RfD). The RfD is an estimate of a daily exposure to the human population (including sensitive subpopulations) that is likely to be without appreciable risk of deleterious effects during a lifetime.[217] The RfD is derived by applying uncertainty or modifying factors to a subthreshold dose (i.e., no observed adverse effect level [NOAEL] or lowest observed adverse effect level [LOAEL] if the NOAEL is not determined) observed in chronic animal bioassay. These uncertainty or modifying factors range from 1 to 10,000 and are used to account for uncertainties in sensitivity differences among human subpopulations; interspecies extrapolation; short-term to lifetime exposure extrapolation; incomplete or inadequate toxicity or pharmacokinetics databases; and, where applicable, the use of a LOAEL instead of a NOAEL.[218]

The SV[219] is an exposure model used by EPA to develop fish advisories, while the HQ is a measure of the degree of risk of adverse health effects to an exposed population. For a person who ingests fish at the Fish Advisory level of 0.5 ppm, the Intake, based on Equation 3-4, is 0.25 µg/kg/day. This is about 80 percent of the Intake derived using the actual mean concentration of mercury in Study Area walleye, indicating that the study population is ingesting mercury at a higher level than the Fish Advisory recommends.

As shown in Table 3-4, the HQ for adult males derived from the Fish Advisory Intake level calculated above is 0.83, indicating that the Fish Advisory level is sufficiently protective of human health, at least in the case of adult males. For adult females, the Intake is 1.4 times higher, resulting in a value of 0.35 µg/kg/day. The resulting HQ_{FA} is 1.17, which places the receptor at moderate risk. The HQ for the fetus exposed under the same conditions is 96.83, which indicates significant risk. Therefore, the Fish Advisory levels should be lowered for pregnant women and children. The EPA should also consider revising their general population fish consumption rates upward to protect the most sensitive members of the population.

As indicated in Section 3.3, a comparison of blood MeHg concentrations in hair associated with a five percent risk for adults of parasthesia versus a five percent risk of neurological and developmental abnormalities for fetuses suggests a possible fivefold increase in fetal sensitivity to MeHg exposure. Consequently, the EPA chose to apply an uncertainty factor of 5 to the 1993 IRIS RfD for MeHg.[220] This suggests that the IRIS RfD for MeHg is not appropriate for use in determining the degree of health risk to the fetus, and is too high to be sufficiently conservative.

The first effects associated with long term daily ingestion of methylmercury are estimated to occur in the most sensitive adults at about 3 to 7 mg/kg/day.[221] This is about four orders of magnitude above the reference dose of 3×10^{-4} mg/kg/day, which is not based on the most sensitive adults, but uses safety factors applied to annual data. A provisional tolerable weekly intake of 0.3 mg total mercury per person, of which no more than 0.2 mg should be methylmercury, was established by a joint Food and Agricultural Organization/World Health Organization Expert Committee on Food Additives.[222] A weekly intake of 5.5 pounds of fish with a lower mercury concentration of 0.12 mg/g, or 1.7 pounds of fish with a higher concentration of 0.39 mg/g, would approach the recommended level of 0.3 mg. The provisional tolerable weekly intake of methylmercury would be reached by weekly consumption of approximately 3.7 pounds of fish with a concentration of 0.12 mg methylmercury/g, or 1.1 pound with a concentration of 0.39 mg methylmercury/g.[223] For the sake of comparison, the intake value used in the exposure assessment of this report would be based on a weekly intake of 1.2 fish meals/day x 8 oz/meal x 1 lb/16 oz x 7 days/week, or 4.2 lb/week. The Minnesota (Amler) mean concentration value is 0.623 µg/g. Appendix A lists the calculations of the Hazard Quotients based on the mean intake and mean concentration values cited above. The results show that these levels contribute to moderate risk levels for adults, and significant risk levels for fetuses. The conclusion is that pregnant women of this study population should refrain from consuming locally caught fish during the gestational period.

Preliminary results of the Peterson Study of six bands of Chippewa Indians in Wisconsin show that 65 (20.6 percent) of 315 participants ate three or more meals of fish per week, while 18 (5.7 percent) did not eat any fish.[224]

Based on reported fish consumption estimates in the Amler study, an adult male of the Fond du Lac Band would approach the WHO tolerable weekly level of 0.2 mg of methylmercury by consuming about one and a half to eight meals per week, depending on the level of contamination in the fish and the amount consumed per meal.[225]

Table 4-1 shows the correlation between intake and risk at the given concentrations for the two health studies.

