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Population-Based Methylmercury Exposure Assessment

Prepared by:

Lynda Knobeloch, Ph.D. Senior Toxicologist
Henry Anderson, Chief Medical Officer
Wisconsin Department of Health and Family Services, Division of Public Health

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EXECUTIVE SUMMARY

Date of Report: August 12, 2005

Title of Project: Population-Based Methylmercury Exposure Assessment

Investigators:

Lynda Knobeloch, Research and Toxicology Supervisor

Henry Anderson, Chief Medical Officer

Wisconsin Department of Health and Family Services, Division of Public Health, Bureau of Environmental and Occupational Health

Research Category: IA. Electrical generation and human health. Mercury: Body burden and levels of exposure in Wisconsin.

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Project Period: July 1, 2003 to June 30, 2005

Object of Research: This study was designed to evaluate fish consumption patterns and mercury body burdens among a representative cross section of Wisconsin's adult population. This research allowed us to identify subpopulations in Wisconsin that consume fish several times a week and populations that had elevated mercury body burdens. Study findings allow us to compare current mercury body burdens among Wisconsin residents to national exposure data from CDC's NHANES study and from the US EPA. Comparison of hair mercury levels with information on types and quantities of fish eaten by study volunteers provides important information on dietary sources of methylmercury. Hair mercury and fish consumption data from this study provide a baseline for future mercury exposure assessments.

Summary of Results/Accomplishments

Based on weighted analysis of BRFSS responses, 83% of the adults who live in Wisconsin eat fish and/or shellfish. Estimates show that men are more likely to eat fish and shellfish than women, but this difference is not statistically significant. The percentage of people who include fish and shellfish in their diets increases with age, household income, and educational attainment. Ethnicity is an important predictor of fish consumption, as well, with people who report their race as white, American or Alaskan Indian or multiple races, being more likely to eat fish/shellfish than others. Among people who don't eat fish or shellfish, slightly more than half of them simply don't like fish/shellfish and nearly 20% were raised in households that never ate fish. Approximately 5% are vegetarians and a similar percentage (4.4%) avoids fish because of concern about contaminants in fish and shellfish.

Average fish consumption frequency ranges from 4 meals/month among all Wisconsin residents to almost 5 meals/month among those who include fish in their diets. The frequency of fish

intake varies by ethnicity and fishing license status. Mean fish consumption is highest among Native Americans/Alaskans and multiracial residents and among people who live in a household where at least one individual has a valid Wisconsin fishing license. Other variables including gender, age, income and education are not significant predictors of fish meal frequency. The highest intake rate reported was 60 fish meals/month which equates with two fish meals per day.

Quantity of fish consumed per meal

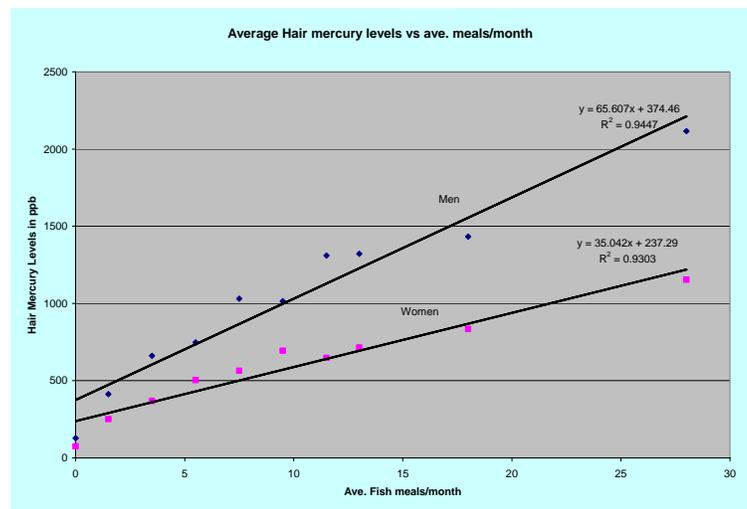
Among people who eat fish and shellfish, the amount of fish consumed at each meal averages slightly more than six ounces and is significantly higher among men than women (7.06 vs 5.08). On average, those over the age of 64 years ate significantly less fish per meal than younger individuals.

Monthly fish intake

Based on weighted meal frequency and quantity per meal estimates, the average fish intake among men and women who include fish in their diets is 35.8 and 23.6 ounces/month, respectively.

Hair Mercury Levels vs Fish Consumption

Hair samples were provided by 981 men and 1050 women. Hair donors were somewhat more likely to consume fish than the general population. Mercury levels ranged from 0.012 to 15.2 ug/g (ppm) and exceeded the guideline value of 1 ppm in 29% of the men and 13% of the women who participated in this phase of our research. Average hair mercury levels were higher in men (0.918 ppm) than in women (0.525 ppm) and were significantly correlated with monthly fish consumption estimates (see inset).



