(3) By October 1, 2007, the owner or operator of a major utility shall submit a compliance plan to the department demonstrating how the combustion units of the major utility are going to meet the mercury reduction requirements of s. NR 446.06(2). The plan shall include, at a minimum, the following information:

(a) A detailed listing of the combustion units on which mercury pollution control equipment will be installed.

(b) A detailed listing of the combustion units which will switch to a lower mercury content fuel.

(c) A detailed description of any plans to improve the combustion efficiency of individual emissions units to meet the requirements of s. NR 446.06(2).

(4) By October 1, 2011, the owner or operator of a major utility shall submit an update to the compliance plan submitted under sub. (3) to demonstrate how the combustion units of the major utility are going to meet the emission reduction requirement of s. NR 446.06(3).

(5) By March 1, 2009 and no later than March 1st of each following year, the owner or operator of a major utility shall submit a compliance certification report to the department certifying that the mercury emissions from the major utility during the preceding calendar year were in compliance with the emission limit requirements of s. NR 446.06, based on the determination made under s. NR 446.09. If the mercury emissions from the major utility from the previous year exceeded the emission limit requirements of s. NR 446.06, the compliance certification report shall include all of the following information:

1. An identification of the amount and cause of the excess mercury emissions.

2. A demonstration of how the major utility will achieve additional emission reductions in the current year equivalent to the excess mercury emissions.

3. A demonstration of how the major utility will comply with the emission limit requirements in subsequent years.

NR 446.09 Annual mercury emissions determination and reporting. (1) The owner or operator of an emissions unit subject to the requirements of s. NR 446.06 shall determine and report to the department by March 1, annual mercury emissions for each emissions unit, beginning with calendar year 2008 emissions, using the following formula:

Annual Mercury Emissions = Fuel Use X Mercury Content of Fuel X Reduction of Mercury Prior to its Release to the Atmosphere

where:

(a) Fuel use is the amount of fuel combusted in the combustion unit, as measured by the procedures specified in Appendices A, B, C and F of 40 CFR part 75, incorporated by reference in s. NR 484.04(26m)(a) to (d). The total amount of the fuel combusted in mmBtus may be apportioned to individual fuels, using consumption and delivery records for the fuels

(b) Mercury content of the fuel is determined according to ASTM D3684-01, incorporated by reference in s. NR 484.10(47m), or an equivalent method approved by the department, following the procedures in s. NR 446.04 (1), (2) and (3).

(c) Reduction of mercury is calculated through source performance tests which follow the procedures in this paragraph. A value of one is assumed for natural gas fired combustion units that are exempt from performance testing under sub. (6).

1. The source performance test shall be conducted according to EPA Method 101A in Appendix B of 40 CFR part 61, incorporated by reference in s. NR 484.04(23), or EPA Method 29 in Appendix A of 40 CFR part 60, incorporated by reference in s. NR 484.04(20m).

2. A sample of the fuel burned during the test shall be analyzed for mercury content, using ASTM D3684-01, incorporated by reference in s. NR 484.10 (47m), or an equivalent method approved by the department. During each of the 3 runs of the performance test, a separate sample of the fuel being burned during the run shall be collected and analyzed.

3. During the source performance testing, the consumption of fuel shall be monitored and recorded.

4. The major utility shall submit to the department the information obtained in subds. 1. to 3. and the calculations for the percent removal efficiency of mercury.

(d) The department may require that more than one source performance test be conducted if a single test is determined to be non-representative of conditions at the combustion unit.

(2) Nothing in this section shall prohibit the department from requiring major utilities to use other methods of determining annual mercury emissions.

(3) The owner or operator of a major utility may request that alternative methods for determining annual mercury emissions be approved by the department.

(4) In addition to the performance test required under s. NR 446.06(1)(b), the owner or operator a major

utility shall conduct source performance tests of the utility's combustion units according to the following schedules:

(a) All units subject to s. NR 446.06, with an electrical generating capacity equal to or greater than 200 MW, and all units that undergo process changes or change control equipment after January 1, 2006, shall have source performance tests conducted during calendar years 2010, 2013, 2015 and biennially thereafter.

(b) All units subject to s. NR 446.06, with an electrical generating capacity of less than 200 MW, and which do not undergo process changes or changes to control equipment after January 1, 2006, shall have source performance tests conducted during calendar year 2015 and every 4 years thereafter.

(5) The owner or operator of a major utility shall use the results of the most recently conducted source performance test for calculating the reduction efficiency under sub. (1)(c).

(6) Combustion units subject to s. NR 446.06 that exclusively combust natural gas are not subject to the source performance testing requirements of this section.

NR 446.10 Variance for major utilities. (1) The owner or operator of a major utility may request a variance from the emission reduction requirements of s. NR 446.06 (2) or (3) by submitting a written request to the department and the commission. The request shall provide sufficient information concerning the conditions or special circumstances on which the variance request is based to demonstrate to the department's satisfaction that a variance from the applicable requirements is necessary. In addition, the request shall include the following:

(a) Where an alternative compliance schedule is sought, the owner or operator shall submit a proposed schedule which demonstrates reasonable further progress and contains a date for final compliance as soon as practicable.

(b) Where an alternative reduction requirement is sought, the owner or operator shall submit a proposed reduction requirement.

(c) Requests for variances shall contain relevant information on the costs and technological feasibility of meeting the reduction requirements as required by the department.

(2) Requests for a variance from the reduction requirements in s. NR 446.06(2) shall be received by October 1, 2007.

(3) Requests for a variance from the reduction requirements in s. NR 446.06(3) shall be received by October 1, 2011.

(4) The department may grant a variance that sets an alternative reduction requirement or schedule, or both.

(5) The department may grant a variance if the owner or operator demonstrates to the department's satisfaction that the reduction requirements in s. NR 446.06 are technologically or economically infeasible.

(6) The department may grant a variance that sets an alternative schedule if the owner or operator demonstrates to the department's satisfaction that the delay is needed to complete installation and place into operation control technology to achieve compliance with a reduction requirement in s. NR 446.06.

(7) Within 90 days of the receipt of a completed request, the department shall publish a public notice on each variance request and the department's preliminary determination to grant or deny the request, to provide the opportunity for public comments including, where requested, a public hearing on the variance request. Following the public comment period, the department shall notify the variance applicant in writing of the reasons for denying, granting or for granting in a modified form any request for a variance.

(8) The department may, after notice and opportunity for hearing, revoke or modify any variance when any term or condition of the variance has been violated.

NR 446.11 Electrical supply reliability waiver. (1) The owner or operator of a major utility may request that the department grant a waiver from meeting the mercury emission cap in s. NR 446.06(1) or an emission reduction requirement in s. NR 446.06(2) or (3) if the major utility demonstrates that the failure was due to one of the following:

(a) A major electrical supply emergency within or outside this state that affected the major utility.

(b) A major fuel supply disruption that affected the major utility.

(c) An unanticipated and unavoidable disruption in the operation of a fossil fuel fired unit at the major utility.

(2) The owner or operator of a major utility shall submit a written request for waiver within 60 days after the date that the annual compliance report required in s. NR 446.09 is due.

(3) The request shall provide sufficient information concerning the conditions on which the waiver request is based to demonstrate to the department's satisfaction that a waiver from the applicable requirements is warranted. In addition, the request shall include the following:

(a)The duration of the conditions during the calendar year.

(b) The specific measures taken to mitigate mercury emissions during the duration of the conditions or to limit annual mercury emissions after the condition has ended.

(c) The reasons why the major utility was unable to achieve compliance with a baseline mercury emission requirement or an emission reduction requirement.

(4) The department may grant a waiver under this section if, in consultation with the commission, the department determines that the major utility's failure to meet a requirement under s. NR 406.06 was due to a condition listed in sub. (1).

(5) Within 60 days after the receipt of a completed request, the department shall publish a public notice on each waiver request and the department's preliminary determination to grant or deny the request, to provide the opportunity for public comments including, where requested, a public hearing on the waiver request. Following the public comment period, the department shall notify the applicant in writing of the reasons for denying, granting or granting in a modified form any request for a waiver.

NR 446.12 Periodic evaluation and reconciliation reports. (1) The department staff shall submit reports to the natural resources board and the presiding officer of each house of the legislature for referral to the appropriate legislative standing committees by January 1, 2006, by January 1, 2009 and by January 1, 2013. Each report shall include:

(a)An evaluation of the scientific and technology developments in relation to the control or reduction of mercury emissions.

(b) An evaluation of whether the requirements of s. NR 446.06 are achievable, given the scientific and technological developments.

(c) Recommendations for revisions to this subchapter or other actions based on the scientific and technological developments.

(d) An assessment of the impact of the compliance alternatives on mercury concentrations in locally affected water bodies.

(2) In addition to the reports required under sub. (1), the department staff shall report to the natural resources board and the presiding officer of each house of the legislature for referral to the appropriate legislative

standing committees within 6 months of the date of the promulgation of a federal regulation under section 111 or section 112 of the Act (42 USC 7411 or 7412) or the enactment of a federal law that has mercury reduction requirements for mercury emission sources affected by this subchapter. The report shall include:

(a) A comparison of the requirements.

(b) Recommendations for revisions to this subchapter or other actions to reconcile the requirements.

(3) The natural resources board shall review these reports and, if they include recommendations for rule revisions or other actions, determine whether the department should proceed with actions based on the recommendations.

SECTION 18. NR 446 Subchapter III (title) preceding s. NR 446.14 is created to read:

NR 446 (title) **Subchapter III - Emission Standards for Mercury.**

SECTION 19. NR 446.14 (title) and (intro.) are created to read:

NR 446.14 (title) **Mercury emission limits.** (intro.) No person may cause, allow or permit emissions of mercury:

SECTION 20. NR 484.04(20m) and (26m) are created to read:

CFR Appendix Referenced	Title	Incorporated by Reference For
NR 484.04 (20m) 40 CFR part 60 Appendix A, Method 29	Determination of Metals Emissions from Stationary Sources	NR 446.09(1)(c)1.
(26m)(a) 40 CFR part 75 Appendix A	Specifications and Test Procedures	NR 446.04(3) NR 446.09(1)(a)
(b) 40 CFR part 75, Appendix B	Quality Assurance and Quality Control Procedures	NR 446.04(3) NR 446.09(1)(a)
(c) 40 CFR part 75, Appendix C	Missing Data Estimation Procedures	NR 446.04(3) NR 446.09(1)(a)
(d) 40 CFR part 75 Appendix F	Conversion Procedures	NR 446.04(3) NR 446.09(1)(a)

SECTION 21. NR 484.05(9) is amended to read:

Document Reference	Document Title	Incorporated by Reference For

NR 484.05 (9)	EPA-450/3-84-014, December 1984	Review of National Emission Standards for Mercury	NR ~~446.04~~ 446.15(3)(d)Note

SECTION 22. NR 484.10(47m) is created to read:

Standard Number	Standard Title	Incorporated by Reference For
NR 484.10 (47m) ASTM D3684-01	Standard Test Method for Total Mercury in Coal by Oxygen Bomb Combustion/Atomic Absorption Method	NR 446.027(1)(b) NR 446.04(1) NR 446.04(2) NR 446.09(1)(b) NR 446.09(1)(c)2.

SECTION 23. EFFECTIVE DATE. This rule shall take effect on the first day of the month following publication in the Wisconsin administrative register as provided in s. 227.22 (2) (intro.), Stats.

SECTION 24. BOARD ADOPTION. This rule was approved and adopted by the State of Wisconsin Natural Resources Board on June 25, 2003 and June 25, 2004..

Dated at Madison, Wisconsin _____.

STATE OF WISCONSIN
DEPARTMENT OF NATURAL RESOURCES

By_____
Scott Hassett, Secretary

(SEAL)

AUG 11 2003

Wisconsin Wildlife Federation

720 ST. CROIX ST., SUITE 101, PRESCOTT, WI 54021 • (715) 262-9279 • 1-800-897-4161

AFFILIATED WITH NATIONAL WILDLIFE FEDERATION

June 29, 2003

Senator Neal Kedzie
Room 313 South
State Capitol

Re: Proposed Mercury Emission Reduction Rule

Dear Senator Kedzie: Neal

Thank you for taking the time to read this letter about the health impacts of mercury in Wisconsin fish. The Wisconsin Wildlife Federation is comprised of 82 hunting, fishing and trapping organizations located throughout the State of Wisconsin. Our members do a great deal of fishing and are genuinely concerned about serving the fish that they catch to their spouses and their children. **This is a real life day-to day health issue for our members.**

Our members are concerned that studies by National Academy of Science and the Center for Disease Control indicate that 1 out of 12 women in the United States have blood mercury levels in excess of that deemed safe from a health standpoint and that 60,000 children born each year in the United States may have their health impaired by the presence of mercury in their bodies. The source of mercury in most humans is the ingestion of fish contaminated with mercury.

I have included some articles that address the issue further. The first documents the tougher standards for mercury in food proposed by the World Health Organization. The second tells the story of Buddy Henk, a Wisconsin fisherman, who became seriously ill from mercury contamination after eating the fish he caught from Windago Lake in Sawyer County. Lastly I would like to share with you a recent article on mercury poisoning from fish consumption that appeared this summer in *Health* magazine.

Please read these materials and keep these public health considerations in mind as you deliberate the proposed mercury emission reduction rule. The Wisconsin Wildlife Federation will be sharing additional information to support with you in support of the rule but we are sending you this information now to emphasize that this issue is about the health of our families. Once again thank you for some of your valuable time.

Very truly yours,
George
George E. Meyer

Neal — Also please note the research by Kurt Watrous documenting that emission reductions will lower mercury in our lakes

Wisconsin Wildlife Federation

720 ST. CROIX ST., SUITE 101, PRESCOTT, WI 54021 • (715) 262-9279 • 1-800-897-4161

AFFILIATED WITH NATIONAL WILDLIFE FEDERATION

Testimony before the Natural Resources Board for Mercury Air Emission Reductions

Good morning Mr. Vice-Chair and Members of the Board. The Wisconsin Wildlife Federation would like to thank you for the opportunity to testify on this important new regulation. The Wildlife Federation is the largest conservation organization in Wisconsin made up of 82 hunting, fishing and trapping organizations located throughout the State of Wisconsin. We are also the Wisconsin affiliate of the National Wildlife Federation.

The Wisconsin Wildlife Federation was one of the initial petitioners for mercury emission reduction rules .We are testifying here today in support of the rule, but in all candor, we barely support the proposed regulations and request that this Board strengthen the rules by increasing the rate of reductions to 90%, basing the reductions on actual current emissions rather than coal content and restoring the 150% offset for future increased mercury emissions.

This is a health issue to our members. They are very active anglers and they are concerned that the fish that they bring home to their spouses and children are heavily contaminated by mercury. They are concerned that studies by the National Academy of Science and the CDC indicate that 1 out of 12 women in the United States have blood levels in excess of that deemed safe from a health standpoint and that 60,000 children in the US have had their health impaired by the presence of mercury in their bodies. The source of mercury in most humans is the ingestion of fish contaminated with mercury. This Board has the responsibility to act to reduce this health hazard to Wisconsin citizens.

Some will argue for no or weak mercury regulations in Wisconsin because of adverse economic impacts to business. However the absence of strong mercury regulations is very harmful to the many resorts, bait shops, gas stations and restaurants that depend on fishing for their tourism business. The traditional first question to resort owners is: How is the fishing? The current second question is now: What is the fish advisory on your lake? Businesses should not be able to harm human health or the livelihood of other businesses by emitting dangerous pollutants into the air.