Table 4-1. Comparison of Amler (Minnesota) and Peterson (Wisconsin) Health Studies[1]

Study	Concentration (μg/g)	Consumption Rate (g/day)	Intake (μg Hg/kg/day)	HQ
Minnesota (Amler)	0.623	39	10.9	36.33
Wisconsin (Peterson)	0.75	26	8.8	29.25

[1] Based on the most sensitive receptor (fetus), assuming mean mercury concentrations and average CR by the mother.

The higher risk of adverse health effects concluded from the Amler calculations is based on higher fish consumption survey results, which more than offset the slightly lower mean mercury concentrations in the fish surveyed.

4.2 Discussion of Mercury Concentration in Fish

The mean mercury concentrations in walleye obtained from the data sources utilized in this report were compared with the State fish consumption advisories. Three discrepancies were noted:

1) On the St. Louis River near Cloquet (in close proximity to the Fond du Lac Indian Reservation), the state recommends the walleye consumption be kept to the rate of one meal per week for the entire population during season. However, mean mercury concentrations in walleye at this location were discovered to be 0.73 ppm. Findings from the Cloquet area indicate that the current fish consumption advisory for Minnesota is not enforced

in this area.

2) Joyce Lake in Vilas County, Wisconsin has yielded walleye with total mercury concentrations of 1.80 ppm. This waterbody is absent from the current Wisconsin advisory and should be added.

3) Ike Walton lake, located within the Lac du Flambeau Indian Reservation, has yielded walleye with mercury concentrations of 0.97 ppm, which is almost twice the FDA action level. This waterbody is missing from the current Wisconsin advisory and should be added.

The Wisconsin Division of Health claims that, if followed properly, Wisconsin's fish consumption advisory limits the average adult's mercury intake from sport fish to 1.5 milligrams (mg).[226] This amount includes a safety factor that protects pregnant women and their fetuses. From case studies in Japan, people eating mercury- contaminated fish accumulated 15 to 20 mg of mercury in their bodies before any effects of poisoning became apparent.[227]

In Minnesota, the State Department of Health maintains that the FDA action level of 1 ppm protects the average fish consumer. They advise consumers to limit their intake of mercury-contaminated fish when the fish mercury concentration is close to 0.2 ppm.[228]

In Minnesota, the State selected the fish species walleye for monitoring on the basis of being commonly used for human consumption and being considered good indicators of mercury contamination. The results of contaminant monitoring of walleye from 1987-1992 indicate that mercury levels are often higher in fish from northeastern Minnesota lakes compared to fish from the rest of the State. Nearly four hundred waterbodies were monitored and about three thousand composite samples were analyzed for total mercury.[229] The following five size ranges were used for processing over 12,000 fish into composite samples: 5.0 to 14.9 inches; 15.0 to 19.9 inches; 20.1 to 24.9 inches; 25.0 to 29.9 inches; 30.0 inches and over. The format of the Minnesota Fish Consumption Advisory is to use these same five size ranges in providing consumption advice. Based on a more detailed review of the databases compiled in this report, total mercury mean concentrations in walleye were found to be 0.24 to 0.31 ppm in 10-15 inch walleye and 0.428 to 1.317 ppm in 25-30 inch walleye. The data show a positive correlation between Hg concentration and size. For the St. Louis River, a total of 41 walleye were sampled by the University of Minnesota/Duluth in 1992. The mercury concentrations in these samples ranged from 0.136 ppm to 1.486 ppm, with a mean of 0.438 ppm and a median of 0.358 ppm.[230]

In remote lakes, such as those found in northern Wisconsin, it is uncertain how much mercury is deposited directly on the lake surface relative to that delivered to the lake from its catchment, and it is not known whether mercury washed in from surrounding soils is derived solely from atmospheric deposition or from local geologic sources as well.[231]