Fish Consumption Advisory Awareness

Most Wisconsin residents are aware that consumption of some types of fish should be limited due to mercury contamination. Based on a weighted analysis of BRFSS responses, 78% of adults living Wisconsin had heard something about this issue. Awareness rates are similar among men and women, but vary by race being highest among Native Americans and white residents. Awareness of this issue increases with household income and educational attainment. While the majority of Wisconsin residents have heard about mercury contamination in fish, less than half of them are familiar with the Wisconsin Sport-fish Consumption Advisory which is issued annually by the Department of Natural Resources. Familiarity with this advisory, which is issued in the form of a published pamphlet, was highest among men and licensed fishermen.

Familiarity was also higher among whites and increased with household income, age and education.

Introduction

Over the past 50 years, several outbreaks and individual cases of organic mercury poisoning have been reported. The most recent case involved a prominent researcher who became ill and died several months after a brief dermal exposure to a small amount of dimethylmercury (Siegler et al., 1999). A large epidemic involving methylmercury exposure occurred in the city of Minamata Japan during the 1950's. Hundreds of people experienced neurological symptoms such as paresthesia, ataxia, constriction of the visual fields, hearing loss and mental confusion and many deaths were reported. Fishermen and their families suffered the worst effects. Government investigators traced the source of exposure to fish caught from the Minamata Bay which had been polluted by a local factory (Harada 1995, Smith and Smith, 1975). A series of epidemics involving methylmercury-treated grain have occurred in Iraq (Jalili and Abbasi, 1961). The most recent outbreak occurred during the winter of 1971-1972 and resulted from the use of mercury-treated wheat to make bread (Bakir et al., 1973). Adult victims of these incidents experienced severe neurological disorders characterized by paresthesia, tremors, ataxia, visual problems, mental confusion and, in the most serious cases, loss of consciousness and death. Prenatal exposures that occurred during these epidemics resulted in a range of disorders including blindness, cerebral palsy, and developmental delays.

Present-day risks to adults who eat frequent meals of marine and freshwater fish are not well understood. Repeated consumption of large, predatory commercial fish, like shark, swordfish, tilefish, and albacore tuna can lead to an elevated mercury body burden (Mahaffey et al. 2004). Large fresh water gamefish, like walleye, bass and northern pike, can also accumulate high mercury levels. Because of the increased popularity of fish as a source of dietary protein, a significant percentage of the US population consumes these species as a regular part of their diet and may be at risk of methylmercury-induced health problems. Although several studies have assessed mercury exposure among women of child-bearing age, very little is known about mercury body burdens among children, men or post-menopausal women in the U.S.

As part of the National Human Exposure Assessment Survey (NHEXAS), a probability-based population scoping study conducted by EPA Region V, mercury exposure was assessed among 182 randomly selected residents of several Midwestern states (Pellizzari, et al. 1999). Hair samples collected between June 1995 and July 1997 from 81 males and 101 females of all ages were analyzed for mercury. Mercury levels among these samples ranged from 0.012 to 3.5 ppm and were slightly higher among women (annualized means 0.315 in women vs 0.260 in men). The 1999 CDC NHANES assessment of hair mercury levels among women of childbearing age identified 50th and 90th percentile values of 0.2 and 1.4 ppm, respectively (MMWR, 2001).

Since the EPA released its Mercury Report to Congress in 1997 in which the agency proposed a daily intake reference dose of 0.1 ug mercury per kg body weight per day, there has been increased interest in methylmercury as a public health hazard (USEPA, 1997). In its report, the EPA described emerging research that raised concerns about the effect of methylmercury on the adult cardiovascular system (Salonen, et al. 1995). Following the report's release, the agency recommended further restrictions on mercury emissions from coal-fired power plants and noted that frequent fish consumers may be exposed to unhealthy levels of mercury.

Following the release of the EPA report, a review of the human toxicology of mercury was commissioned by the National Academy of Sciences. After a one-year review, the NAS panel of experts concluded that the EPA recommendations were valid and confirmed the need for stronger fish consumption advisories and research to evaluate methylmercury exposure among consumers of commercially-sold and sport-caught fish (National Academy of Sciences, 2000). The NAS report also identified the need for research that would evaluate the health effects of chronic, low-level methylmercury exposure among children and aging adults. The authors of the report cited recently published studies by Faroos Island (Sorenson, et al. 1999) and Finnish researchers (Salonen et al. 1995) and emphasized the need to consider the emerging evidence that methylmercury may be more toxic to the developing and aging cardiovascular system than has been recognized in the past. The panel recommended that this effect be considered in the development and application of the reference dose for this toxin.

The EPA's reference dose of 0.1 ug/kg/day corresponds to a blood mercury level of 5.8 ug/L (ppb) and a hair mercury level of approximately 1 ug/g (ppm). The reference dose was based on human studies and is intended to protect against the neurodevelopmental effects of prenatal exposure as well as potential effects of this toxin on the cardiovascular system and aging nervous system. Symptoms of clinical toxicity such as vision problems, hypertension, and tremors are usually associated with blood mercury levels above 50 ug/L (ATSDR 1999). In July 2002, the US FDA's Food Advisory Committee advised the agency to revise its consumer advisory on methylmercury in fish with special concern for pregnant women, nursing mothers, women who may become pregnant, and young children. One recommendation was for the FDA to coordinate its advisory for commercial fish with the sport-fish consumption advisory issued by the EPA. In 2004 these agencies issued a joint consumer advisory on methylmercury in fish and shellfish which was intended to reduce exposure to mercury among young women and children. The 2004 advisory supersedes FDA's 2001 advice for commercial fish.