You will hear from some that Wisconsin should not act because Wisconsin emissions are a small percentage of total global emissions. That ignores the fact that Wisconsin sources contribute the substantially highest percentage of the mercury that falls in our waters. If we reduce our emissions we can make a significant contribution to the reduction of mercury in our waters. Secondly, we do need strong federal regulations to ultimately improve the health of our citizens---stronger than those currently proposed. How can

Secretary Hassett or the Wisconsin Congressional delegation fight for tough new federal regulations for Wisconsin citizens if Wisconsin does not act or if it only adopts a 60 % to 65% mercury reduction level----which is the actual reduction of mercury in the rule before you today-----it is not an 80% reduction or the 90% reduction so strongly called for by the public at the hearings on this rule.

In the similar situation in 1986, Wisconsin led the nation by adopting strong acid rain regulations. Not only did they work well in Wisconsin from both an environmental and economic standpoint, they became the model for the acid rain provisions of the Clean Air Act Amendments off 1990. That is the opportunity and I would argue the responsibility that you have before you today.

You are not alone in making this decision. Both the states of Connecticut and North Carolina have adopted mercury emission reduction provisions stronger than those before you today.

The Wisconsin Wildlife Federation, while supporting the proposed rule, strongly requests you to modify its provisions to require the reduction of mercury emissions by 90% of the current emissions and require the offset of 150% for new mercury emissions.

In conclusion, in April of this year, 82% of Wisconsin voters spoke loudly by adopting the Constitutional Amendment Right to Fish. Two weeks ago one of my members said to me, "you know, when we adopted the constitutional right to fish, I thought that included the right to eat the fish." It is up to this Board to determine whether our rights include the right to eat our fish.

MERCURY MAN

Although children and fetuses are the most at risk from mercury poisoning, there is at least one person who would warn adults to be careful how many and which fish from Wisconsin waters they eat too. That person is Henry (Buddy) Henk Jr. He learned the hard way—real hard.

The headline in the March 3rd 1993 edition of the Duluth News-Tribune read "Love of fish almost kills man." Buddy Henk always loved fish—he'd eat fish every chance he had. "I'd eat fish for two or three meals in a day and then snack on pickled fish while watching TV the way other people snack on potato chips," remarked Henk. "I was a regular Swede."

Henk especially liked eating northerns and got nearly all of his northerns from Windago Lake just a couple miles from his home south of Hayward in Sawyer Co. Windago Lake is one of the 275 lakes on the DNR's health advisory listing of lakes with unsafe levels of mercury in some of the fish. Henk's fish eating frenzy apparently peaked in December of 1991 when he ate more than 40 northerns ranging in size from 18 to 32 inches, all from Windago Lake. The DNR's health advisory recommends that no one eat more than 26 meals of 18 to 22 inch Windago Lake Northerns in a year, and no more than 13 of those meals in any one month. Fish over 26 inches should be eaten less often.

Just two months later, Henk was already feeling the adverse affect, apparently, of his high-fish diet. Between February and November of 1992 Henk experienced sores that wouldn't heal, tremendous leg and back pain, eventual loss of all feeling in his legs and a 100 pound weight loss. He stopped eating fish for the same reason he stopped eating nearly everything—he had no appetite and his throat muscles had atrophied to the point where he couldn't swallow anything but soft cereal. His body was deteriorating quickly. "He was a dying man," said Henk's wife Sue.

His mind was deteriorating too. Henk checked into two hospitals over this period; the second was St. Mary's Medical Center in Duluth on November 3rd. There Henk suffered hallucinations. "I was flying planes in bed. I went crazy. They had to restrain me with a straight jacket. I didn't recognize my own wife. I ground my teeth down to the bone," said Henk.

Photo courtesy of Terry Boettcher

Doctors in Duluth performed a litany of tests on Henk. Tests on his blood, his urine , his spinal fluid—a nerve biopsy test, muscle and nervous reaction tests. All tests came back negative. While discussing the puzzling diagnosis effort with a nurse, Henk's wife mentioned his affinity for fish. Doctors sent a sample of Henk's hair to the Mayo Clinic in Rochester Minnesota for mercury testing. It came back showing an elevated mercury level, though not as high as the doctors might have expected given his extreme symptoms. The next day Henk's bedside chart read "severe mercury toxicity," and doctors began to give him D-Penicillamine, a drug that draws mercury out of the body tissue. Within days the symptoms began reversing—his appetite returned, the hallucinations stopped and the restraints were removed. After several weeks of physical therapy and rehabilitation at Miller-Down Medical Center, Henk returned home on December 23rd 1992 for long-term recuperation.

Public health officials in Wisconsin could not make a definitive finding to confirm that Henk's case was one of acute mercury poisoning because blood tests for mercury were not drawn prior to treatment and while Henk was eating fish. Hair tests for mercury levels can be quite variable, and therefore, are not considered as reliable as blood. But if you ask Buddy Henk, he laughs and says there's no doubt it was mercury poisoning: "I don't recommend that diet to anyone," said Henk.

Henk blames himself though because he knew Lake Windago was on the DNR's fish advisory when he was eating the northerns from it. He wants others to know too. "I think they should put a sign up at each boat landing—they have two signs up to protect the loons," said Henk. "If it keeps one person from going through what I went through I'd be worth it."

Source: "Area man says mercury-tainted fish almost killed him," March 10, 1993, Terrell Boettcher, Sawyer County Record; "Love of fish almost kills man," March 3, 1993, Susan Stanich, Duluth News-Tribune; Buddy Henk, personal communication.

U.N. panel sets strict limits for mercury in food

WASHINGTON (AP) — The United Nations' World Health and Food and Agriculture organizations recommended tougher standards for levels of mercury in food on Friday, citing concerns that pregnant women who eat fish are exposing their children to harmful levels.

The Joint FAO/WHO Expert Committee on Food Additives recommended the reduction of weekly methyl mercury intake levels to 1.6 micrograms per kilograms of bodyweight — nearly half the original standard of 3.3 micrograms per kilograms.

The recommendation by the panel is more stringent than the weekly standard of 2.8 micrograms of mercury per kilogram set by the Food and Drug Administration.

Scientists say children exposed to high levels of mercury when they're in the womb are at risk of developing disabilities.

FDA officials said they will consider the commission's latest recommendations. The agency is under pressure from consumer groups to change its standard.

The recommendation by the panel is more stringent than the weekly standard of 2.8 micrograms of mercury per kilogram set by the Food and Drug Administration.

The Environmental Working Group, a consumer watchdog organization, said the committee had taken an important step toward protecting pregnant women and their unborn children, and the United States should consider doing the same.

"It sort of isolates the FDA as the weakest standard in the world," said Richard Wiles, senior vice president for the group. "It leaves us unprotected."

Michael Bender, director of the Mercury Policy Project, said the new recommendations "are more reflective of the latest science."

"While fish is a good source of protein, we urge caution when consuming predatory fish with higher mercury levels," Bender said.

The FDA says mercury vapors emanating from burned industrial waste may change into a more dangerous form, methyl mercury, when they enter water bodies. The new mercury form may taint fish, and cooking does not get rid of it.

Scientists have warned women to beware of possibly harmful levels of methyl mercury in fish — but also say that there is no need for them to completely remove the highly nutritious food from diets. In its recommendation Friday, the committee also underscored fish's value as a good source of protein.

On the Net: Joint FAO/WHO Expert Committee on Food Additives: www.codexalimentarius.net/jecfa.stm; Food and Drug Administration: www.fda.gov

Frank Lasee

State Representative • 2nd Assembly District

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July 29, 2003

State Senate
Neil Kedzie
313 South, State Capitol
District 11
P.O. Box 7882
Madison 53707-7882

Dear Senator Kedzie,

Last month, the DNR Board voted to enact new rules governing mercury emissions in Wisconsin. I agree with their decision in principle: mercury is a toxic substance, which must be regulated.

However, mandating 80% reductions for Wisconsin businesses will not have a meaningful effect on pollution in Wisconsin's environment. That's because mercury is a national problem – not a local problem. Mercury emissions from other, nearby states drift into Wisconsin, coming to rest in our lakes and rivers. Even environmental groups, including the DNR, admit that at least 50% of mercury found in Wisconsin originates in other states. Other estimates put the amount as high as 90%.

At the same time, these new rules will have a negative effect on Wisconsin's economy. This is a particularly bad time for us to tell businesses that it's going to cost more to do business here. Wisconsin typically follows 12-18 months behind the national economy, which has only begun to crawl up out of the doldrums of the past few years, and which may still fall back down.

Approving the new rule would tell business that Wisconsin is still an over-regulated state where bureaucracy comes first, while failing to solve the problem. I urge you to reverse this rule, and call upon our congressional delegation to enact sensible legislation at the federal level.

Sincerely,

Frank G. Lasee
State Representative
2nd Assembly District

Firm, Fair, Honest & Committed

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Recent declines in mercury concentration in a freshwater fishery: isolating the effects of de-acidification and decreased atmospheric mercury deposition in Little Rock Lake

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Received 21 April 2001; accepted 13 March 2002

Abstract

The atmospheric deposition of H^+, SO_4, and Hg to Little Rock Lake in northern Wisconsin has declined substantially during the past decade. Parallel decreases have been observed in the surface waters of the lake. Here we extend the observations to the fish community and we present evidence of a contemporaneous decline in levels of Hg in fish tissue. By comparing data from two separated basins of the lake, we then make an initial effort to isolate and quantify the relative importance of de-acidification and reduced Hg deposition on mercury contamination in fish. Statistical modeling indicates that fish Hg in both basins decreased by roughly 30% between 1994 and 2000 (−5%/y) due to decreased atmospheric Hg loading. De-acidification could account for an additional 5% decrease in one basin (−0.8%/y) and a further 30% decrease in the other basin (−5%/y), since the basins de-acidified at very different rates. These results are consistent with the hypothesis that depositional inputs of SO_4 and $Hg^{(II)}$ co-mediate the biosynthesis of methyl mercury and thereby co-limit bioaccumulation. And they suggest that modest changes in acid rain or mercury deposition can significantly affect mercury bioaccumulation over short-time scales. © 2002 Published by Elsevier Science B.V.

Keywords: Yellow perch; Mercury bioaccumulation; Methyl mercury; Atmospheric mercury deposition; Acid rain

1. Introduction

Human perturbation of the atmospheric cycles of sulfur and mercury has had a deleterious effect on aquatic resources across the northern hemisphere for several decades. The atmospheric transport, transformation and deposition of oxidized S emitted largely from coal combustion has depleted alkalinity, lowered pH, and altered the biological communities in many lakes and watersheds (Schindler et al., 1991). Atmospheric emissions of Hg from a variety of human sources (including coal combustion, waste incineration, smelting, chlor-alkali facilities, gold mining, and house paint) enhanced the net deposition of mercury to remote

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soils and sediments (Nriagu and Pacyna, 1988; Nater and Grigal, 1992; Swain et al., 1992). Both of these atmospheric perturbations may have exacerbated the problem of Hg contamination in freshwater fisheries, which has become widespread in North America and Europe (Lindqvist, 1991; Watras and Huckabee, 1994; Porcella et al., 1995).

Early synoptic surveys first suggested that fish contamination was related to both acidification and waterborne mercury concentrations Hg (Spry and Wiener, 1991). Mercury concentrations in fish tended to be highest in low pH waters and in waters known to be contaminated with Hg—but these observations provided no clear mechanistic insight. Gilmour and Henry (1991) established an important connection between acidification and fish mercury by demonstrating that the production of methyl mercury (MeHg) by sulfate-reducing bacteria (SRB) was dependent on aqueous $[SO_4]$, which in many lakes has a large atmospheric source. Mass balance studies on whole watersheds established the importance of atmospheric Hg deposition by demonstrating that the dominant source of inorganic Hg, ($Hg^{(II)}$), was precipitation (Baeyens et al., 1996). Atmospheric deposition, then, hypothetically provides two key substrates for the biosynthesis of MeHg, (SO_4 and $Hg^{(II)}$), which subsequently accumulates in aquatic food chains.

Although sediment geochronologies and other historical evidence clearly indicate that the emission and deposition of SO_x and Hg increased with industrialization over the past century (Lindberg et al., 1990; Baeyens et al., 1996), recent data suggest that this trend has reversed in some regions of the northern hemisphere due to pollution abatement policies enacted during the 1990s (Slemr, 1996; Engstrom and Swain, 1997; Stoddard et al., 1999; Munthe et al., in press). For the airshed and watershed of Little Rock Lake in northern Wisconsin, we recently documented strong declines in H^+ and SO_4 as well as significant decreases in Hg (Watras et al., 2000). The declining trends were observed in lake water and in precipitation over the past decade. The decline in H^+ and SO_4 was attributable to regional reductions in SO_2 emissions (WDNR, 1998), but the cause of declining Hg was not so clearly defined. It may have been the combined effect of regional decreases in smelting activity, the commercial and industrial use of Hg, and/or changes in the fuel mix of coal-burning power plants (Watras et al., 2000). In any case, the observations indicated that remote lake waters might respond quickly to reductions in atmospheric pollutants.

In this paper, we extend our observations on the airshed and watershed of Little Rock Lake to the fish community, which is dominated by yellow perch (*Perca flavescens*). Our objectives were to: (1) determine whether there have been declines in levels of fish Hg that parallel those seen in atmospheric deposition; and (2) to make an initial estimate of the relative effects of de-acidification and declining Hg deposition on fish Hg. The second objective was facilitated by the extensive database available for Little Rock Lake, which has been intensely monitored as an experimental ecosystem since 1984.

2. Methods

2.1. Study site and rationale

Little Rock Lake is an 18 ha precipitation-dominated seepage lake located in a forested and undisturbed catchment of north central Wisconsin (46°N, 89°W). In 1984, the lake was divided into two basins by placing an impermeable curtain across a narrows (Watras and Frost, 1989). One of the basins was then experimentally acidified from pH 6.1 to pH 4.7 by gradually mixing sulfuric acid into surface waters over a period of 6 years. The southerly basin was left undisturbed to serve as a reference. The purpose of this experiment was to investigate the biogeochemical and ecological effects of increasingly acidic rain (Brezonik et al., 1993). In 1990, the treated basin was allowed to de-acidify naturally—a process that was associated with the metabolic activity of SRB (Sampson, 1999). The time-course of acidification and recovery is illustrated graphically on Fig. 1.