Recently, researchers have attempted to address these issues by applying a simple mass-balance model to mercury flux data generated from the sediments of a relatively undisturbed lake in northern Wisconsin, Little Rock Lake, as well as six others in various parts of Minnesota.[232] Whole-basin mercury accumulation rates were calculated for each lake from multiple (7 to 15) sediment cores that were analyzed stratigraphically for mercury and dated by ^{210}Pb.[233] By comparing whole-basin mercury fluxes from a group of lakes in a geographic region, they were able to estimate atmospheric deposition rates for modern and preindustrial times and the contributions of mercury from catchments surrounding the lakes.[234] Additionally, Swain and Helwig analyzed the mercury content of twelve museum specimens of walleye and northern pike collected from six lakes in or near the study area in 1935 and 1936. These were compared with the concentration in similarly-sized fish collected in the 1980s. The data show a significant increase in fish mercury from a mean of 0.13 mg/g in the 1930s to a mean of 0.31 mg/g in the 1980s ($p<0.01$, $n=12$).[235] Unfortunately, there appears to be a gap in the data available in the intervening years, until about 1970, when interest in mercury contamination increased.

In order to evaluate mercury mass balance, it is necessary to use complex fate and transport models for each medium of concern, including air-source pathways through deposition and precipitation, surface/sedimentary transport, as well as cycling between compartments. Many years of further research is required to show correlations between individual point sources and increased ambient concentrations in lakes.

4.3 Interpretation of Results

In both States, these data are based on surveys completed in 1991-1992. The risk assessment methodology is based on animal studies consisting of observing adverse effects from high doses of toxicants which are extrapolated to low doses resulting from environmental exposure. Safety factors are applied to derive the risks to humans. There is uncertainty associated with these factors. Some sources of uncertainty in this study include the following:

a) the surveys of fish consumption relied on mercury concentrations over a span of time or place;

b) consumption of fish was estimated;

c) the memories of the respondents could be faulty.

Greater accuracy could be achieved by utilizing a cohort who maintain diary entries of the quantities of fish consumed, in a addition to other pertinent factors, such as the locations fished. It is recognized that this may lower compliance with completing the survey, and greater incentives are required to motivate the respondents. However, as more lakes and rivers are discovered to contain increasing levels of contamination, the need for more accurate survey data may translate into greater willingness to comply with more intrusive data gathering techniques. Additionally, further monitoring and modelling of environmental mercury contamination, as well as more research into mercury cycling, uptake and methylation, may reduce the geochemical uncertainties currently encountered. This may permit more accurate prediction of the levels of bioaccumulation of methylmercury in fish at firm similar waterbodies.

Recent survey data of Wisconsin Chippewa indicate mean consumption levels of 1.2 fish per week.[236] Males and unemployed individuals had higher fish consumption. Mean consumption of walleye during spearing season (April and May) was almost ten-fold higher than that of three other fish that are also sometimes contaminated with methylmercury, as was shown in Table 3-2. This table displayed the "worst case" fish mercury concentrations found in the study area. The data were gleaned from a review of all walleye mercury concentrations greater than 1 ppm and harvested from waters fished by the Tribes, based on geographic proximity and survey results. The threshold of 1 ppm was selected based on a review of regulatory action levels, noting that this value was the highest regulatory level in the study area. This would tend to indicate that additional protective measures should be considered for those who consume large quantities of local fish from these waters.

Chapter 5.0

CONCLUSIONS/RECOMMENDATIONS

5.1 Statement Of The Problem

Three major problems complicate the mitigation of the risk that the study population faces from consumption of mercury contaminated fish:

1) Problems with the enforcement of the fish advisories;
2) Poor risk communication approach; and
3) Study limitations and uncertainties.

5.1.1 Shortfalls in Current State Fish Advisories

As stated in Section 4.2, mean mercury concentrations in walleye from the data sources utilized in this report were compared with the State fish consumption advisories. Three discrepancies were noted:

1) On the St. Louis River near Cloquet (in close proximity to the Fond du Lac Indian Reservation), mean mercury concentrations in walleye exceeded the protective action level by almost 50 percent. This indicates that the current fish advisory for Minnesota is not enforced.

2) Joyce Lake in Vilas County, Wisconsin has yielded walleye with total mercury concentrations of 1.80 ppm and should be added to the current Wisconsin advisory.

3) Ike Walton lake, located within the Lac du Flambeau Indian Reservation, has yielded walleye with mercury concentrations of 0.97 ppm and should be added to the current Wisconsin advisory.