In 2000, Wisconsin adopted a general consumption advisory for most inland waters based on the National Academy of Sciences recommendations about mercury ingestion. Wisconsin revised its consumption advisory in 2004 to include advice for popular commercial fish. This was done out of the recognition that most people who eat sport-caught fish also include commercial fish in their diets. The current advisory for men and women beyond their child-bearing years allows "unlimited" consumption of locally-caught panfish, purchased salmon, shrimp, pollock and canned light tuna, but limits consumption of tuna steaks, halibut, canned white tuna, and predatory gamefish like walleye and northern pike to no more than one meal a week. Shark, swordfish, king mackerel and tilefish are limited to one meal per month.

Dietary fish intake is the most important source of human exposure to methylmercury. Nearly 90% of the United States population consumes fish on a regular basis. Mercury levels in commercially-sold fish and seafood are regulated by the US Food and Drug Administration (FDA). That agency advises women of child-bearing age and young children to limit their consumption of swordfish, shark and other species that are high in mercury. Despite these efforts, the National Health and Nutrition Survey found that a substantial number of individuals who regularly consume fish have blood or hair mercury levels that pose a risk of long-term health problems. In states such as Wisconsin with a robust local sport fishing tradition, methylmercury exposure from locally-caught fish is superimposed upon the background

exposure from commercial fish. The Wisconsin Departments of Health and Family Services and Natural Resources advise sport fish consumers to avoid frequent consumption of mercury-contaminated fish. There are lake-specific and regional differences in Wisconsin sport fish mercury contamination.

In an effort to evaluate fish consumption patterns and methylmercury exposure in a representative cross section of Wisconsin's adult population, a fish consumption module was added to the 2004 Behavioral Risk Factor survey. BRFSS survey responses from 4,206 Wisconsin residents are weighted to provide representative fish consumption and sport-fish advisory awareness for the adult population.

In addition, all Wisconsin residents over the age of 18 years were invited to complete a mailed survey on their fish consumption habits and provide a hair sample for mercury analysis. As result of this effort, fish consumption information and hair mercury levels were collected from 2,029 adults. Nearly all (95%) of the men and women who provided hair samples for mercury analysis included fish in their diets. Slightly more than 40% of them ate sport-caught fish at least once a month. Mercury levels exceeded the current federal advisory of 1 ppm in 29% of the men and 13% of the women who provided hair samples.

Project Activities:

This project involved the addition of a module to the 2004 Behavioral Risk Factor Surveillance Survey on Fish Consumption and Advisory Awareness and a state-wide recruitment of 2,000 adults who completed fish consumption surveys and provided hair samples for mercury analysis. Each of these components of our project is described in more detail below.

A fish consumption survey was conducted as part of the 2004 Behavioral Risk Factor Surveillance Survey (BRFSS). The BRFSS is a randomized telephone survey that is designed to be representative of all adults (age 18+) living in Wisconsin households, with the exception of persons in nursing homes, prisons and other institutions. It is conducted by the University of Wisconsin Survey Center and has been conducted annually since 1984. More than 300 adults are interviewed each month. This survey collects demographic and risk-behavior information from approximately 4,000 residents each year. The continuous nature of the survey is important because sport fish consumption habits and the resulting mercury body burdens may vary by season. The 2004 BRFSS was administered to 4,502 Wisconsin residents; however, the fish consumption module was not included during the first two weeks of January of 2004. Therefore, fish consumption information is available for 4,206 BRFSS participants.

Weighting of BRFSS data to represent all Wisconsin residents

Weighting is used to adjust for over and under sampling of specific subpopulations within Wisconsin. These weights are applied by the US Center for Disease Control and Prevention (CDC). All results shown in this report have been weighted to be representative of the adult population living in Wisconsin in 2004. The final 2004 data set consists of 4,503 records. When the appropriate weight is applied to each record, the BRFSS data are representative of the total non-institutionalized Wisconsin adult population (age 18+) living in households with land-line

telephones. Weighting of the final data set is necessary to adjust for disproportionate sampling rates and different response rates across strata.

The weight variable is constructed by the CDC in several steps. First, a raw weight is calculated by dividing the total number of adults in the household by the number of residential telephone numbers for that household. From this a final weight is calculated incorporating the size of the state's adult population in 12 age-sex cells. The total Wisconsin adult population for 2004 produced using the weight variable is 4,155,116. The difference, as a proportion, between this estimate and the population estimate produced by the U.S. Census Bureau for 2004 is less than 1%.