During the course of the acidification experiment, a gradual decline in the background atmospheric loading of H_2SO_4 and Hg to both basins of the lake was observed (Watras et al., 2000). This decline has been attributed to regional decreases in anthropogenic emissions of SO_2 and Hg to the

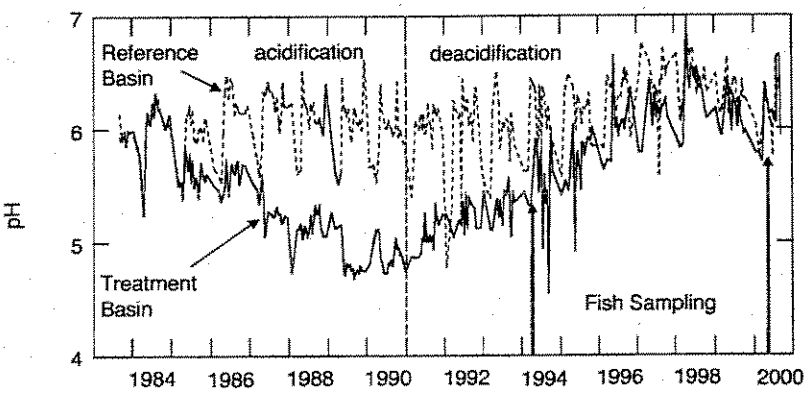

Fig. 1. Time trend of the experimental acidification and recovery of Little Rock Lake, Wisconsin, 1983–2000. Arrows indicate collection times for yellow perch (*Perca flavescens*) in the acidified (treatment, solid line) and un-acidified (reference, dashed line) basins of the lake. In 1994, the epilimnetic pHs were 5.5 and 6.07; and in 2000, they were 6.14 and 6.16, for the treatment and reference basin, respectively.

atmosphere. The drop in background depositional rates allowed us to compare Hg bioaccumulation in two parallel fisheries that were exposed to similar changes in Hg deposition but different changes in acid loading over a 6-year period. Since the two lake basins underwent different rates of de-acidification but the same decline in Hg loading, isolating the two effects was hypothetically possible—given some prior knowledge about the empirical relationship between pH and bioaccumulation.

2.2. Field collections and analytical procedure

Hg analysis was performed on yellow perch from each basin of Little Rock Lake collected during the summers of 1994 and 2000 using beach seines, fyke nets, AC electrofishing, and angling. The primary objective of the sampling scheme was to capture yellow perch of various sizes to examine variability in Hg concentration as it related to fish size, the year of collection and the acidification of one of the basins. Hg concentrations for whole yellow perch were obtained by analysis of ground homogenate for each individual fish. Analysis of the samples was performed at the Wisconsin State Laboratory of Hygiene using cold vapor atomic absorption spectroscopy (Sullivan and Delfino, 1982). Blanks from sample vials, calibration standards and a standard reference material were used to assure sample integrity. The limit of detection was ~4 ng/g. In the reference basin, Hg concentration was measured in 19 yellow perch ranging from 4.1 to 29.1 g in 1994, and 29 fish ranging from 6.1 to 52.9 g in 2000. In the treatment basin, Hg concentration was measured in 20 yellow perch ranging from 7.0 to 26.0 g in 1994, and 30 fish ranging from 18.6 to 113.6 g in 2000. Fish analyzed in either year were 5 years old or less. By using relatively young fish, the inclusion of fish from the 1994 cohort in 2000 subset of data was avoided.

2.3. Statistical analyses

We first tested for differences in growth rates among fish collected in each basin of the lake by examining for differences in size at age. We fit the von Bertalanffy growth model (von Bertalanffy, 1938; Ricker, 1975) to length at age data for all fish analyzed for mercury concentration from each basin, then for a pooled data set that included all fish analyzed. This growth model takes the form:

$$l_t = L_\alpha(1 - e^{-K(t-t_0)}) \quad (1)$$

where l_t = length at age t, L_α = asymptotic length, K = the Brody growth coefficient, and t_0 = the age intercept term. We tested for differences in growth among basins by examining for differences in the

variance ratio (F). We compared the variance from model estimates produced by the least squares fit for the data pooled from each basin to variance from those parameter values produced from fits for data from each individual basin. These variance ratios (F ratios) were then compared to critical values of the F distribution to determine if significant differences in growth existed among basins. Also, to test for age specific differences in size, we used pair-wise t-tests as well as Kolmogorov–Smirnov paired distribution tests to examine size distributions of fish of each age (1–5) for differences between basins.

Variability in the Hg concentration of yellow perch owing to fish weight (log-transformed), changes in pH and Hg deposition rates was assessed using linear regression analysis. Analysis of covariance (ANCOVA) was used to test for variability in fish Hg concentration owing to fish weight and the year of collection, where the year of collection is associated with measured differences in atmospheric deposition rates and lake pH. If significant differences in the slope of the relationship between weight and mercury concentration exist among the reference and treatment basins, the interaction between weight and basin would explain significant variance (at $\alpha < 0.05$).

After finding no significant interaction between year and log-weight, a generalized linear model of Hg concentration as a function of log-transformed fish weight and a dummy variable for year of collection was used to estimate the magnitude and direction of changes in fish Hg concentration through time. This simplified model was

$$Hg_{fish} = b_0 + b_1(\log \text{Weight}) + b_2(\text{Year}) \quad (2)$$

where Year was assigned a value of 1 or 0 (1994 or 2000). The coefficient b_2 and standard error associated with the term was used to estimate the magnitude of the shift for each basin. This change (ΔHg) was then compared to changes in atmospheric deposition and water chemistry that have occurred between 1994 and 2000.

All model fitting and statistical procedures were performed using Systat statistical software (SPSS Inc. v. 9) using methods described in Wilkinson et al. (1996).

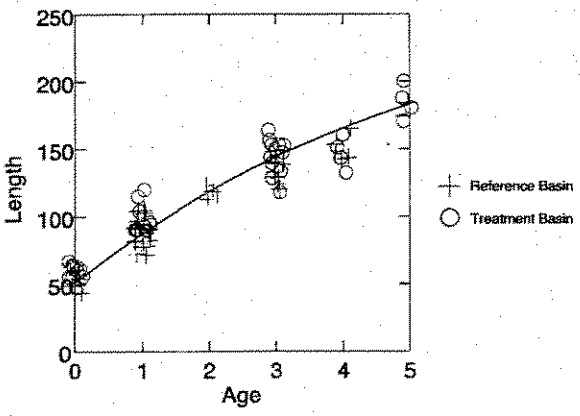

Fig. 2. Length at age data for the reference (+) and treatment basin (○) of Little Rock Lake. The solid line indicates the least squares fit of the von Bertalanffy growth model for the pooled length at age data from each basin. Symbols were jittered to allow visualization of overlap in length at age.

3. Results

We first examined the data for differences in fish growth between basins or over time, since growth rates are known to affect biomass-specific rates of contaminant accumulation. No significant differences were found when the variance ratios (F) were computed from von Bertalanffy growth model variance, fit using the pooled data set, were compared to variance computed using the parameter values estimated from the pooled data set relative to data from individual basins; sizes at a given age were not significantly different among basins across all ages (Fig. 2.). To test for age specific differences in length among basins, we also used pair-wise t-tests and Kolmogorov–Smirnov paired distribution tests for each age. There was no difference among size at any age between perch from the reference and treatment basins of Little Rock Lake (Table 1). As such, each results showed non-significant differences among size at age among basins indicating no difference in growth of perch in each basin of Little Rock Lake over the time period of interest. This result is consistent with the findings of Eaton et al. (1992) who observed no differences in perch growth during the acidification phase of the experiment.

Table 1
Results of pair-wise *t*-tests and Kolmogorov–Smirnov paired distribution tests for differences in size at age for yellow perch in each basin of Little Rock Lake

Age of perch	*N*	*P* (*t*-test)	*P* (K–S)
Age 1	(16, 10)	0.355	0.129
Age 2	(4, 0)	NA	NA
Age 3	(12, 13)	0.155	0.067
Age 4	(5, 4)	0.638	0.920
Age 5	(2, 4)	0.460	0.999

The number in parentheses indicates the number of fish of each age in the reference and treatment basin, respectively.

We then examined patterns of Hg accumulation in yellow perch caught in each of the basins of Little Rock Lake in each year of study. Hg concentrations in yellow perch collected from the reference and treatment basins in both 1994 and 2000 were strongly correlated to wet weight of the fish (Fig. 3a and b). The ANCOVA model that included the interaction term testing for differences in the slope of the weight effect between the two basins yielded non-significant differences in slope. As such, we used Eq. (2) to test the significance of year, given the relationship with log-transformed fish weight. The resulting relationship indicated a significant decline in the Hg concentration in the fish in the reference and the treatment basin of the lake between 1994 and 2000 (Table 2). In the treatment basin, the decrease over time was magnified by the experimental acidification, and fish of a given weight were approximately 57% higher in Hg concentration in 1994 when compared to those collected in 2000 (Table 2, Fig. 3a). Yellow perch collected in the reference basin in 1994 exhibited concentrations approximately 36% higher for a given weight than fish collected in 2000 (Table 2, Fig. 3b). By the year 2000, there was

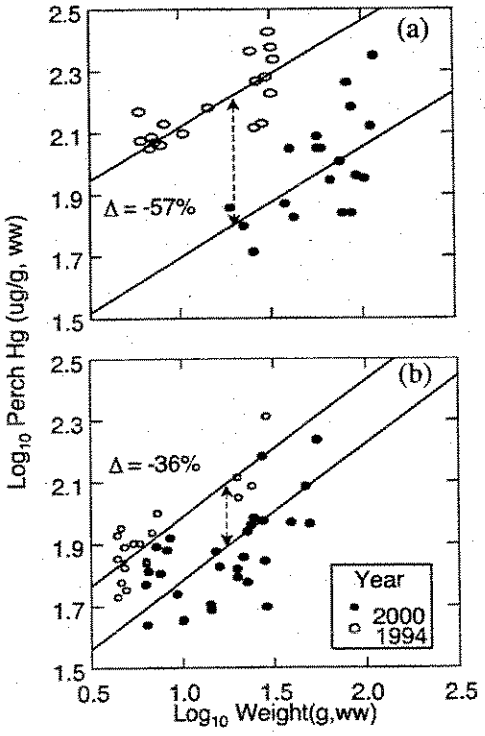

Fig. 3. The relationship between Hg concentration and fish weight in yellow perch collected in (a) treatment basin and (b) the reference basin. Open circles indicate data collected in 1994, closed circles indicate data collected in 2000. Lines from multiple regression model represent: Log Hg = $b_0 + b_1$ Log Wt + b_2 Year, where year is a dummy variable (1994 = 1, 2000 = 0).

Table 2
Results of the regression analysis of fish Hg concentration (μg/g, ww) using a dummy matrix for year of collection (1994 = 1, 2000 = 0) and wet weight (g) as independent variables (Eq. (1))

Dependent variable	Independent variable	Coefficient	Standard error	*T*-statistic	Probability evel
Log_{10} fish Hg (μg/g, ww) in treatment basin	Intercept	1.35	0.124	10.85	<0.0001
	Log_{10} weight	0.36	0.069	5.18	<0.0001
	Year	−0.42	0.055	7.64	<0.0001
Log_{10} fish Hg (μg/g, ww) in reference basin	Intercept	1.54	0.074	20.92	<0.0001
	Log_{10} weight	0.44	0.082	5.39	<0.0001
	Year	−0.19	0.035	−5.51	<0.0001

The R^2 for the full regression for the treatment basin was 0.63 and 0.57 for the reference basin.

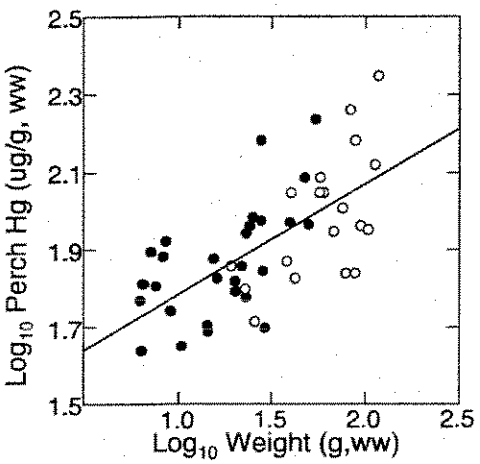

Fig. 4. Yellow perch Hg concentration in both basins of Little Rock Lake in 2000. Closed circles indicate data collected from the treatment basin, reference basin data are indicated by open circles.

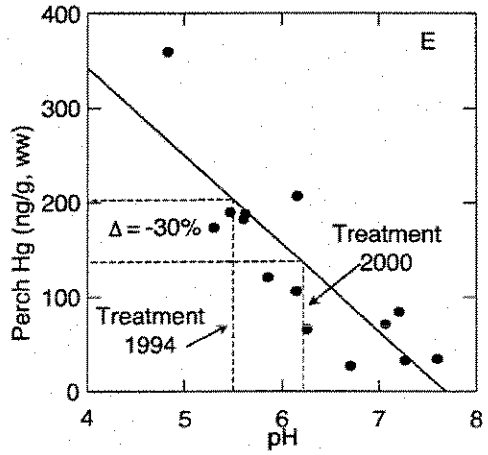

Fig. 5. Empirical relationship between fish Hg and pH in small lakes of northern Wisconsin (from Watras et al., 1998). Arrows indicate predicted status of the treatment basin fish in 1994 and 2000, based on pH for those years.

no statistically significant difference in fish Hg between basins of the lake (Fig. 4).

To isolate and quantify the relative effect of changes in pH and Hg deposition, we coupled observations made in the treatment and reference basins with the empirical relationship between fish Hg and pH derived from a previous study of multiple lakes in this region (Fig. 5). Given the pH of the two basins in 1994 and 2000, this empirical model predicts declines of approximately 30 and 5% in Hg concentration in yellow perch for the treatment and reference basin, respectively, owing to acidification factors alone. Subtracting the change attributed to pH from the total change in Hg concentration observed in each basin yields very similar levels of change for the treatment and reference basins owing to atmospheric Hg deposition (27 and 31%, respectively, Table 3). This result is consistent with a uniform change in Hg loading to both basins.

The results for the treatment basin indicate that approximately one-half of the observed change in fish Hg between 1994 and 2000 was due to de-acidification. The remainder was attributable to a regional decline in the atmospheric deposition of Hg over the same time period. For the reference basin, less than 15% of the observed decline in fish Hg was attributable to de-acidification of the lake water. The factor accounting for approximately 85% the decrease in fish Hg for this basin was the decrease in atmospheric Hg deposition (Table 3).

Table 3
Separating and quantifying the relative effects of acidification factors and Hg deposition on declines in fish Hg observed in Little Rock Lake

Lake basin	Total decline observed in fish Hg (%)	Attributed to de-acidification (%)	Attributed to lower atmospheric deposition of Hg (%)
Treatment	−57	−30	−27
Reference	−36	−5	−31

The de-acidification effect was calculated from an empirical model relating fish Hg to pH (see text) and the depositional effect was estimated by difference. Time period: 1994–2000.

Table 4
Trends for Hg in the reference basin of Little Rock Lake over recent time

Variable	Time period	Rate of change	P	Average change per year (%)	Reference
Atmospheric Hg deposition	1995–1999	−1 μg/m²/y	<0.001	−10.4	Watras et al. (2000)
Lake water Hg	1995–1999	−0.04 ng/l/y	<0.01	−5	Watras et al. (2000)
Yellow perch Hg	1994–2000	−9.3 ng/g/y[a]	<0.001	−5	This paper

[a] Estimated for a standard 30 g fish, wet weight basis.

4. Discussion

These findings have several implications with respect to the aquatic Hg cycle in remote freshwaters. First, they imply that changes in atmospheric deposition can propagate rapidly through a precipitation-dominated aquatic ecosystem like Little Rock Lake. In Little Rock, an annual depositional change of −10%/y translated to an −5%/y change in aqueous Hg and a −5%/y change in fish Hg averaged over the study period (Table 4). We know of no other ecosystem where such a rapid response has been observed, with the possible exception of some highly contaminated sites following remediation (Turner and Southworth, 1999; Southworth et al., 2000). It is unclear whether the mechanisms governing bioaccumulation in grossly contaminated and relatively pristine systems are comparable.