5.1.2 Risk Communication Improvements

The inference from the fish consumption data is that the Tribes who inhabit the study areas have strong cultural reasons for high walleye consumption as one of the mainstays of their diets. This necessitates caution in any risk communication approach. The following considerations should be included in the approach selected:

1) Obtain input and feedback from Tribal leaders and those engaged in fishing on acceptable ways of mitigating risks.

2) Use a trusted, authoritative source of risk information as a reference or spokesperson to establish confidence in the risk management methodology being conveyed.

3) State the benefits to the Tribal anglers and their families, friends and neighbors from logistical adjustments that can reduce their risk, such as periodically changing fishing locations and releasing the larger fish.

4) Present the facts surrounding hazardous exposures (those above regulated levels) in a clear and consistent manner. Anticipate questions and have background information

available for timely response.

5) Focus on the groups that are most at risk and consider the needs of the community as a whole.
6) Keep emotions in check and be honest about the certainty (or lack thereof) of the information presented.
7) Give feedback directly to the Tribes on results of testing.

If these guidelines are followed, the long term response to a risk minimization strategy will be enhanced. Failure to implement any one of these concepts is potentially detrimental to a successful risk communication approach, since a holistic approach that considers the viewpoint of the Tribes is necessary.

5.1.3 Limitations of Study Approach

1) The high Hazard Quotients derived in this study were based on fish consumption of walleye exclusively, which is not realistic according to dietary survey information. The maximum concentrations found were about four times that of the mean concentrations. This suggests four times higher risk, based on equal consumption rates at these areas designated as "hot spots."
2) There is a high degree of uncertainty associated with the body of scientific knowledge of mercury's characteristics in relation to: residence time, fate and transport, cycling, methylation and toxicity at low doses.

Furthermore, there is debate concerning the accumulation trends of methylmercury, which appear to differ between media due, in part, to mercury's volatility and ease of chemical transformation. Moreover, there is moderate uncertainty regarding the presence of acute or chronic health effects from methylmercury poisoning within the Great Lakes basin. Only one such episode was reported, from the literature reviewed, and sufficient tests were not performed to validate this report.

3) Within the U.S. and Canada, mercury is recognized as a critical pollutant of concern, due to its toxicity and high bioaccumulation rate. However, powerful interests are arrayed against the rapid elimination of mercury from environmental release:

   a) utilities have previously been exempt from regulation of mercury emissions and must analyze the economic and engineering tradeoffs required to reduce emissions to a significant degree;
   b) regulations for disposal of items containing mercury and incentives for their reuse must be examined; and
   c) increasingly scarce remediation and research funds must be sought and applied to deal with the contamination that is currently present in all media.

Mercury poses a threat to both human and ecosystem health, as determined by numerous risk assessments and characterizations. The qualities of latency and developmental toxicity make it an insidious threat, but one which cannot be ignored or assumed under control until further research is conducted to reduce the uncertainties existant.

5.2 Risk Reduction Strategy

Given the historically long lead time between government awareness of a problem and applying solutions to it in a strategic, coordinated manner, there are several approaches that should be considered:

1) Education The Tribes, as well as other at risk subpopulations, should be targeted for comprehensive educational campaigns to convey the nature of the risks they face and how to avoid or mitigate them. Educational programs might emphasize the following:

a) avoid eating a lot of the older, bigger walleye;

b) freeze a portion of fresh-caught fish to spread out consumption;

c) children and women who are pregnant, or might become pregnant in the near future, should forego walleye consumption during the spearfishing season and limit consumption of frozen fish from local waters throughout the year;

d) children, women of child-bearing age, and anglers should be instructed in the health risks associated with mercury ingestion;

e) information on how to interpret fish advisories and how they are derived, presented in layperson's terms, would be beneficial.

2) Communications A continuous, dedicated dialogue with two-way data exchange between government monitoring/health agencies and the Tribes should be pursued. Nontraditional avenues should be examined, including coordination through trusted agencies, such as the Great Lakes Indian Fish and Wildlife Commission (GLIFWC).