Objectives, methods, and deliverables

Research Objectives

This research was designed to meet the following objectives:

1. Evaluate fish consumption patterns among adults living in Wisconsin, i.e. How much fish do they eat? What types of fish are they eating the most? Where do these fish come from?
2. Evaluate hair mercury levels among a representative cross section of Wisconsin residents. What is the overall distribution? Are levels higher among men vs women? Are there differences among members of certain ethnic or racial subpopulations?
3. Identify subgroups that are at risk of mercury exposure due to their reliance on fish as a dietary staple or due to their selection of fish that are known to be high in mercury. The hair mercury levels measured in these subgroups will be used to evaluate their actual body burdens.
4. Compare fish consumption patterns and methylmercury body burdens. This comparison will allow us to determine whether people who eat a lot of sport fish or commercial fish have mercury body burdens that are of concern.
5. Compare our findings to national and regional data in an effort to determine whether mercury exposure levels in Wisconsin are significantly higher or lower than those observed elsewhere in the United States.

Findings presented in this report can be used to gauge fish consumption, methylmercury body burdens, and awareness of fish consumption advisories that have been issued by the Wisconsin Department of Natural Resources and the US Food and Drug Administration. They can also be used to evaluate the need for additional, more targeted advisories for special subpopulations.

Methods

A fish consumption module, added to the 2004 Behavioral Risk Factor Survey (BRFSS), was used to collect fish consumption and advisory awareness information from more than 4,000 Wisconsin residents. At the end of the survey, participants were invited to participate in a mercury exposure assessment and given a toll-free phone number to call if they were interested. Those who called were sent a hair collection kit with a prepaid return envelope. Hair mercury levels were matched to fish consumption information to assess mercury levels among various subpopulations, e.g. men versus women, different age groups, ethnicities, frequent consumers of fish, region and seasonality etc.

Because very few BRFSS participants responded to this invitation, we publicized this research statewide inviting all adult Wisconsin residents aged 18 and older to provide hair for a free mercury analysis. A toll-free telephone line was established so that people could call in to request a hair sampling kit. Kits that contained a letter of invitation, consent form, hair collection instructions, return envelope, and zip lock baggie for the hair sample (see attachment A) were mailed to each volunteer. Approximately 60% of the kits were returned. It is believed that the amount of hair needed for testing (approximately 100 hairs cut at the scalp) may have deterred some volunteers from participating.

Hair mercury analysis is a convenient, non-invasive biomarker that is frequently used to assess chronic exposure to methylmercury. Mercury is bound to sulfhydryl groups in hair protein and is not affected by shampooing or chemical treatments such as coloring or bleaching of the hair. Hair mercury levels have been used by the US Environmental Protection Agency (EPA) and Center for Disease Control and Prevention, as well as by researchers in the Seychelles and Faroes Island studies to assess mercury body burdens.

Laboratory method for hair analysis

Hair samples were analyzed by the Wisconsin State Laboratory of Hygiene. Hair was acid digested in nitric and sulfuric acid and analyzed for mercury according to EPA method 631, Revision B: Mercury in water by oxidation, purge and trap, and cold vapor atomic absorption fluorescence. This method has a detection limit of 0.011 ug/g for hair.

Statistical analysis of data. Fish consumption data and hair mercury levels were analyzed using SAS and MS Access and MS Excel software to determine means, medians, standard deviations and correlations. Linear regression analysis was used to compare hair methylmercury levels to fish consumption estimates.

Deliverables

This report provides the following deliverables which were outlined in our proposal for funding:

1. Fish consumption rates by gender, age group, race, and socioeconomic level.
2. Regional differences in fish consumption.
3. Regional differences in mercury exposure.
4. Hair mercury levels in a representative cross section of Wisconsin's adult population including men and women, and members of all races and ethnicities.
5. Hair mercury levels among frequent and infrequent fish eaters.
6. Correlation between fish intake and mercury levels.
7. Comparison of Wisconsin mercury body burdens to national and regional data.

Deliverables 1 and 2 are addressed using information from the 2004 BRFSS Fish Consumption Module. Deliverables 3, 5, 6 and 7 are addressed with data from the hair donor project, while deliverable no. 4 is based on data from both the BRFSS and hair collection modules of this project.

Fish consumption rates by gender, age group, race and socioeconomic level

Representative, statewide fish consumption information was collected as part of the 2004 Behavioral Risk Factor Surveillance Survey (see BRFSS Tables 1 through 13). Based on weighted analysis of BRFSS responses, 83% of the adults who live in Wisconsin eat fish and/or shellfish. Men are slightly more likely to eat fish and shellfish than women, but this difference is not statistically significant. The percentage of people who include fish and shellfish in their diets increases with age, household income, and educational attainment. Ethnicity is an important predictor of fish consumption, as well, with people who report their race as white, American or Alaskan Indian or multiple races, being more likely to eat fish/shellfish than others. Among people who don't eat fish or shellfish, slightly more than half of them simply don't like fish/shellfish and nearly 20% were raised in households that never ate fish. Approximately 5% are vegetarians and a similar percentage avoids fish because of concern about contaminants in fish and shellfish.

Average fish consumption frequency ranges from 4 meals/month among all Wisconsin residents to almost 5 meals/month among those who include fish in their diets. The frequency of fish intake varies by ethnicity and fishing license status being highest among Native Americans/Alaskans and multiracial residents and among people who live in a household where at least one individual has a valid Wisconsin fishing license. Other variables including gender, age, income and education are not significant predictors of fish meal frequency. The highest intake rate reported was 60 fish meals/month which equates with two fish meals per day.