The rapid response observed in this relatively pristine lake indicates that the input of 'new' $Hg^{(II)}$ is an important determinant of waterborne and biotic Hg pools. Although sediments constitute a large Hg reservoir, and although a fraction of that reservoir is recycled back into the water column each year (Watras et al., 1996, 2000), the recycling of 'old' $Hg^{(II)}$ is not the major source of waterborne Hg nor does it dominate the bioaccumulation process. 'Old' $Hg^{(II)}$ may partially buffer the system against change, as evidenced on Table 4, but 'new' $Hg^{(II)}$ appears to be of primary importance.

Likewise, it follows that bioaccumulation in this ecosystem appears to depend more on the production of 'new' MeHg, than the recycling of 'old' MeHg from decomposing organisms. Otherwise, we are at a loss to explain the rapid decline in fish. The biotic reservoir of MeHg in Little Rock Lake is large and it turns over at a high rate (Watras et al., 1996). In order to sustain the large biotic MeHg pool, either direct recycling must be very efficient or rates of new MeHg production must be high. If recycling was indeed efficient, we should not have seen a rapid decline in the fish pool. Instead, our observations are consistent with the hypotheses that (1) 'new' MeHg sustains the biotic pool and (2) the production of 'new' MeHg depends largely on inputs of 'new' $Hg^{(II)}$ from the atmosphere.

Our findings are also consistent with the hypothesis that sulfate and 'new' $Hg^{(II)}$ co-mediate bioaccumulation in Little Rock Lake—hypothetically by co-limiting rates of MeHg biosynthesis by SRB (Compeau and Bartha, 1985; Gilmour and Henry, 1991; Hudson et al., 1994). Broadly speaking, the lake wide rate of MeHg biosynthesis is a function of the bioavailability of $Hg^{(II)}$ substrate, the specific activity of methylating microbes, and the biomass of the microbial community (Hudson et al., 1994; King et al., 2001). Atmospheric loading is one factor determining the availability of $Hg^{(II)}$ and, by simultaneously supplying sulfate, it may also affect the activity and biomass of sulfate reducers relative to other anaerobic microbes—provided the system is sulfate limited. The production of S^{2-} as a by-product of sulfate reduction may further enhance $Hg^{(II)}$ bioavailability via the formation of neutrally charged mercury-sulfide species that diffuse into bacterial cells (Hudson et al., 1994; Benoit et al., 2001).

In Little Rock Lake, the concentration of aqueous sulfate is indeed within the range considered limiting for SRBs in temperate freshwaters (Lovley and Klug, 1983, 1986). During acidification of the treatment basin with H_2SO_4, sulfate loading was artificially increased fourfold (Brezonik et al.,

1993); and concomitantly, the biomass of sulfur bacteria and the concentration of MeHg increased dramatically in the anoxic hypolimnion (Hurley and Watras, 1991; Watras and Bloom, 1994). Also during acidification, MeHg in plankton and fish was elevated in the treatment basin, by 20–100% relative to the reference basin (Watras and Bloom, 1992; Frost et al., 1999). During de-acidification, we observed that fish Hg declined in both basins along with decreased Hg deposition; but the decline in fish Hg was much greater in the Treatment basin where SO_4 declined at a higher rate.

5. Conclusions

We conclude that atmospheric deposition supplies two of the key substrates required to elevate MeHg biosynthesis and bioaccumulation in Little Rock Lake above some, as yet unknown, background level. Regional changes in the emission of SO_2 and Hg have apparently had a significant and immediate impact on Hg cycling and levels of fish contamination in this ecosystem. Since the trends that we have observed over the past decade are related to anthropogenic perturbations of the S and Hg cycles, they may or may not continue. The direction of future change will depend, in part, on the magnitude of future human emissions to the atmosphere.

6. Uncited reference

Iverfeldt et al. (1995).

Acknowledgments

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THE POWER OF LIVING WELL

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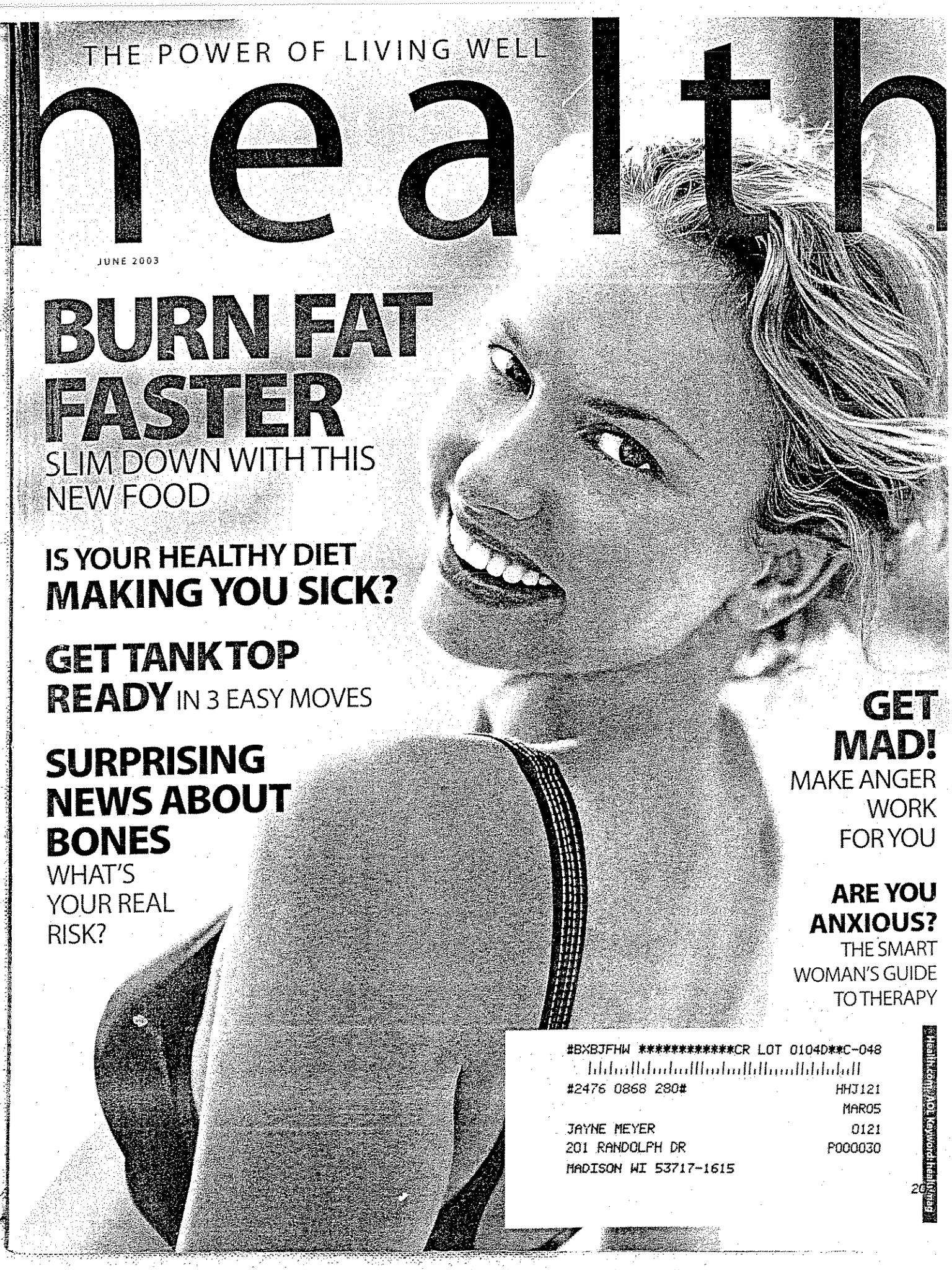

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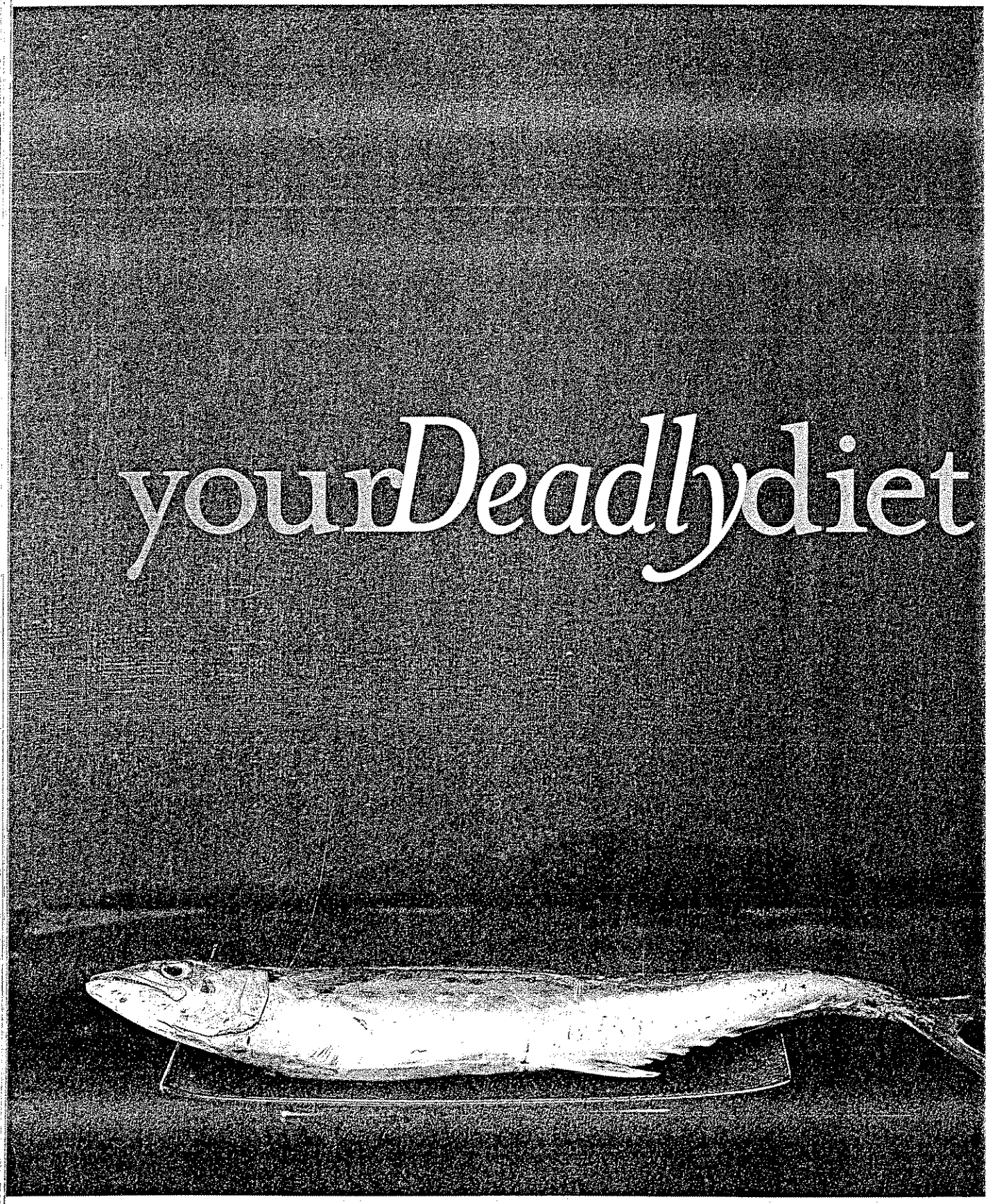


For years, doctors have been talking about the health benefits of eating fish. There's just one problem: It might be poisoning you.

BY BEN RAINES PHOTOGRAPHY BY SANG AN

WILL SMITH'S LIFE WAS FALLING APART. • He had worked for years as a geophysicist, analyzing data for companies that hunted oil under the ocean. But lately, he'd begun to have trouble functioning at the most basic levels. He would leave the house for a meeting only to forget where he was going before he reached his car. Though he had lived in San Francisco for decades, he kept getting lost. And after a career spent in highly technical

scientific research, the 52-year-old found himself stymied by simple subtraction and unable to string words into coherent sentences.

He went to his doctor, but none of the usual diagnostic tools—heart tests, CAT scans, blood work—revealed anything out of the ordinary. He was fit and trim, and yet his doctor told him he might have to trade his current career for a job that would be less mentally demanding.

In hopes of finding clues to his illness, Smith began to keep a journal. In it, he described tremors in his hands and tongue, slurred speech, an ever-present metallic taste in his mouth, numbness in his fingers, crushing fatigue, and depression. He couldn't concentrate. He couldn't watch television without getting dizzy. He felt high all the time.

"My doctors thought I had encephalitis. Then they thought I had Lou Gehrig's disease," Smith says. "There were four or five months where they were testing, testing, testing, and coming up with wild diseases. I went quite a long time thinking I was going to die."

Then one day his physician, San Francisco internist Jane Hightower, M.D., called. Abruptly, she asked him how much fish he ate.

"It was the weirdest thing," Smith says, "because I ate a lot of fish. Loved it."

Smith told her he ate a can of tuna as a snack three or so days a week. He also enjoyed sushi, especially the ruby-red slices of yellowfin tuna known as ahi. He ate other kinds of fish once or twice a week, sometimes for lunch, sometimes for dinner. He had been eating that way for a long time.

"I think you have mercury poisoning," Hightower said. "Quit eating fish."

A perfectly normal diet was causing a host of ills. Some patients who ate fish just twice a week had severe memory and concentration problems—"fish fog."

FOR YEARS, doctors have been telling the public to eat more fish. Jane Hightower was one of those doctors, and her well-educated, health-conscious patients were apt to follow her advice. But her message isn't so simple anymore. Hightower's research suggests that even moderate consumption of certain kinds of fish—eating seared tuna a couple of times a week, say—can raise mercury levels high enough to cause serious neurological problems. She calls the resulting poor memory and impaired concentration "fish fog."

Hightower's interest in mercury started undramatically in 1999, when a patient came in complaining of hair loss. Hightower sent her to a colleague, dermatologist Kathy Fields, M.D.

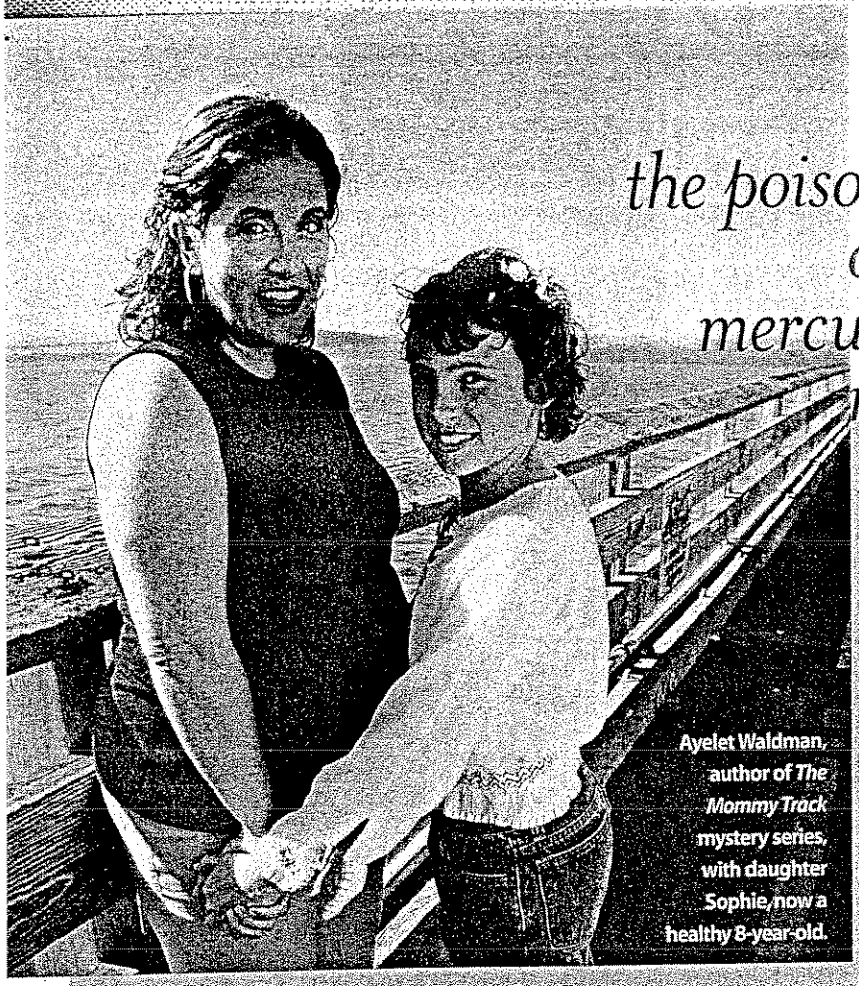
During the woman's office visit, Fields remembered a story she'd heard earlier on National Public Radio about research linking hair loss and exposure to heavy metals such as lead. So she ordered a blood test. The results showed extremely high levels of a heavy metal, but it wasn't lead.