3) Monitoring Until further research can clarify the health risks associated with exposure to methylmercury at low levels, it is recommended that the States continue their current practice of monitoring fish mercury levels and reporting high-risk lakes. Additionally, the usefulness of vegetation in distinguishing between anthropogenic and natural sources of environmental mercury has been well documented in the literature (e.g., Bargagli et al., 1989 and Rasmussen and Mierle, 1991). Therefore, biogeochemical surveys have excellent potential for evaluating the contribution of mercury from natural geologic sources to lakes in the Great Lakes basin which show anomalously high mercury concentrations in fish, but which have no known industrial point sources.[237]

5.3 Selection of Monitoring Programs

A critical factor in reducing risks is proper selection of monitoring sites, frequency and media. The selection of sites should be scientifically based, with constant revision based on the best research data available. For example, one research study developed and tested a model to predict mercury concentrations in various lengths of walleye from 43 Wisconsin lakes. This study showed that, based on strong statistical correlation, soft-water, poorly buffered, low pH lakes have the highest concentrations of mercury.[238] The mechanisms responsible for this are not clear and require further study. However, these environmental correlates may be useful as an indicator for additional monitoring and research. For example, the frequency of monitoring depends on trends in ambient and fish concentrations, as well as how many environmental correlates (parameters which have a strong relationship with the presence of methylmercury) exist at particular lakes or rivers. The current situation is that the State and Federal governments are resource-constrained and cannot sample all such waterbodies, so an additional factor is how to structure the monitoring program so as to sample representative lakes in all distinct geographic areas and extrapolate those results to similarly configured waterbodies.

Selection of media to monitor is related to the residence times of mercury in various forms and states as well as bioavailability to the ecosystem.

Overall, the monitoring strategy should:

1) consider the environmental trends and devote more resources where needed;
2) involve random, probabilistic sampling within areas targeted by trend analysis and the other factors

enumerated above (e.g., changes in acidity, alkalinity, and buffering capacity of fresh waterbodies may be factors);

3) ensure more frequent sampling near sensitive subpopulations (e.g., all lakes where spearfishing takes place should be monitored at least once during a walleye generation); and

4) ensure equity among affected groups.

5.4 Long-term Strategy

To reduce Tribal dependence on external governmental support, interested parties, particularly the Federal government with its trust responsibilities, must focus on education and training. This includes encouraging and identifying scholarships and fellowships for Indian students, such as the Environmental Science and Management Fellowship of Tufts University and Sea Grant programs.

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Appendix A

Calculations

Part I. Mean Concentration = $\Sigma \frac{X_i}{n}$ where

X_i = Concentrations from Table 3-1

n = number of mean database values (multiple samples from each database)

Mean Conc = $\frac{5.61}{9}$ = 0.623 µg/g

Standard Deviation (s) = $\sqrt{\Sigma(X_i^2 - \bar{X})^2}$ (1)

s = $\sqrt{.4917/8} = \sqrt{.06147}$

s = 0.248

Part II. Mean "Worst Case" Concentration = $\Sigma X_i/n$ where
X_i = Concentrations from Table 4-2
n = number of samples

Mean Conc = 46.48/32 = 1.4525

s = 0.3225 using equation (1) above

Part III. Consumption Rate (Mean, based on survey data)

CR = 1.2 fish meals/week x 8 oz/fish meal x 1 week/7 days x 28.349523 g/oz
= 38.88 g/day

Part IV. Intake = (C x CR x AF x EFD)/(BW x AT)

A. "Mean" Intake based on Part I

I_{MA} = (0.623 µg/g)(38.88 g/day)(0.9)(70 yrs)/(70 kg)(70 yrs)

= 0.3114 µg/kg/day

based on male adult consumption rate and body weight (for adult females: multiply male estimate by 1.4; for fetuses: multiply female estimate by 25). This is so because Intake is inversely proportional to body weight.

Calculations (continued)

B. "Worst Case" Intake

I_{MA} = (1.4525 µg/g)(38.88 g/day0(0.9)(70 yrs)/(70 kg)(70 yrs)

I_{MA} = 0.726 µg/kg/day

Part V. HQ = Intake/D_{ref}

A. Mean: HQ_{MA} = 0.3114 µg/kg/day ÷ 0.3 µg/kg/day
HQ_{MA} = 1.038, HQ_{FA} = 1.4532, HQ_{fetus} = 36.33

B. Worst Case: HQ_{MA} = 2.42, HQ_{FA} = 3.39, HQ_{fetus} = 84.71

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