Quantity of fish consumed per meal

Based on BRFSS responses, the amount of fish consumed at each meal averages slightly more than six ounces and is significantly higher among men than women (7.06 vs 5.08). On average,

those over the age of 64 years ate significantly less fish per meal than younger individuals (4.9 oz vs 6.2 oz).

Monthly fish intake

Based on weighted meal frequency and quantity per meal estimates, the average fish intake among men and women who include fish in their diets is 35.8 and 23.6 ounces/month, respectively.

Types of fish consumed

BRFSS participants who included fish in their diets were asked to estimate the number of times they had eaten specific types of fish including canned tuna, varieties of commercial fish that tend to be high in mercury such as shark and swordfish, sport fish from inland waters of Wisconsin and the Great Lakes during the previous 12 months. A detailed summary of responses are provided in BRFSS tables 3 through 11.

Percentage that had eaten various types of fish during previous 12 months*

Type of Fish	Men	Women
Canned Tuna	58.5%	65.8%
Albacore Tuna	48.7%	53.1%
Fresh/frozen Tuna, swordfish, seabass, halibut, shark	30.2%	25.1%
Sportfish from Wisconsin inland waters	48.5%	34.3%
Great Lake Sport-caught fish	24.8%	18.8%
All fish and shellfish	85.0%	81.2%

*Based on weighted analysis of BRFSS survey data

Regional Differences in Fish Consumption

The percentage of residents who consumed fish and shellfish and annual fish consumption rates were similar among the five Division of Public Health regions. However, residents of the northern, northeastern and western regions ate significantly more sport-caught fish from inland waters and the Great Lakes than residents of the southern and southeastern regions (see table below).

Average fish consumption rate by DPH Region from BRFSS Survey

DPH Region	Average number of fish meals			% Who Consume Fish/Shellfish
	In last 12 months		Per month	
	Inland Sportfish	Great Lake Sportfish	All Fish	
N	8.54 (6.66-10.43)	2.70 (1.98-3.42)	4.21 (3.69-4.74)	88%
NE	6.61 (5.22-8.00)	2.74 (2.06-3.41)	4.19 (3.66-4.71)	86%
S	3.92 (3.09-4.76)	1.12 (0.67-1.56)	3.94 (3.50-4.38)	83%
SE	2.82 (2.16-3.49)	1.05 (0.70-1.37)	4.28 (3.80-4.77)	82%
W	5.72 (4.43-7.01)	1.33 (0.83-1.83)	3.73 (3.23-4.22)	86%
All	4.78 (4.30-5.27)	1.61 (1.38-1.84)	4.11 (3.87-4.35)	85%

licensed fishermen. Familiarity was also higher among whites and increased with household income, age and education.

People who provided hair for mercury analysis were more likely to be familiar with the Wisconsin sport-fish advisory than the general population (77.5% vs 43.3%). Familiarity rates among this group also varied by gender, race, income and education (HD Table 3). Women were slightly less likely to be aware of the advisory than men, and awareness was positively associated with income and education. The greatest disparities were noted among racial groups with white, Native American, and multiracial participants being more than twice as likely to know about the advisory as black participants. The length of time the person lived in Wisconsin was also important with awareness rates increasing from 60% among those who had lived in Wisconsin for less than 5 years to 81% among people who had lived in Wisconsin 5 years or more.

Hair mercury analysis

2,031 Wisconsin residents submitted hair samples for mercury analysis. Three hair samples were insufficient for testing, however, so results are presented for 2,028 hair samples. Hair donors were more likely to be white and have a 4-year college degree compared to the general population. They were also more likely to include fish in their diets and more likely to hold a valid sportfishing license compared to the general Wisconsin population (see table below).

Demographic Differences between BRFSS participants and Hair Donors

Characteristic	BRFSS Population Estimates	Hair Donors	2000 WI Census
Income (% > \$50,000)	35%	53%	45%
Gender (% Male)	49%	50%	49%
Race			
White, non-Hispanic	89.7%	95%	89%
Black, non-Hispanic	3.1%	0.8%	5.7%
Hispanic	1.9%	0.6%	3.6%
Asian	1.3%	1.0%	1.7%
Multiple races	1.3%	1.5%	1.2%
Native American	1.5%	0.1%	0.9%
Education			
% High School Graduate	93%	98%	85%
% Bachelor's degree	30%	59%	22%
% of Homes with a Fishing License	37%	52%	Not Available
% Who consume fish	83%	95%	Not Available
% Aware of WI Advisory	42%	78%	Not Available

Hair samples were provided by 981 men and 1050 women. Hair donors were somewhat more likely to consume fish than the general population. Mercury levels ranged from 0.012 to 15.2 ug/g (ppm) and exceeded the guideline value of 1 ppm in 29% of the men and 13% of the women who participated in this phase of our research.

Average hair mercury levels were higher in men (0.918 ppm) than in women (0.525 ppm), and higher among licensed anglers compared to others. Averaged hair mercury levels were significantly correlated with averaged monthly fish consumption estimates.