"Her mercury levels were through the roof," Fields says. The patient's daughter was also losing hair, it seemed; her blood-test results showed the same thing.

Fields and Hightower, friends as well as colleagues, routinely talked shop, especially when confronted with a puzzling case. Neither doctor could figure out where the mercury was coming from. The family hired an environmental-testing firm to analyze their water, their home, the dirt surrounding it, even the air. But there was no mercury to be found.

"And then I asked them about their diet, because I

the poisoning of sophie: mercury and my daughter



Ayelet Waldman, author of *The Mommy Track* mystery series, with daughter Sophie, now a healthy 8-year-old.

WHEN MY DAUGHTER Sophie was 4, she was a Jewish mother's dream. Her favorite lunch wasn't Chicken McNuggets, but a tuna sandwich with plenty of celery and pickles. And you should have seen her in a sushi restaurant, gobbling up maki rolls. I, of course, attributed her sophisticated palate to my parenting skills. But all was not as it seemed. Our bright, inquisitive child had lately begun to exhibit some peculiar developmental plateaus. By age 3, she could tie her shoes; at 4, she had inexplicably forgotten how. For a while, she'd been making good, even accelerated, progress in learning to read. More recently, she seemed to slow down or (could it be?) regress.

Don't get me wrong—nothing about her behavior could be described as developmentally delayed. Only we, her parents, were worried, albeit suspicious of that worry. After all, what kind of nut starts fretting not that her child is below average, but that she isn't sufficiently *above* average? We hesitated to express our fears, even to each other.

I wish I could say it was our intimate knowledge of our daughter that led us to figure out that something was seriously wrong, but only an accidental discovery saved her from permanent brain damage. Sophie, like many kids whose parents are devoted to the architecture of generations past, was at risk for exposure to lead in paint from the walls of our Craftsman bungalow. On our pediatrician's advice, we were all regularly tested for lead. When Sophie was 4, a heavy-metal test revealed something even more frightening. Our perfect baby, our darling firstborn, had high levels of mercury—just above the cutoff the FDA considered acceptable.

That day, I panicked. I desperately inventoried the contents of our house, snatching up thermometers to ensure they weren't broken. As I watched Sophie sleep that night, I wished I could reach into her skull and tear out with my naked fingers the poison that was wreaking havoc on her brain.

Then I did what any American mother with a computer would do. I surfed the Web, and there I found the person who would answer all my questions. Jane Hightower, a physician who has made the dangers of mercury a professional crusade, agreed to see me right away. While we were still on the phone, she told me the likely source of Sophie's exposure: canned tuna.

Within a couple of days, I was in Dr. Hightower's office, listening as she assured me that the damage, while serious, was still reversible. In words that seemed designed to strike fear in the hearts of neurotic Yuppie parents the world over, she said, "Look, if this child ends up going to state college, you'll never know if it was the mercury exposure that kept her out of Harvard."

Out of Harvard? Mentally, and with deep sorrow, I began to unpeel the proud decal from our car's rear window.

Happily, that was a bit premature. As Dr. Hightower suggested, we eliminated fish from Sophie's diet. This resulted in more than a few grocery-store tantrums, Sophie clinging to a can of tuna while I tried to entice her with boxes of cookies. But within a couple of months, her mercury levels dropped. Her reading skills came back on track. One day, she put on her shoes and effortlessly tied two perfect bows.

I had encouraged Sophie to eat fish because I believed it was good for her brain, her heart, and her immune system. But I had poisoned her. For now, my children eat no fish but salmon, and I, pregnant with baby number four, haven't enjoyed a piece of seared ahi in longer than I can remember. As for Sophie? Once a year on her birthday, her father makes her a special dinner: tuna casserole, crumbled potato chips and all.—***Ayelet Waldman***

knew that some fish were supposed to have mercury in them," Hightower remembers. "They were eating tons of fish. Swordfish, tuna, everything."

Hightower told them to cut it out, all of it. Within a few months, the family's mercury levels returned to normal. Their hair started to grow back, too.

After that, Hightower began running mercury tests on lots of her patients, especially those with persistent symptoms that she couldn't explain or cure. Test after test came back showing levels higher—many times higher, in some cases—than those deemed safe by the U.S. Environmental Protection Agency (EPA).

A psychiatrist who regularly ate tuna and Chilean sea bass was hospitalized for an irregular heartbeat. His mercury level was twice the EPA's safe limit.

A plastic surgeon who ate no seafood except for fresh tuna steaks twice a week was suffering from hair loss, tremors, memory problems, and confusion so intense that she was preparing to give up her medical practice. Her mercury level was six times the EPA's safe limit.

A child who began to eat fresh tuna and king mackerel at age 3 had become profoundly withdrawn by the time he was tested at 5. His mercury level was 15 times the EPA's safe limit.

Many of Hightower's patients ate seafood just

the good, the bad, and the briny

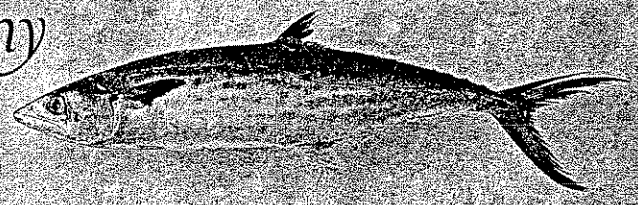
MEMORY LOSS, depression, nerve damage. The consequences of mercury poisoning are enough to make you lose your appetite. But you don't have to give up the pleasures of fish or its heart-healthy omega-3s. To be safe:

THINK SMALL. Big, boneless fillets may be easy to cook, but they come from large fish that have absorbed mercury from the smaller fish they've eaten. Species that run small, like flounder and sole, are better choices for frequent consumption than tuna, swordfish, or other predators.

DEVELOP A TASTE FOR SHELLFISH. It's generally low in mercury. But beware of scallops. While the genuine article is safe, unscrupulous fishermen create a dangerous ersatz version using a sort of cookie cutter on mercury-rich shark meat. Real scallops have a small "stalk" at one end.

SUPPORT YOUR LOCAL FARMS. Tests have shown that farm-raised fish are lower in mercury than their wild cousins. But farm fishing is an imperfect solution, as waste from penned fish can damage the surrounding environment.

BE ADVENTUROUS. Mercury is not the only danger that lurks in the deep. PCBs (polychlorinated biphenyls), for instance, can also accumulate in fish. To avoid exposure to high levels of any toxin, eat a variety of fish rather than making a habitual meal of any single kind.



EAT ALL YOU WANT: Pick frequently from this group, especially if you follow the American Heart Association's recommendation to eat fish at least two times a week.

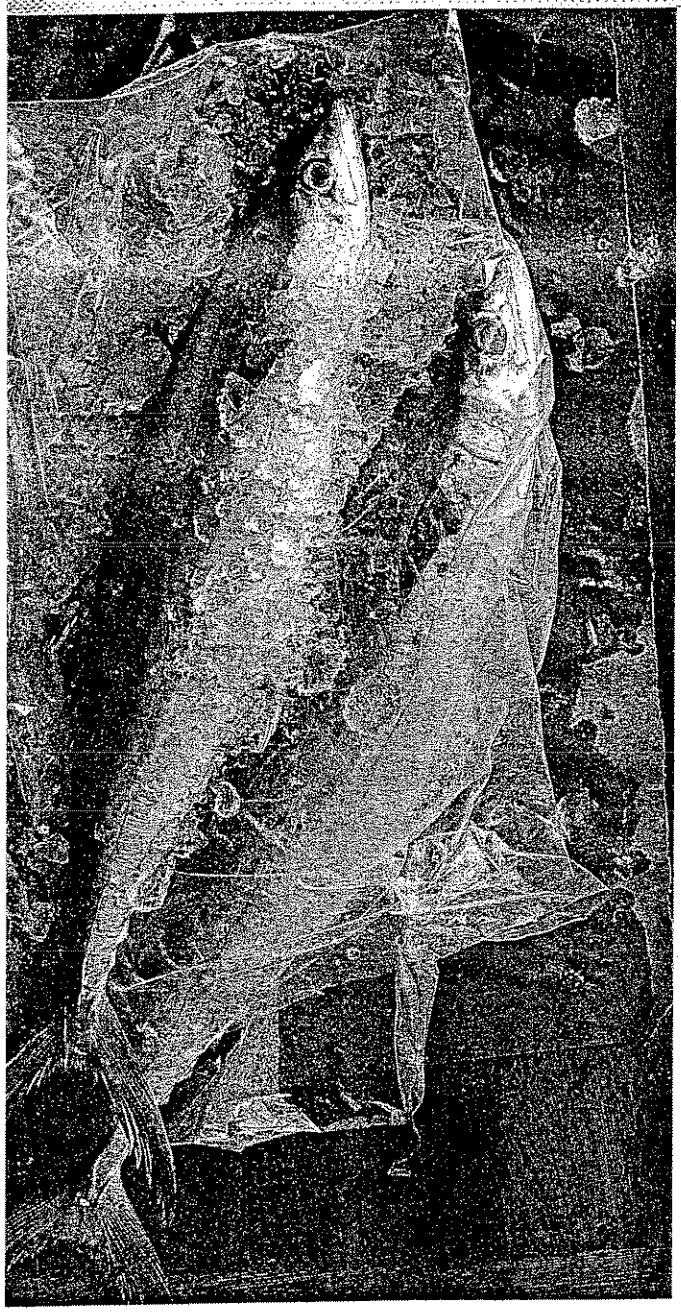
	MERCURY LEVELS	OMEGA-3 LEVELS
CATFISH	low	low
CLAMS	low	low
ORANGE ROUGHY	low	low
OYSTERS (PACIFIC)	low	high
OYSTERS (ELSEWHERE)	low	medium
SALMON	low	high
SARDINES	low	high
SHRIMP	low	low
TILAPIA	low	low

FOR OCCASIONAL MEALS: Once a week is safe for men, and for women finished with childbearing. Women in their reproductive years and children should limit mahimahi and red snapper (which have the highest mercury levels in this group) to once a month.

	MERCURY LEVELS	OMEGA-3 LEVELS
FLOUNDER	medium	medium
MAHIMAHI	medium	low
RED SNAPPER	medium	low
TROUT	medium	high

AVOID THIS FISH: A single meal can put you over the Environmental Protection Agency's safe limit for the month.

	MERCURY LEVELS	OMEGA-3 LEVELS
AMBERJACK	high	low
CHILEAN SEA BASS	high	medium
GROUPER	high	low
HALIBUT	high	low
SHARK	high	medium
SWORDFISH	high	medium
TUNA (FRESH)	high	high



A married couple in Wisconsin had mercury levels 10 to 12 times as high as the EPA's safe limit. They ate Chilean sea bass once a week.

twice a week, their choices being some of the most popular fish in America. Apparently, though, that perfectly normal diet caused a host of ills: impaired memory, depression, disorientation, irritability, headaches, shakiness, numbness and tingling in the hands and feet, thinning hair, joint pain, and speech difficulties.

Every time a test came back showing high mercury levels, Hightower told the patient to stop eating fish. And in every one of the cases, she says, those levels came down, and most of the symptoms disappeared. "In medicine, you don't get much better evidence than that," she says.

As the pile of test results grew, Hightower and Fields started spreading the word to local medical groups. Their efforts, while generally well-received, didn't cause a ripple in the wider scientific community. After all, few thought the problems they described could stem from eating fish—not the EPA, which regulates fish caught for sport, and not the U.S. Food and Drug Administration (FDA), which governs seafood sold commercially. According to conventional wisdom, the metal poses a threat only to a fetus, a young child whose brain is still developing, or a woman who plans to conceive. Fish consumption simply isn't cause for concern in most adults.

Hightower is primarily trained in clinical practice. She is quick to admit that her findings need to be followed up with rigorously controlled studies and reviewed by experts. Still, she believes that high mercury levels and illnesses related to them are much more common than they seem, and that more people will be diagnosed as doctors become aware of the symptoms. With reports pouring in from all over the nation, an increasing number of scientists and federal health officials are beginning to agree with her.

SCIENTISTS HAVE known for centuries that mercury is dangerous. The phrase "mad as a hatter" stems from a psychosis that plagued 18th- and 19th-century hatmakers exposed to the metal in their work. Hundreds of years later, two famous environmental tragedies, one in Japan and the other in Iraq, formed the basis of modern mercury science.

In the1950s, the small fishing village of Minamata, Japan, was devastated when mercury discharged by a chemical company built up in Minamata Bay. People in the town gradually began to have trouble with rudimentary tasks: walking, buttoning their clothes, even swallowing. Sixty-eight died; mothers exposed during pregnancy gave birth to children who were blind, deformed, or mentally disabled. In 1971, another disaster unfolded when Iraqi villagers made bread out of American grain meant for planting, unaware that the seeds had [*continued on page 184*]

your deadly diet

continued from page 125

been treated with a mercury-based fungicide. These episodes made clear that mercury poisoning can be catastrophic. But scientists also took away another lesson: that adults risk neurological damage only when contamination is extreme. On the other hand, studies showed that children exposed in the womb or during their first few years of life are likely to have learning disabilities. So when regulators set limits for mercury in fish, they focused on protecting the young.

The FDA's only warning regarding mercury in fish is directed toward children and women of reproductive age. These people, the organization says, should avoid eating shark, swordfish, tilefish, and king mackerel. Otherwise, the FDA has been relatively unconcerned about the effects of mercury in adults. For years, the agency maintained that men and women could safely harbor levels of about 4 parts per million (ppm), measured in hair. That's four times as high as the EPA's recommended level. Just a couple of months ago, however, the FDA made a sudden about-face. Now, along with the EPA, it uses 1 ppm as the upper safety limit.

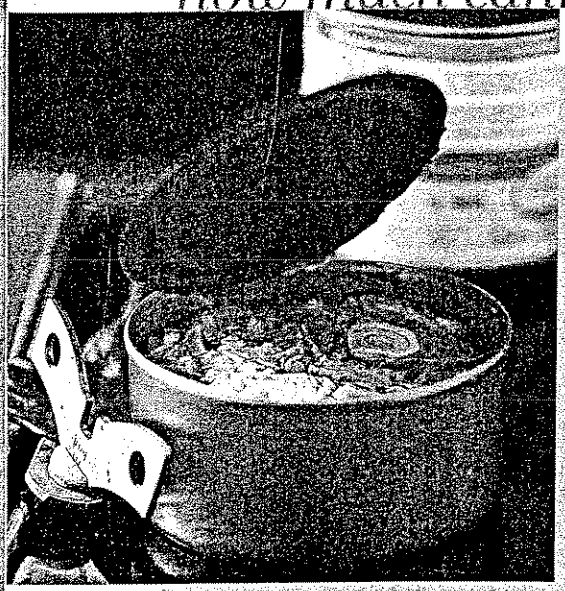
If new research is right, though, even that level might be much closer to the danger zone than previously thought. Many of Hightower's adult patients exhibited symptoms with levels as low as 2 ppm, for instance. And several recent studies appear to support her contention that such levels can cause problems.

Among the most alarming discoveries comes from Finland. Research undertaken there suggests that low levels of mercury can increase heart disease risk. One study, for example, tracked 1,833 Finnish men for seven years. All the men were healthy to begin with, but those who had mercury levels of 2 ppm or higher were more likely to have suffered heart attacks by the study's end than men who had levels of around 1 ppm.

"They found an increased risk of death from coronary heart disease—and it wasn't small," says Kate Mahaffey, Ph.D., author of the exhaustive *Mercury Study Report to Congress* and director of the EPA division that sets the agency's mercury policy. "Increased amounts of mercury almost doubled the risk."

But the metal's effect on heart health is still very much an open question, Mahaffey says. Last year, two other major studies were published, one showing an increase in heart disease risk in men with elevated

how much canned tuna is safe to eat?



IT'S A HOTLY CONTESTED question. The lunchtime staple is generally believed to be low in mercury, but that assumption is based on fairly limited testing. To make things even more complex, many different tuna species go into the can, each with a different mercury profile.

At a recent meeting of the U.S. Food and Drug Administration, H. Vas Aposhian, Ph.D., a scientist on the agency's Food Advisory Committee, announced that he had personally tested 10 cans of tuna for mercury. One contained 1.24 parts per million, more than 500 percent higher than the FDA's published average for mercury in canned tuna—so high, in fact, that federal rules would prohibit that can from being sold to the public.

The FDA's current standards say that kids and women of childbearing age can safely eat 12 ounces (or two regular cans) of tuna per week. Yet that advice puts a woman over the Environmental Protection Agency's safety limit, says Alan Stern, who served on a National Academy of Sciences panel that studied mercury's health effects. "A woman can safely eat about 8 ounces of canned tuna a week, provided she eats no other fish high in mercury," he says. Kate Mahaffey, whose EPA division regulates mercury, says a small child should eat no more than one-third of a can per week.

Last summer, the FDA assembled an internal panel to examine the canned-tuna issue. That panel strongly advised the agency to lower its recommended consumption limit for kids and women who might get pregnant to a single can per week. The FDA has yet to act, however.

mercury levels, and another showing no increase. "We just don't know as much as we should about the health effects of mercury in adults," Mahaffey says.

If mercury does turn out to be more dangerous at lower levels than previously believed, that's just half the bad news. Americans also seem to be getting more mercury from fish than regulators have figured.

That's partly because people are eating more fish than they used to. Between about 1980 and 1991, the amount of seafood caught for market each year nearly doubled, according to the National Marine Fisheries Service, from 6.5 billion to 10 billion pounds a year.

The types of fish favored by consumers have changed, too. The most popular choices used to be small inshore fish such as flounder and mullet. But these days, people like the big ones: huge predators such as swordfish and tuna, and hulking, sedentary giants like Chilean sea bass, halibut, and grouper. A growing body of evidence shows that these are the very fish most laden with mercury, because of the way the metal moves through the environment.

Most mercury is bound up underground or inside plants. But when it's released into the atmosphere through the burning of fossil fuels, it falls back to Earth and ends up in waterways and oceans. Bacteria make a meal of the metal; then these organisms are eaten by creatures like snails, which are eaten by small fish, which are eaten by larger fish—each absorbing the mercury from the animals it follows in the chain.

In a little-publicized bulletin from 2001, known internally as the Do Not Consume list, the FDA said that children and women of childbearing age should avoid swordfish, shark, king mackerel, and tilefish (sometimes sold as snapper), because mercury levels in those fish are too high—more than 1 ppm. That's the "action level": According to federal regulations, fish with levels above 1 ppm can't be sold. (Government data shows that many samples of these species contain levels as high as 6 ppm.)

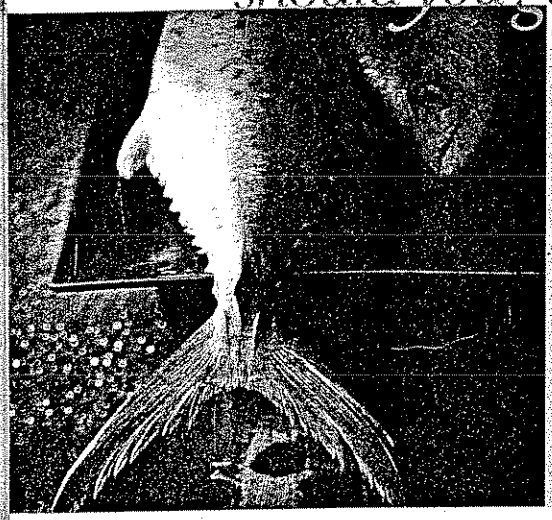
In practice, however, the action level isn't enforced. The FDA simply doesn't know how much mercury is in the high-dollar fish popular in restaurants and at the nation's seafood markets, agency officials acknowledge. The FDA publishes what it believes to be average mercury levels for many of these fish, but EPA scientists say the data is fundamentally flawed and essentially useless.

That's because no one recorded the size of the fish when most of the testing was performed. Size is critical, because smaller, younger specimens tend to contain much less mercury than bigger, older ones.

Recent tests conducted by the National Marine Fisheries Service, the state of Florida, and the *Mobile Register,* an Alabama newspaper that has reported extensively on mercury contamination, indicate that such species as Chilean sea bass, fresh tuna, grouper, bluefish, amberjack, cobia, and redfish are often every bit as high in mercury as the swordfish and shark on the FDA's Do Not Consume list.

These contamination levels may help explain recent reports of Americans who eat fish once or twice a week but have mercury levels comparable to those of Alaska's Inuit people, who subsist almost entirely on fish and are thought to be among the

should you get a mercury test?



IF YOU EAT large ocean fish on a regular basis, you might want to consider a mercury test, say experts like Kate Mahaffey, Ph.D., a co-author of the Environmental Protection Agency's *Mercury Study Report to Congress.*

WHAT KIND SHOULD YOUR DOCTOR ORDER? A hair test is best when long-term exposure is the concern. While the amount of the metal in your blood fluctuates dramatically with meals, hair provides a sort of ticker tape record of a person's average level, possibly going back several months, depending on the length of the hair.

HOW MUCH MERCURY IS OK? The EPA sets the safe level for mercury, as measured in hair, at 1 part per million. Some studies suggest that a mere doubling of that level increases the risk of heart disease.

WHAT IF YOU TEST HIGH? Don't panic. Because mercury is excreted in hair, skin, nails, and feces, your levels will begin to decline as soon as you stop exposing yourself to the stuff.

most mercury-contaminated populations on Earth.

Alarmingly high levels are being reported all around the United States, mostly in upper-middle-class people who eat moderate amounts of fish. In Wisconsin, the state health department was stunned to discover two married lawyers with mercury levels 10 and 12 times as high as the EPA's safe level; they ate Chilean sea bass once a week. In Louisiana, a museum director who ate fresh tuna weekly had levels four times the upper limit.

"People with these high mercury levels are certainly not particularly hard to find," says Mahaffey, who last year won the EPA's highest scientific honor for her research. "We find them every time we start looking. I think it indicates they are much more common nationwide than we thought."

LAST FEBRUARY, SIGNS started going up at seafood counters across California, with "Warning" in prominent letters, a drawing of a fish, and the names of the four species on the FDA's hit list. The signs were brought in to satisfy Bill Lockyer, the state attorney general, who had filed suit against major grocery chains. He charged that the stores had been violating California's Proposition 65, which requires retailers to warn customers when they sell products containing chemicals known to cause reproductive harm or cancer. "The signs are a step in the right direction," Hightower says. "But we need to tell people how much mercury is in other kinds of fish."

Right now, no one can give people that information, because nobody knows for sure. But that may be about to change. The National Marine Fisheries Service has started testing 2,500 samples of fish from the Gulf of Mexico and plans to test in the Pacific and Atlantic as well. Results won't be known for at least a year, but if they show that mercury levels in other species top 1 ppm, the FDA will consider adding more fish to its Do Not Consume list, says David Acheson, M.D., chief medical officer of that organization's Center for Food Safety and Nutrition.

In the meantime, what are you supposed to eat? Mercury aside, seafood *is* good for you, as the American Heart Association has stated. It's low in saturated fat and high in omega-3 fatty acids, which Western diets sorely lack, says Alan Stern, a doctor of public health who served on a National Academy of Sciences panel that studied the mercury issue. Fortunately, he says, you can get the benefits of seafood with minimal risk—if you choose your fish wisely.

In many cases, the large ocean fish with the highest mercury levels also happen to be poor sources of omega-3s, for instance (see "The Good, the Bad, and the Briny," page 124). Conversely, many of the best sources of those beneficial fatty acids, like salmon, are low in mercury. In addition, relatively small species such as flounder, sole, mullet, and sardines are known to be low in the metal, Stern says. Farm-raised fish also tend to have lower levels than their wild counterparts.

Hightower offers some homespun advice: "If the fish you're cooking is too big for your pot, buy a smaller fish, not a bigger pot." If you see a large, boneless hunk of fish at a seafood counter, be wary; she says it could only come from a very large fish. And if you frequent sushi restaurants, be aware that much of the menu is composed of large predators like tuna. (Some bluefin tuna has been shown to contain mercury at more than 10 ppm—on par with many of the fish consumed by victims of the Minamata disaster.)

If the fish you're cooking is too big, buy a smaller fish, not a bigger pot. And be aware that much of a sushi menu consists of large predators like tuna.

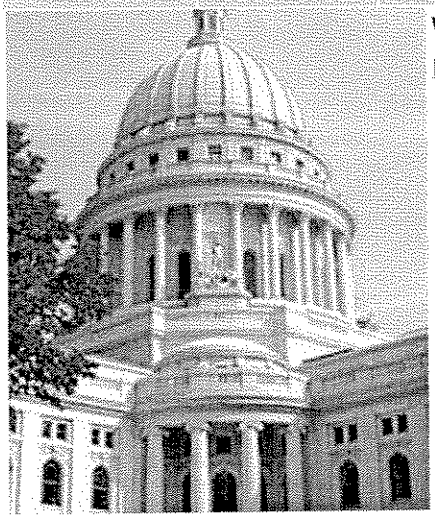
If your levels are high (see "Should You Get a Mercury Test?," page 186), don't panic, Mahaffey says, especially if you haven't noticed symptoms. Mercury is excreted in hair, skin, nails, and feces, which means that the amount in your body is halved every 40 to 100 days.

That's why the advice Hightower gave years ago to her geophysicist patient Will Smith was so effective. "Change your diet," she'd said. Once so severely debilitated that he couldn't think clearly, Smith is feeling much better these days.

He's back at work. He can watch television without getting dizzy, and he can remember where he's going when he gets in the car. The tremors are gone, and he can once again manage complex mathematical computations.

As for fish, he won't go near it.

Ben Raines, a reporter for the Mobile (Ala.) Register, *has received awards from the National Press Club and the Oakes Fund for Environmental Journalism for investigating the issue of mercury in fish.*



WMC

June 30, 2003

Memo to Natural Resources Board re: NR 446

TO: Natural Resources Board

FROM: Jeff Schoepke, Director, Environmental Policy

DATE: June 25, 2003

RE: NR 446, Proposed Mercury Regulations

Thank you for the opportunity to provide comments on proposed revisions to NR 446, creation program regulating air emissions of mercury.

Wisconsin Manufacturers & Commerce (WMC) is a statewide, non-profit association representi Wisconsin business. WMC has 4,300 members that include both large and small manufacturer utilities, service companies, local chambers of commerce and specialized trade associations.

WMC has opposed the rule throughout this rulemaking process for three major reasons: 1) It is widely accepted that mercury loadings are affected by long range transport, and that a Wiscon rule will have little impact on mercury in Wisconsin lakes; 2) The rule as proposed will increase electric rates and cost jobs; 3) Because the federal government is moving forward with rules, a voluntary program as a bridge to the federal program is the most prudent interim policy approa

The final rule package before you today has several important revisions that improve the propo WMC is pleased, for example, that the final rule removes the major stationary source cap. WM also pleased that burdensome offset requirements have been eliminated from the rule.

However, WMC still has significant concerns regarding the overall approach of the effort and w oppose the rule unless several modifications, outlined below and in the attachment to this mem are made prior to adoption.

First, the rule should be amended to exempt sources subject to a federal mercury emiss limit. Under section 285.27 (2) (a) Wis. Stats. DNR would be required to promulgate a corresponding state standard once EPA finalizes their proposal next year. While the above provisions reference section 112 of the Act, there is no logical policy reason to treat differently federal mercury emission limitation under another section of the Act. If the source is covered b

federal mercury program, that program should control to avoid duplication and inconsistencies. Thus, the simple policy change would be to exempt from the rule all sources subject to a federa emission limitation.

Second, the rule's second-phase, 80 percent reduction requirement should be removed from the rule. It is impossible to predict in 2003 the appropriate Wisconsin mercury program fc 2015. However, we know the current state of technology is such that the 80 percent reduction mandate likely could not be met. Technology and policy developments will surely evolve, howe the decision of the appropriateness of an 80 percent reduction is better made after the first pha and a thorough review of the rule at that time.

For example, almost everyone agrees that a federal mercury program will be in place by that d This rule, always promoted by the DNR as a "bridge" to the federal program, need not address second reduction phase at this time – it may simply be unnecessary. Should the federal government falter, there is ample opportunity before 2015 to develop a second phase. From a practical perspective, the delay of the 80 percent reduction decision will also help assure swift enactment of this rule without compromising DNR's primary objective for 40 percent reduction pending federal action.

Several utilities regulated under this rule have communicated technical and policy concerns wit the latest draft. Unfortunately, major changes to the rule were shared with stakeholders less th month before the board is being asked to adopt them. Thus, there are many additional issues t have arisen that could be addressed if more time were allowed. **WMC requests the Board consider the technical changes requested by utilities before adoption of the rule.**

Also, with the elimination of the major sources cap, trading with non-regulated entities is no lon allowed under the rule. In order to help reduce the total cost of reducing mercury emissions, W recommends the rule be amended to allow non-regulated companies to trade.

WMC's objections to the rule are based on a general position that the rule's costs and benefits not commensurate. That is, the rule will impose significant costs to ratepayers and provide little benefits to Wisconsin fishermen and aquatic ecosystems. We still believe that for these reason Wisconsin-only rule makes little sense. However, these concerns could be mitigated by the adoption of an exemption for sources covered by federal rules and elimination of the second-phase, 80 percent reduction requirement. Should the Board make these changes, WMC will remove its official objection.