Hair Mercury Levels versus Demographic Variables

Demographic	Mean (median) Hg Level	Range (Min-Max)	% above 1 ppm
Gender			
Male	0.918 (0.577)	0.012-15.2	29%
Female	0.525 (0.345)	0.013-5.30	13%
Race			
White	0.720 (0.422)	0.012-15.2	20%
Asian	0.865 (0.713)	0.371-2.36	30%
Black	0.266 (0.135)	0.022-1.73	5%
Hispanic	0.936 (0.552)	0.337-2.38	46%
Multiple races	0.548 (0.311)	0.029-1.44	19%
Native American	0.814 (0.793)	0.099-1.55	33%
Annual Household Income			
<\$25,000	0.597 (0.421)	0.013-8.78	15%
\$25-35,000	0.710 (0.337)	0.022-4.81	19%
\$35-50,000	0.731 (0.375)	0.018-15.2	19%
\$50-75,000	0.711 (0.443)	0.012-11.0	22%
>\$75,000	0.755 (0.537)	0.019-5.72	24%
Fish License in Home			
Yes	0.858 (0.564)	0.021-11.00	27%
No	0.563 (0.337)	0.012-15.20	14%
Familiar with WI Advisory			
Yes	0.766 (0.467)	0.018-15.20	22%
No	0.541 (0.313)	0.012-9.60	14%
Region of Wisconsin			
Northern	0.850 (0.523)	0.021-9.45	25%
Northeastern	0.678 (0.440)	0.033-4.57	20%
Southern	0.670 (0.394)	0.012-15.20	17%
Southeastern	0.623 (0.382)	0.022-5.42	19%
Western	0.813 (0.434)	0.018-6.52	25%
Years Education			
<12	1.025 (0.293)	0.018-6.52	30%
12	0.830 (0.471)	0.036-9.45	25%
1-3 yrs college	0.670 (0.267)	0.013-15.20	17%
4 yrs college or more	0.701 (0.449)	0.012-11.00	21%
All	0.714 (0.422)	0.012-15.20	20%

Fish Consumption among Hair Donors

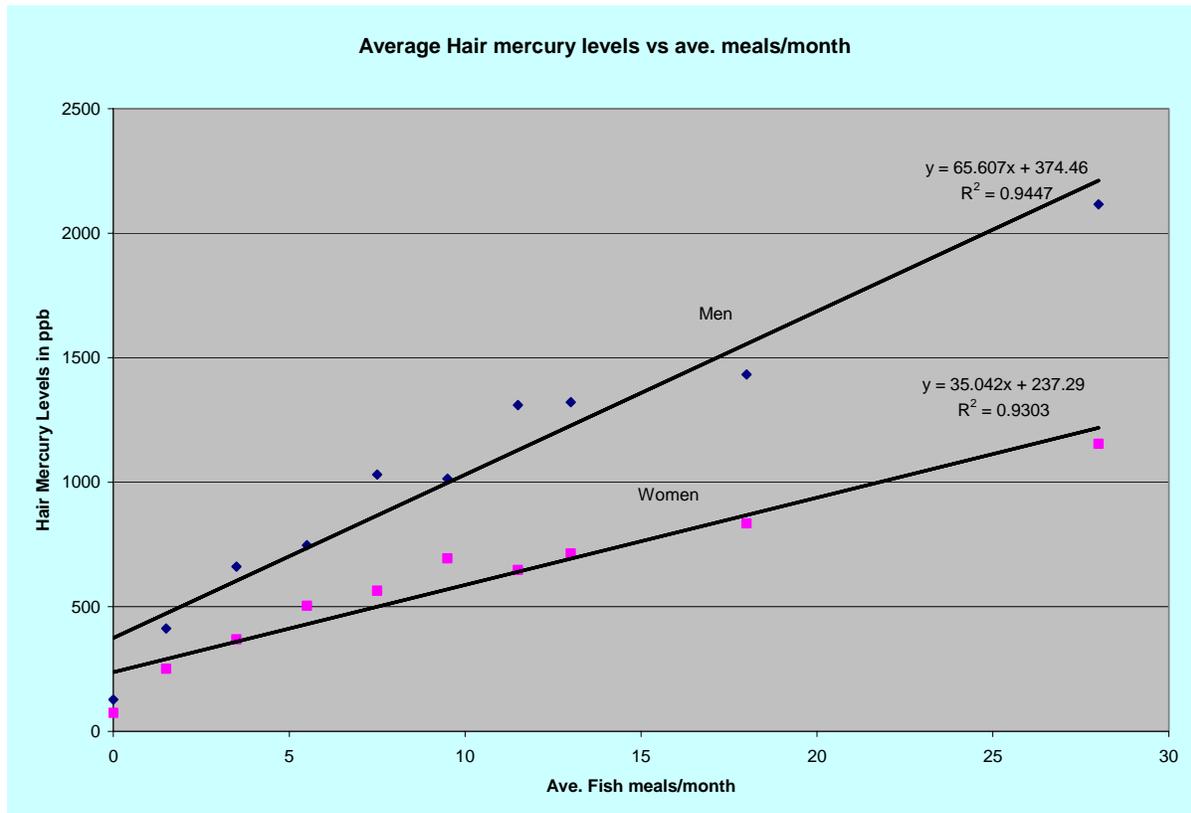
2,031 hair donors reported monthly consumption of 15,635 fish meals (ave 7.7 meals/month). This total included 3,701 (24%) tuna servings of which 1,898 servings (51%) were albacore tuna; 3,921 (25%) restaurant meals, 4,469 (29%) meals of fish that was purchased and prepared at home, and 2,628 (17%) meals of fish that were caught by the respondent or provided to them by someone they knew.