POLK·BURNETT
A Touchstone Energy® Cooperative

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August 8, 2003

The Hon. Neal Kedzie, Chair
Senate Committee on Environment and Natural Resources
313 South, State Capitol, P.O. Box 7882
Madison, WI 53707-7882

The Hon. DuWayne Johnsrud, Chair
Assembly Committee on Natural Resources
323 North, State Capitol, P.O. Box 8952
Madison, WI 53708

Dear Senator, Representative & Committee Members:

Polk-Burnett Electric Cooperative serves approximately 18,000 consumer-owners in northwestern Wisconsin. Our part of the state is home to the Crex Meadows wildlife area and many excellent fishing lakes. We are sensitive to the fact that our quality of life is enhanced by sound environmental protection policies.

It is therefore only after serious reflection that we conclude the pending Department of Natural Resources mercury emissions rule (Clearinghouse Rule 01-081) should not be implemented. Our most direct concern is that we anticipate a major increase--several percentage points--in our cost of wholesale electricity. There is no alternative to us passing this cost along to our members and it would represent a significant burden for many of them.

Significant burdens may be worth bearing if genuine benefit results. In this case, better public health would be the benefit presumably sought. But the evidence we have seen fails to suggest the existence of any public health problem requiring a remedy this rule would provide. It's known that some state public health officials have been seeking to assist the DNR in *regulating* mercury. It seems fair--and well worthwhile--to ask whether they have been called upon to assist people *affected* by mercury.

The toxic effects of mercury in a sufficient dose are beyond dispute. We have seen no evidence that Wisconsin residents are at much risk of exposure to such doses, but we have strong doubts that the pending rule would account for enough mercury to reduce exposure to safe levels if dangerous ones were now present.

Polk-Burnett Electric Cooperative therefore requests that considering its likely negligible benefit and excessive cost to Wisconsin residents, Clearinghouse Rule 01-081 be recognized as an unreasonable burden, and not be implemented.

Sincerely,

POLK-BURNETT

Steve A. Glaim
General Manager

SAG/gm

(oppose)

WMC
REPRESENTING WISCONSIN BUSINESS

Wisconsin Manufacturers & Commerce

Memo

TO: **Assembly Committee on Natural Resources**
Senate Committee on Environment & Natural Resources
FROM: **Jeff Schoepke, Director, Environmental Policy**
DATE: **August 13, 2003**
RE: **ACR 01-081, Proposed Mercury Regulations**

Thank you for the opportunity to provide comments on proposed revisions to NR 446, creation of a program regulating air emissions of mercury.

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The final rule package before you today has several important revisions that improve the proposal. WMC is pleased, for example, that the final rule removes the major stationary source cap. WMC is also pleased that burdensome offset requirements have been eliminated from the rule.

However, WMC still has significant concerns regarding the overall approach of the effort and will oppose the rule unless several modifications, outlined below and in the attachment to this memo, are made prior to adoption.

First, the rule should be amended to exempt sources subject to a federal mercury emission limit. Under section 285.27 (2) (a) Wis. Stats. DNR would be required to promulgate a corresponding state standard once EPA finalizes their proposal next year. While the above provisions reference section 112 of the Act, there is no logical policy reason to treat differently a federal mercury emission limitation under another section of the Act. If the source is covered by a federal mercury program, that program should control to avoid duplication and inconsistencies. Thus, the simple policy change would be to exempt from the rule all sources subject to a federal emission limitation.

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Second, the rule's second-phase, 80 percent reduction requirement should be removed from the rule. It is impossible to predict in 2003 the appropriate Wisconsin mercury program for 2015. However, we know the current state of technology is such that the 80 percent reduction mandate likely could not be met. Technology and policy developments will surely evolve, however, the decision of the appropriateness of an 80 percent reduction is better made after the first phase and a thorough review of the rule at that time.

For example, almost everyone agrees that a federal mercury program will be in place by that date. This rule, always promoted by the DNR as a "bridge" to the federal program, need not address the second reduction phase at this time – it may simply be unnecessary. Should the federal government falter, there is ample opportunity before 2015 to develop a second phase. From a practical perspective, the delay of the 80 percent reduction decision will also help assure swift enactment of this rule without compromising DNR's primary objective for 40 percent reduction pending federal action.

Several utilities regulated under this rule have communicated technical and policy concerns with the latest draft. Unfortunately, major changes to the rule were shared with stakeholders less than a month before the board is being asked to adopt them. Thus, there are many additional issues that have arisen that could be addressed if more time were allowed. WMC requests the Board consider the technical changes requested by utilities before adoption of the rule.

Also, with the elimination of the major sources cap, trading with non-regulated entities is no longer allowed under the rule. In order to help reduce the total cost of reducing mercury emissions, WMC recommends the rule be amended to allow non-regulated companies to trade.

WMC's objections to the rule are based on a general position that the rule's costs and benefits are not commensurate. That is, the rule will impose significant costs to ratepayers and provide little in benefits to Wisconsin fishermen and aquatic ecosystems. We still believe that for these reasons, a Wisconsin-only rule makes little sense. However, these concerns could be mitigated by the adoption of an exemption for sources covered by federal rules and elimination of the second-phase, 80 percent reduction requirement. Should the Board make these changes, WMC will remove its official objection.

Proposed Changes to DNR's Proposed Mercury Rule
(June 25, 2003)

Proposed Amendment 1 – Existing NR 446.01 (1) is amended to read:
APPLICABILITY. This chapter applies to all air contaminant sources which may emit mercury and to their owners and operators. Stationary sources that are subject to a federal emission limit for mercury are exempt from the requirements of this chapter.

Rationale. This amendment is consistent with the relevant statutory provision, Section 285.27(2) (a), Stats., which provides:

> If an emission standard for a hazardous air contaminant is promulgated under section 112 of the federal clean air act, the department shall promulgate by rule a similar standard but this standard may not be more restrictive in terms of emission limitations than the federal standard . . .

DNR has proposed several rule provisions that are consistent with this statutory provision and the suggested amendment, including NR 446.05 (2) in the proposed mercury rule relating to new or modified sources:

> **(2)** New or modified stationary sources that are subject to an emission limit for mercury required under section 112 of the Act are exempt from the requirements of this section.

In addition, this policy is reflected in proposed NR 445.01(1)(b) [Air Toxic Program], which is recreated to read:

> The emission limitations and control requirements in this chapter do not apply to hazardous air contaminants emitted by the emissions units, operations or activities that are regulated by an emission standard promulgated under section 112 of the Clean Air Act (42 USC 7412).

While the above provisions reference section 112 of the Act, there is no logical policy reason to treat differently a federal mercury emission limitation under another section of the Act. If the source is covered by a federal mercury program, that program should control to avoid duplication and inconsistencies.

Related Changes. Should this amendment be adopted, several provisions are no longer necessary, including:

- NR 446.05 (2), providing an exemption for new sources subject to federal standards)
- NR 446.12 (2) and (3), relating to report on effect of federal mercury regulations.

Proposed Amendment 2 – Proposed NR 446.06 (Mercury emission limits for major utilities) is amended to read:

(1) (a) Beginning January 1, 2008, no owner or operator of a major utility may cause, allow or permit mercury emissions from all stationary sources of the major utility on an annual basis in an amount which exceeds the controlled mercury emissions for the major utility's stationary sources, determined by the department under par. (b).

(b) No later than October 1, 2005, the owner or operator of a major utility shall conduct a source performance test on each combustion unit to determine the control efficiency of any control equipment or emission reduction activity on the mercury emissions from the combustion unit. This control efficiency shall be applied to the baseline mercury emissions calculated under s. NR 446.03 for the unit, using the procedures in s. NR 446.09, to determine the controlled mercury emissions of the combustion unit.

(2) Beginning January 1, 2010, no owner or operator of a major utility may cause, allow or permit mercury emissions from all stationary sources of the major utility on an annual basis in an amount which exceeds 60% of the baseline mercury emissions for the major utility's stationary sources, determined by the department under s. NR 446.03.

~~**(3) Beginning January 1, 2015, no owner or operator of a major utility may cause, allow or permit mercury emissions from all stationary sources of the major utility on an annual basis in an amount which exceeds 20% of the baseline mercury emissions for the major utility's stationary source's, determined by the department under s. NR 446.03.**~~

Rationale. It is impossible to predict in 2003 the appropriate Wisconsin's mercury program for 2015. Technology and policy developments will surely evolve. For example, almost everyone agrees that a federal mercury program will be in place by that date. This rule, always promoted as a "bridge" to the federal program, need not address the second reduction phase at this time – it may simply be unnecessary. Should the federal government falter, there is ample opportunity before 2015 to develop a second phase. From a practical perspective, the delay of the 80 percent reduction decision will also help assure swift enactment of this rule without compromising DNR's primary objective for 40% reduction pending federal action.

Related Changes. Proposed NR 446.12 (Periodic evaluation and reconciliation reports) is deleted and recreated to read:

NR 446.12 Additional reductions for major utilities. (1) By January 1, 2009 [one year before the first phase reduction deadline], the department staff shall submit a report to the natural resources board if major utilities are not subject to a emission limit for mercury required under the Clean Air Act by that date. The report shall include:

(a) An evaluation of the scientific and technology developments in relation to the control or reduction of mercury emissions.

(b) An evaluation of whether mercury emission reductions for major utilities beyond those required by s. NR 446.06 are achievable, given the scientific and technological developments.

(c) Recommendations for revisions to this subchapter relating to major utilities based on the scientific and technological developments, and existing or pending federal mercury programs.

(2) The natural resources board shall review this report and, if they include recommendations for rule revisions, determine whether the department should proceed with actions based on the recommendations.

Exhibit List

Wisconsin Federation of Cooperatives
Joint Hearing on NR 446-Assembly Committee on Natural Resources/
Senate Committee on Environment and Natural Resources

August 13, 2003

1. *Healthiest Wisconsin 2010* (State Health Plan) Department of Health and Family Services, 2002
2. *Assessing the Ecological Risk of Mercury in Common Loons: 2001 Progress Report* Meyer, Kenow, Karasov and Fournier January 17, 2002
3. Extracted data from U.S. Census Bureau: per capita income of Wisconsin electric cooperative members
4. Bar Graph: Total deposition of mercury by source. Lake Michigan Air Directors Consortium (LADCO) 1996.
5. Letter from the Wisconsin Public Service Commission to Mr. Jon Heinrich of the Wisconsin Department of Natural Resources
6. Mercury Control and Cost for Major Utilities, Department of Natural Resources (July 2003)
7. University of Rochester Medical Center "No Detectable Risk from Mercury in In Seafood, Study Shows", May , 2003

By State

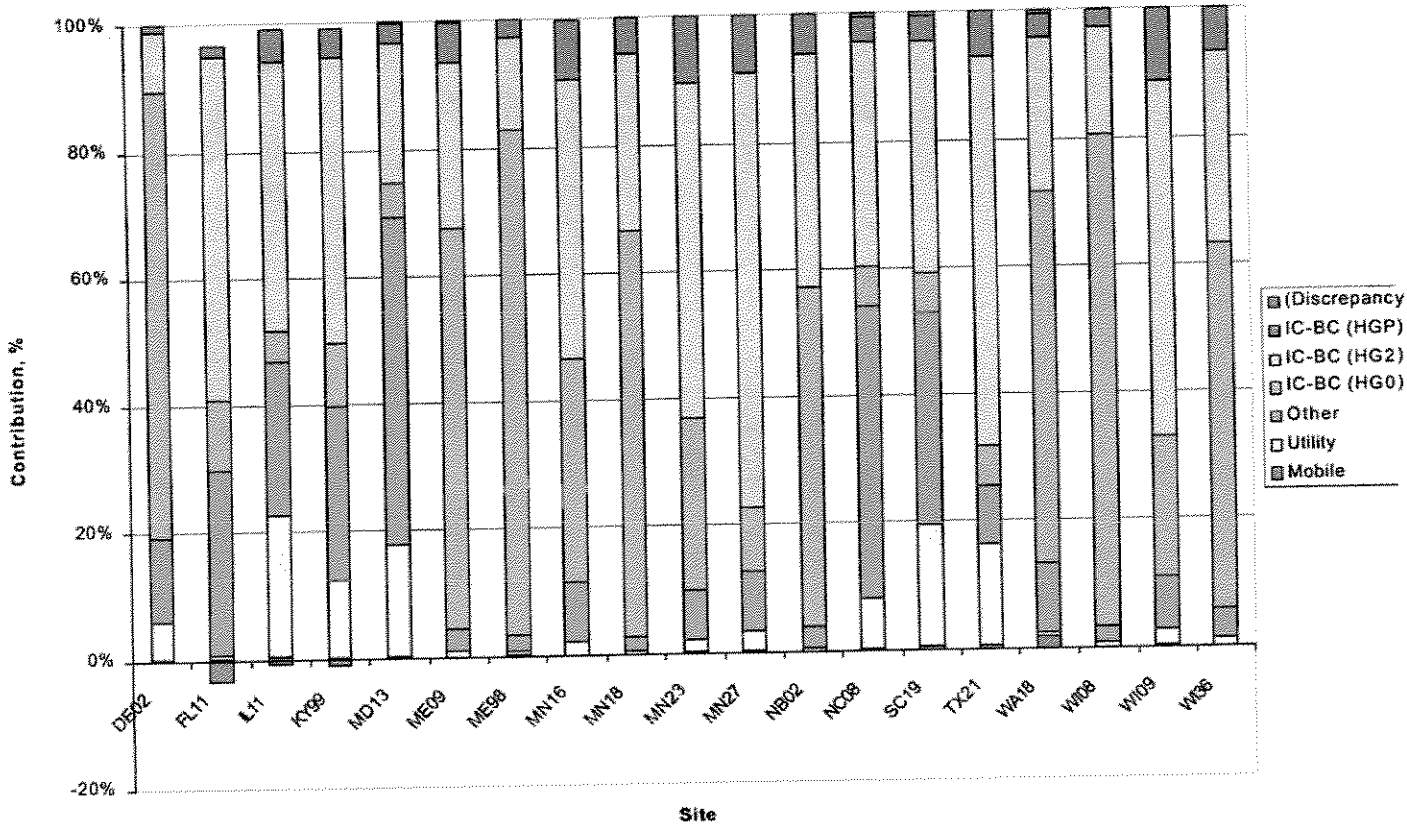
Select a state to see state profile:

Wisconsin Profile

				Coop vs State:		Coop vs US:	
Income	**Co-op:**	**State:**	**US:**	**$ Diff:**	**% Diff:**	**$ Diff:**	**% Diff:**
Average HH:	$52,295	$65,869	$69,756	($13,574)	-20.6%	($17,439)	-25.0%
Per Capita	$20,150	$25,625	$26,170	($5,475)	-21.4%	($6,007)	-23.0%
Race	**Co-op:**	**State:**	**US:**	**Occupation**	**Co-op:**	**State:**	**US:**
White	96.4%	88.8%	74.9%	White Collar	41.4%	52.5%	58.3%
Black:	0.5%	5.9%	12.6%	Blue Collar	43.0%	33.2%	27.8%
Asian	0.8%	2.1%	4.6%	Service	15.6%	14.3%	13.9%
Other	2.3%	3.2%	7.8%	Total	100%	100%	100%
Total	100%	100%	100%				
				Agriculture	11.9%	4.5%	2.5%
Hispanic	1.0%	3.6%	12.6%				
Education	**Co-op:**	**State:**	**US:**	**Housing**	**Co-op:**	**State:**	**US:**

Relative Contributions of Mercury Sources to dry+wet deposition

ladco.1996.hgt.aO Run



Mercury tagging results for total (wet + dry) deposition from the application of REMSAD for the 1996 simulation period for all MDN monitoring site locations (in terms of percent contribution from each tagged species). The first two letters in each site name are the state abbreviation. Contribution to total deposition from initial and boundary conditions for all three mercury species, utility, mobile, and other sources is displayed. The discrepancy represents the difference between the REMSAD simulated values and the sum of all tagged components.