Hair Mercury Levels vs Fish Consumption

Mean hair mercury levels and the percentage of adults whose mercury result exceeded the guideline value of 1 ppm were correlated with monthly fish consumption estimates (see table and figure below).

Correlation of average hair mercury levels vs average no. of meals/month

No. of fish meals/month	Ave hair mercury levels (min, max)	No. of hair samples	% Results > 1 ppm
0	0.092 (0.012-0.731)	96	0
>0 - 2.9	0.322 (0.013-3.69)	175	8 (5%)
3.0 - 4.9	0.529(0.030-6.52)	394	53 (13%)
5.0 - 6.9	0.623 (0.021-4.53)	358	60 (17%)
7.0 - 8.9	0.823 (0.022-5.18)	320	90 (28%)
9.0 - 10.9	0.836 (0.044- 9.45)	206	62 (30%)
11.0 - 15.9	0.959 (0.048-11.00)	307	98 (32%)
≥ 16	1.290 (0.047-15.2)	172	61 (35%)
0-60	0.714 (0.012-15.2)	2,028	414 (20.4%)



Projected Mercury Exposure Levels among Wisconsin Residents

Fish consumption data provided by hair donors and BRFSS participants were combined to predict the number of Wisconsin residents and number of Wisconsin women of childbearing-age who consume enough fish to be at risk of exceeding the current federal exposure guideline for methylmercury . As shown in the following tables, more than 400,000 men and women who live in Wisconsin consume fish often enough to have a hair mercury level greater than 1 ppm. This number includes more than 50,000 women of child-bearing age.

Projected no. of Wisconsin Adults with Hair Mercury Levels > 1 ppm

Ave. no Fish Meals per Month	Estimated no. of WI Residents Who Consume This Amount	% of Hair Mercury Levels >1 ppm at this Intake Rate	Estimated population. with hair mercury > 1 ppm
0	667,248	0%	0
> 0 - 2.9	1,072,128	5%	57,017
3-4.9	1,168,414	13%	152,408
5-6.9	438,257	15%	66,002
7-8.9	191,554	23%	44,472
9-10.9	134,674	29%	39,195
11-19.9	108,605	35%	38,064
≥ 20	97,038	41%	39,969
Total population	3,877,918	11%	437,127

Projected no. of Women aged 18-45 years with Hair Mercury Levels > 1 ppm

Ave. no fish meals per month	Estimated no. of women aged 18-45 years who consume this amount	% of Mercury Results >1 ppm among Women	Estimated no. of women with hair mercury > 1 ppm
0	273,264	0%	0
>0-2.9	268,376	5%	13,419
3 – 4.9	261,672	5%	13,084
5-6.9	77,187	9%	6,947
7-8.9	37,663	17%	6,403
9-10.9	34,406	20%	6,881
11-19.9	20,680	24%	4,963
≥20	13,371	37%	4,947
Total population	986,619	6%	56,644

Projected no. of Women aged 46 and older with Hair Mercury Levels > 1 ppm

Ave. no Fish Meals per Month	Estimated no. Who Consume This Amount	% of Mercury Results >1 ppm	Estimated population. with hair mercury > 1 ppm
0	108,250	0%	0
1-2.9	258,771	0%	0
3-4.9	350,204	8%	28,016
5-6.9	119,351	11%	13,129
7-8.9	60,398	10%	6,281
9-10.9	33,295	25%	8,204
11-19.9	26,952	21%	5,663
≥ 20	23,659	21%	5,018
Total population	980,880	7%	66,311

Projected no. of Men with Hair Mercury Levels > 1 ppm

Ave. no Fish Meals per Month	Estimated no. of Men Who Consume This Amount	% of Mercury Results >1 ppm among Men	Estimated population. with hair mercury > 1 ppm
0	285,734	0%	0
>0 - 2.9	544,981	8%	43,598
3 – 4.9	556,538	20%	111,308
5 – 6.9	241,719	19%	45,927
7 – 8.9	93,493	34%	31,788
9 - 10.9	66,973	36%	24,110
11 – 19.9	60,973	45%	27,438
> 20	60,008	50%	30,004
Total population	1,910,419	16%	314,172

Projected no. of Licensed Anglers with Hair Mercury Levels > 1 ppm

Ave. no Fish Meals per Month	Estimated no. of Licensed Anglers Who Consume This Amount	% of Mercury Results >1 ppm among Licensed Anglers	Estimated no. of anglers with hair mercury >1 ppm
0	1,648	0%	0
1-2	452,082	9%	40,687
3-4	511,260	21%	107,365
5-6	198,279	20%	39,656
7-8	92,759	30%	27,828
9-10	61,366	35%	21,478
11-20	49,907	34%	16,968
>20	63,385	35%	22,185
Total population	1,430,686	19%	276,167

Summary and Discussion

This study is among the first to assess mercury exposure among Wisconsin residents. Our finding that a high percentage of men have hair mercury levels above the federal guideline of 1 ppm is novel since only a few studies have assessed hair mercury levels in men in the US and no previous studies have been conducted in Wisconsin. Until recently, fish consumption guidelines were targeted at women of childbearing age and children. As a result, most men have little awareness of the health effects of methylmercury or the need to limit their consumption of large, predatory fish that are often contaminated with mercury.

As part of the National Human Exposure Assessment Survey (NHEXAS), a probability-based population scoping study conducted by EPA Region V, mercury exposure was assessed among 182 randomly selected residents of several Midwestern states (Pellizzari, et al. 1999). Hair samples collected between June 1995 and July 1997 from 81 males and 101 females of all ages were analyzed for mercury. Mercury levels among these samples ranged from 0.012 to 3.5 ppm and were slightly higher among women (annualized means 0.315 in women vs 0.260 in men). The 1999 CDC NHANES assessment of hair mercury levels among women of childbearing age identified 50th and 90th percentile values of 0.2 and 1.4 ppm, respectively (MMWR, 2001). The US EPA has estimated from food consumption surveys, that approximately 7% of women exceed the advisory for methylmercury ingestion and have hair mercury levels above 1 ppm.

Methylmercury levels among women who provided hair for analysis and fish consumption information from BRFSS participants are consistent with this estimate.

People who consume fish more than twice a month have a significant risk of exceeding federal guidelines for methylmercury exposure. Their risk increases with the number of meals they consume. However, the majority of people who consumed fish several times a week had hair mercury levels below 1 ppm. This result is consistent with our finding that most Wisconsin residents know about mercury contamination in certain types of fish and might be selecting fish that are low in contamination.

Findings presented in this report provide a baseline for future mercury exposure assessments in Wisconsin. In addition, they can be used to gauge the success of existing fish consumption advisories issued by the Wisconsin Department of Natural Resources (WDNR) and the US Food and Drug Administration and to determine the need for additional, more targeted advisories.

References:

- American Heart Association. 2004. Eating Plan: Meat, Poultry, Fish. URL: www.americanheart.org.
- Bakir F., Damluji S.F., Amin-Zaki L., Murtadha M., Khalidi A., Al-Rawi Y., et al. 1973. Methylmercury Poisoning in Iraq. *Science* 181, 230-241.
- Clarkson T.W. 1977. Mercury poisoning. *Dev Toxicol Environ Sci* 1, 189-200.
- FDA, 2004. Mercury Levels in Commercial Fish and Shellfish. U.S. Department of Health and Human Services and U.S. Environmental Protection Agency. <http://www.cfsan.fda.gov/~frf/sea-mehg.html>
- Harada, M. 1995. Minamata Disease: Methylmercury poisoning in Japan caused by environmental pollution. *Crit. Rev. Toxicol.* 25:1, 1-24.
- Jalili H.A. and A.H. Abassi. 1961. Poisoning by ethyl mercury toluene sulphonamide. *Br. J. Ind. Med.* 18, 303-308.
- MMWR. 2001. Blood and hair mercury levels in young children and women of child-bearing age – United States 1999. 50:8, 140-143.
- National Academy of Sciences. 2000. Toxicological Effects of Methylmercury. National Academy Press, Washington DC.
- Pellizzari E.D., Fernando R., Cramer G.M., Meaburn G.M., Bangerter K. 1999. Analysis of mercury in hair of EPA Region V population. *Journal of Expos Anal and Environ Epidemiol.* 9:393-401.
- Salonen J.T., Seppanen K., Nyyssonen K., Korpela H., Kauhanen J., Kantola M., Tuomilehto J., Esterbauer H., Tatzber F., Salonen R. 1995. Intake of mercury from fish, lipid peroxidation, and the risk of myocardial infarction and coronary, cardiovascular, and any death in Eastern Finnish Men. *Circulation* 91(3):645-655.
- Smith W. E. and Smith A. M. 1975. Minamata. New York: Holt, Rinehart and Winston.
- Sorenson, N., Murata K., Budtz-Jorgensen, E., Weihe P., Grandjean P. 1999. Prenatal methylmercury exposure as a cardiovascular risk factor at seven years of age. *Epidemiology* 10(4):370-377.
- USEPA. 1997. Mercury Study Report to Congress, Vol 5. Health Effects of Mercury and Mercury Compounds.
- Virtanen JK.; Voutilainen S; Rissanen T H; Mursu J; Tuomainen TP; Korhonen MJ.; Valkonen VP; Seppänen K; Laukkanen JA.; Salonen JT. 2005, Mercury, fish oils, and risk of acute

coronary events and cardiovascular disease, coronary heart disease, and all-cause mortality in men in Eastern Finland. *Arteriosclerosis, Thrombosis, and Vascular Biology*, 25(1):228-233.

Wisconsin Department of Natural Resources. 2004. Choose Wisely. PUB-FH-824. Madison, WI.

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