Source: LADCO (Lake Michigan Air Directors Consortium), Des Plaines, IL

Mercury Control and Cost for Major Utilities
Summary Sheet

Mercury Control and Cost Estimate

- The cost reflect use of the most promising technology (surrogate technology) to measure mercury control and cost over a specific installation schedule. It is likely that other technologies will emerge with equal capability and a lower cost compared to the surrogate technology.

- The surrogate technology uses combinations of activated carbon injection and a dedicated polishing fabric filter.

- The costs include equipment purchases, installation, operation and maintenance. The surrogate technology preserves 95% of flyash generated by units with the fabric filter system. The lost revenue and disposal cost is included for the remaining unusable portion of flyash.

- A cost range is provided. The "expected" case represents equipment and actions required for mercury control. The "high" case represents additional modifications or action to mitigate potential operational impacts or requirements to achieve the assumed control efficiencies.

- Annual costs anticipate control equipment installations occur from 2010 through 2015 (year 7 through 12 of surrogate installation schedule). The cost ramps up over this time with each additional installation. The annual cost is anticipated to continue from year 12 to 20 based on equipment lifetime. Cost will likely begin to decline after year 20 as equipment or generation units begin to be retired or replaced. No estimate is made of the resulting costs.

Incremental Cost of Surrogate Control Technology

Cost Case	Schedule Year						Outgoing Years	
	2010	2011	2012	2013	2014	2015	2030	2035
	7	8	9	10	11	12	20	25

Million Dollars per Year

Expected	28	30	56	71	81	87	87	<87
High	33	35	66	84	96	104	104	<104

Cents per Kilowatt-hour

Expected	0.06	0.07	0.12	0.16	0.18	0.19	0.19	<0.19
High	0.07	0.08	0.15	0.18	0.21	0.23	0.23	<0.23

Incremental Cost of Surrogate Control Technology to the Average Consumer (dollars per year)

Sector	Unit	Indices	7th Year ($/year)		12 Year ($/year)	
			Expected	High	Expected	High
Residential	Household	9,240 kWh/year (1)	6	7	18	21
Commercial	Customer	60,513 kWh/year (1)	37	44	116	138
Industrial	Net Proceeds	0.46 kWh/$1000 (2)	0.28	0.33	0.88	1.05
	Value Shipped Product	0.21 kWh/$1000 (3)	0.13	0.16	0.41	0.49

Comparison to Control and Cost of other Pollutants

- The cost of operating the surrogate control technology is comparable to EPA estimates of NOx and SOx control.

Pollutant	Control Efficiency	cents / kWh
Hg	80%	0.19 – 0.23
NOx – Low NOx Burners	50%	0.021 – 0.083
NOx – Selective Catalytic Reactor	80 - 90%	0.185 – 0.361
SOx	80 – 90%	0.6 – 0.8

- In comparison, Wisconsin's current NOx reduction program affects five utility facilities in eight southeast counties. The NOx rule established a 40 – 50% reduction across these facilities with an estimated annual cost of 8 – 10 million dollars per year or 0.03 – 0.04 cents per kilowatt hour. Based on information submitted in a NOx control docket to the Public Service Commission in 2000 it is estimated a statewide NOx rule achieving a 80 – 90% reduction would have an annual cost of 70 – 100 million dollars per year or 0.15 – 0.22 cents per kilowatt-hour. Technology advancements since this time may result in a lower cost.

- A multi-pollutant approach for mercury and any one of particulate, sulfur dioxides, and nitrogen oxide pollutants has the potential to reduce the cost attributed to control of the individual pollutants. Control of particulate and sulfur dioxides is anticipated to be synergistic with mercury control. The control of NOx may provide some benefit but is more independent of mercury control based on current information.

Cost of Monitoring and Determining Compliance

- The cost of compliance determination for the major stationary sources is anticipated to consist of compiling existing data, maintaining records of appropriate fuel consumption or process utilization, and performing calculations necessary to determine mercury emissions. It is anticipated that no or minimal emissions, fuel, or process stream testing will be required to determine annual emissions.

- The cost of compliance determination for the major utilities consists of two separate actions. 1) The initial mercury baseline and unit control efficiency determination. The cost is approximately 490,000 dollars or 12,000 dollars per boiler based on monthly fuel mercury testing in 2004 and one stack emission test. 2) The major utilities begin monitoring and testing in 2008 to demonstrate annual compliance. The annual cost is estimated to be 220,000 dollars or 5,200 dollars per unit based on monthy fuel sampling and stack testing every two years for units larger than 200 MW or every four years for small units.

Revised Mercury Rules
June 2003

Critical Considerations

- *Planning and Design Period* – The proposed rules do not require mercury emission reductions until seven years after promulgation (2010). This provides time for refinement of mercury control technologies, planning and design for controls, and initiating the installation of equipment.
- *Staged Installation Schedule* – There are 42 coal-fired boilers at the four utilities affected by the proposal. The schedule we are proposing does not require all these units to be controlled at the same time. We recognize that equipment installation must be staged to avoid disruption in service. Thus the proposal has an initial reduction at year seven (2010) and a final reduction at year twelve (2015).
- *Compliance Flexibility* – Each of the four major utilities is allowed to average their mercury emission reduction requirement across their entire system allowing flexibility in the deciding how the mercury reductions will be achieved. In addition, the four major utilities can enter into agreements with each other to exchange excess mercury reductions to meet the rule requirements.
- *Multi-pollutant Approach* – The proposal allows relief from the initial reduction requirement if a major utility is interested in pursuing a multi-pollutant approach.
- *Fuel Mix* – The proposal does not force utilities to switch to natural gas to meet mercury reduction requirements. The reductions proposed can be met by installation of controls on existing coal-fired units. Fuel switching is an option not a mandated action.
- *Electric Reliability Waiver* – It is recognized that unanticipated events beyond the control of a utility may result in mercury emissions above the proposed limitations. The proposal includes a provision that would allow a waiver under these circumstances. The Public Service Commission would be consulted as part of any waiver request.
- *Variance* – In addition to the waiver there is provision for a variance that could specify a different schedule or reduction level or both based on a showing of technological or economic infeasibility. The Public Service Commission would also be consulted as part of the variance review.
- *Periodic Evaluation of Requirements* – At two specific times a report to the Natural Resources Board is required that would allow for revision to mercury reduction requirements based on control technology development and other factors.

Summary Table

PROPOSED RULES	REVISED RULES
Utilities Affected – Affects all major utilities in the state (mercury emissions greater that 100 pounds per year) – Dairyland Power Cooperative, WE Energies, Wisconsin Public Service Cooperation and Alliant Energy.	No change
Determining Baseline Emissions – Baseline emissions must be determined by a procedure that includes evaluation of historical fuel mercury content and use information from the years 1998 through 2000. This requirement affects major utilities (>100 pounds per year) and other significant sources (>10 pounds per year). Stack emissions of mercury are the foundation for establishing the baseline.	Only major utilities are required to set baseline emissions. Mercury content in fuel and fuel consumption are the foundation for establishing the baseline. *Supports methodology favored by major utilities. The need for historical data is minimized and this method avoids the issues of determining current equipment performance and lack of credit for recent changes at a facility. This method puts all major utilities on a uniform footing with good quality control on mercury testing. Facilities keep good records of coal consumption so using current and historical basis is fair. No penalty for already having made improvements*

PROPOSED RULES	REVISED RULES
	since the baseline is from uncontrolled emissions.
Emissions Cap – Beginning in the 4th year after promulgation a cap is placed on mercury emissions from each major utility and other significant commercial and industrial sources.	Cap becomes effective in 2008 for major utilities. Industry mercury emissions would not be subject to emission caps. A voluntary program to reduce mercury emissions will be developed. Progress on this voluntary program would be provided to the NRB.
Major Utility Reduction Requirement – Three reductions required over a fifteen-year period – 30% five years, 50% in ten years and 90% in Fifteen years.	The fifteen-year 30/50/90 percent reduction requirement for major utilities is replaced with a two-step reduction requirement that results in 80% reduction of uncontrolled mercury emissions in 12 years (2015). An initial reduction of 40% is required at seven years (2010).
Electric Reliability – Variance process provided in the proposed rules	Specific electric reliability waiver that may provide short-term relief if certain circumstances are met is added. PSC would be consulted. A variance for economic or technological hardships would be retained.
Emission Offsets – New utility sources that have mercury emissions greater than 10 pounds per year are required to obtain offsets at a ratio of 1.5 to 1.0.	The requirement for offsets for new mercury emission sources is eliminated. Significant new sources would be required to limit mercury emissions through application of control technology if not covered by a federal requirement under section 112 of the Clean Air Act.
Trading – Emission reduction credits can be used by major utilities to meet reduction requirements in the rules. These are credits that are created by pollution reduction projects initiated by industrial and commercial sources or by mercury containing product collection program.	Trading provisions are largely eliminated. *Additional analyses have determined that you cannot accurately measure the amount of credit from a product collection program or reduction at a source of process emissions. Additionally, the amount of credit that was initially felt to be available from industrial combustion sources is much less than anticipated. One source, Vulcan Chemical, may be in a position to set the market price.*
Compliance Flexibility – Major utilities can average their mercury emissions across their entire system to demonstrate compliance. In addition, ½ of required reductions may be achieved by obtaining emission reduction credits from the trading provisions.	System-wide averaging is maintained. Emission reduction credits are not available to meet rule requirements. Major utilities can enter into agreements with each other to share reductions to meet rule requirements. Utilities would be required to comply annually with the reduction requirements. However, they will have opportunity to true-up over two years if a timely commitment is made. A multi-pollutant option is included that would allow relief from the initial reduction requirement of 40% to accommodate those major utilities that desire additional time for comprehensive planning if they choose this approach.
Periodic Evaluation – Proposed rules include a review every 18 months.	Evaluation report provided at 6 years (2009) and 10 years (2013). In addition, a NRB report would occur upon the promulgation of a federal regulation or enactment of a federal law that addresses utility mercury emissions in the state.

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No Detectable Risk from Mercury in Seafood, Study Shows

An exhaustive study of 643 children from before birth to 9 years of age shows no detectable risk from the low levels of mercury their mothers were exposed to from eating ocean seafood, according to a study in the May 16 issue of *The Lancet.*

Children born to mothers-to-be who ate an average of 12 meals of fish a week – about 10 times the average U.S. citizen eats – showed no harmful symptoms.

The study by scientists at the University of Rochester Medical Center is the latest in a series of updates on children who have been studied since their birth in 1989 and 1990 in the Republic of the Seychelles, an island nation in the Indian Ocean. The children have been evaluated five times since their birth, and no harmful effects from the low levels of mercury obtained by eating seafood have been detected.

"Consumption of fish is generally considered healthy for your heart, yet people are hearing that they should be concerned about eating fish because of mercury levels," says lead author Gary Myers, M.D., a pediatric neurologist. "We've found no evidence that the low levels of mercury in seafood are harmful. In the Seychelles, where the women in our study ate large quantities of fish each week while they were pregnant, the children are healthy."

In a commentary on the research in *The Lancet*, Johns Hopkins scientist Constantine Lyketsos writes that, "For now, there is no reason for pregnant women to reduce fish consumption below current levels, which are probably safe." He calls the Seychelles study a "methodological advance over previous studies."

Questions about the health effects of mercury often boil down to seafood because fish are the primary source of exposure to mercury for most people. Scientists estimate that about half the mercury in the Earth and its atmosphere originates from natural sources such as volcanoes, and about half comes from man-made sources.

People receive most of their mercury exposure by eating ocean fish like tuna, swordfish and

shark. The fish eaten by women in the Seychelles had approximately the same levels of mercury as those eaten by consumers in the United States – but they ate much more fish than most people in the United States. The Seychelles women, however, had an average of six times as much mercury in their bodies, as measured in hair samples, as most people in the US.

"This study indicates that there are no detectable adverse effects in a population consuming large quantities of a wide variety of ocean fish," says Myers, the senior author of the Seychelles study and an internationally recognized authority on mercury. "These are the same fish that end up on the dinner table in the United States and around the world."

In the current study doctors and nurses tested the children in a variety of ways and measured 21 different cognitive, behavioral, and neurological functions such as concentration, attention span, problem-solving abilities, intelligence, and motor skills. Only two functions varied slightly according to mercury level: Children of women with higher mercury levels were slightly less likely to be hyperactive, and sons of such women did slightly worse on a pegboard task. Statistically, both findings are likely due to chance, the researchers say.

The Seychelles findings apply to fish bought and sold commercially, at grocery stores, supermarkets, seafood markets, and restaurants. Those fish are already regulated based on their mercury levels. Consumers should carefully follow advisories about eating fish caught in lakes and rivers, since there are hundreds of polluted waterways whose fish *are* dangerous to eat in abundance, often because of pollutants like PCBs.

The Seychelles study came about as a result of previous work by the same Rochester team, which put together the first precise data showing that pre-natal exposure to mercury could harm a developing child. Their study of the victims of an accidental mercury poisoning event in Iraq more than 30 years ago spurred them to start the Seychelles study to try to pinpoint the levels at which mercury poses a danger.

Now the team is launching a new study in the Seychelles to compare the levels of nutrients pre-natally to the health of children early in their lives. The study has its roots in a finding in one of the previous Seychelles reports, that children born to mothers with slightly higher mercury levels did better on some neurological and intelligence tests than their counterparts. That may be because those children's mothers with the higher mercury ate more fish. This study, funded by the National Institute of Environmental Health Sciences, is being done with colleagues at the University of Ulster in Northern Ireland and Cornell University.

"There are a lot of good, vital nutrients in fish," says Myers, who is directing the team that is studying 300 children to compare their health with the levels of polyunsaturated fatty acids,

selenium, and other nutrients in their mothers during pregnancy.

The Seychelles study, ongoing since 1989 with funding from the National Institute of Environmental Health Sciences, is one of the longest "longitudinal" studies ever done in children. The research has been funded by the NIH, the U.S. Food and Drug Administration, and the Republic of the Seychelles.

"The cooperation from people in the Seychelles and the Ministry of Health has been extraordinary," Myers says. "They recognize the importance of this subject both to their own citizens and to the people around the world who consume fish."

In addition to Clarkson and Myers, the Seychelles team includes Philip Davidson, Ph.D.; Donna Palumbo, Ph.D.; Li-Shan Huang, Ph.D.; Elsa Cernichiari; and Jean Sloane-Reeves, all of the University of Rochester; and Conrad Shamlaye of the Republic of the Seychelles. Christopher Cox, Ph.D., of the National Institutes of Health; Gregory Wilding, Ph.D., of the University at Buffalo; and James Kost, Ph.D., also took part.

ASSESSING THE ECOLOGICAL RISK OF MERCURY EXPOSURE IN COMMON LOONS (*GAVIA IMMER*): 2001 PROGRESS REPORT

Submitted to the Electric Power Research Institute and
the Wisconsin Utilities Association

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