Methylmercury Science

Gregory Conko and Morgan Wildermuth

During the past few years, environmental activists, public health officials, and the media have become increasingly concerned about consumers' exposure to mercury, primarily methylmercury in fish. In response to exaggerated risk estimates, many consumers have been advised to reduce their fish consumption. However, the most reliable scientific analyses continue to show that eating at least two servings of fish each week produces health benefits that substantially outweigh any hypothesized risk—even for young children and pregnant mothers.

The advisory warnings that spawned this unhealthy trend were not created on a scientific or nutritional basis. Rather, they were created for political reasons. Environmental activists have buoyed the fish scare in an attempt to increase regulation of mercury emissions from electric power plants. The theory is that methylmercury in fish is unhealthy for pregnant women and children and that mercury emissions must therefore be significantly reduced.

A substantial body of evidence indicates, however, that (a) the amount of mercury in the American diet is so low that it has little or no health effect on even at-risk populations, and (b) even sizable reductions in mercury emissions would have no appreciable effect on American exposure to mercury. Furthermore, the cost of complying with new power plant emissions regulations is estimated to have a large human impact.

Mercury Exposure and Health Effects

Very large doses of mercury are known to have substantial adverse health effects, includ-

ing impacts on neurodevelopment in both adults and children.[1] Effects on developing fetuses are of special concern, because mercury in the diet of pregnant women can affect the hearing, intelligence, and other cognitive functions of those children. However, all that we currently know about the health effects of methylmercury exposure is derived from (a) the study of mass poisonings in Iraq and Japan, (b) epidemiological studies conducted with populations that are different from Americans in important ways, and (c) experimental studies on lab animals. Each of these sources suffers from shortcomings, but the existing science suggests that methylmercury exposure at the very small current dietary levels does not pose a genuine health or developmental risk.

The dangerous effects of methylmercury exposure were first highlighted when, from the 1930s to the 1960s, people living around Minamata Bay, Japan, ate fish heavily contaminated with mercury wastes discharged from a plastics factory.[2] Hundreds died, and thousands more were left with varying degrees of neurological damage. The precise level of mercury exposure was never accurately calculated, but it is generally believed to be far higher—perhaps several hundreds of times higher—than current U.S. dietary exposure from fish. A similarly tragic case, resulting from mercury-contaminated grain in Iraq, occurred in the 1970s—again, however, with mercury exposure thousands of times greater than seen today with normal dietary fish consumption.[3] Because the exact dosage is important in determining whether exposure to a substance will be harmful, these mass poisoning scenarios have little or no relevance for determining whether fish consumption, under normal circumstances, poses any legitimate health threat.

Researchers have instead turned to epidemiological studies of various fish-eating populations to determine whether typical dietary mercury exposure poses a real risk. Several different study populations have been examined, but the two largest and most extensive studies have considered populations in the Faroe Islands and the Seychelles Islands. Researchers conducting the Faroe Islands study claim to have found a link between small dosages of mercury and negative health impacts, whereas authors of the Seychelles study are convinced there is no such link.

Faroe Islands

The Faroe Islands study examined 917 children, and the researchers reported an association between prenatal methylmercury exposure (as measured in maternal umbilical cord blood at birth) and subtle neuropsychological changes.[4] However, several important factors call this finding into question. Perhaps most important, the major source of methylmercury in the Faroe Islanders' diet was not fish, but pilot whale meat. However, whale meat is also known to contain very high levels of PCBs (polychlorinated biphenyls) and other synthetic chemicals, none of which were taken into consideration in the study. One of the authors, Philippe Grandjean, acknowledges that such high levels of

1. Mark Wheeler, "Mercury," *Environmental Health Perspectives* 104, no. 8 (1996): 826–30.

2. Judith E. Foulke, "Mercury in Fish: Cause for Concern?" *FDA Consumer* 28 (September 1994), http://www.fda.gov/fdac/reprints/mercury.html.

3. H. Rustam and T. Hamdi, "Methyl Mercury Poisoning in Iraq: A Neurological Study," *Brain* 97, no. 3 (1974): 499–510.

4. Nicolina Sorensen, Katsuyuki Murata, Esben Budtz-Jorgensen, Pal Weihe, and Philippe Grandjean "Prenatal Methylmercury Exposure as a Cardiovascular Risk Factor at Seven Years of Age," *Epidemiology* 10, no. 4 (1999): 370–75.

other chemicals makes accurate interpretation of the study's data very complicated.[5]

Some scientists also question the study's use of maternal cord blood as the indicator of mercury exposure, because blood mercury levels can vary dramatically from day to day and do not give an accurate picture of total exposure throughout a pregnancy. The World Health Organization, for example, indicates that mercury levels in the mother's hair are the most accurate reflection of fetal mercury exposure.[6] When hair methylmercury levels were used, however, no link was found between developmental delays and methylmercury exposure in the Faroe children.[7]

In addition, though 17 neuropsychological tests were conducted on the Faroe Islands children, the results of only 3 of the tests were statistically significant.[8] Of those three tests, the results of only one test clearly indicated neurodevelopmental problems, while another showed a beneficial association with increased mercury exposure, and the third was indeterminate. Consequently, a number of scientists, including Kenneth Poirier and Michael Dourson, former co-chairmen of the U.S. Environmental Protection Agency (EPA) Reference Dose/Reference Concentration Work Group, have advised the EPA and the U.S. Food and Drug Administration (FDA) that the Faroe Islands study is not useful for determining a safe level of exposure to methylmercury.[9]

Seychelles Islands

The most exhaustive study of methylmercury exposure has been an ongoing study begun in 1989 in the Seychelles, an island chain off the coast of eastern Africa. Seychelles residents generally eat fish 12 times a week, which is believed to be the highest per capita consumption of fish in the world.[10] The methylmercury exposures in the Seychelles children studied were 10 to 20 times that of their U.S. counterparts, yet not a single test showed any negative effects from the exposure to mercury in their diet.[11] The study authors concluded, "There is no evidence of neurodevelopmental risk from prenatal meth-

5. Food and Drug Administration, "Methylmercury," Transcript of the Center for Food Safety and Nutrition, Food Advisory Committee Methylmercury Meetings, Beltsville, MD, July 23–24, 2002, http://www.fda.gov/OHRMS/DOCKETS/ac/02/transcripts/3872t2.htm.

6. E. Cernichiari, R. Brewer, G. Myers et al., "Monitoring Methylmercury during Pregnancy: Maternal Hair Predicts Fetal Brain Exposure," *Neurotoxicology* 16, no. 4 (1995): 705–10. See also Gary Myers, "Statement of Dr. Gary Myers, Pediatric Neurologist and Professor, University of Rochester," Senate Committee on Environment and Public Works, Senate Hearing 108-359, *Climate History and the Science Underlying Fate, Transport, and Health Effects of Mercury Emissions*, 108th Congress (July 29, 2003), 299–308.

7. Philip W. Davidson, Gary J. Myers, Christopher Cox, Elsa Cernichiari, Thomas W. Clarkson, and Conrad Shamlaye, "Effects of Methylmercury Exposure on Neurodevelopment," *Journal of the American Medical Association* 281, no. 10 (1999): 897.

8. Center for Science and Public Policy, "Critical Comments on EPA's Proposed National Emission Standards for Hazardous Air Pollutants; and, in the Alternative, Proposed Standards of Performance for New and Existing Utility Steam Generating Units: Notice of Data Availability," Center for Science and Public Policy, Washington, DC, December 2004. http://ff.org/centers/csspp/pdf/EPANODAComments-121804.pdf.

9. Michael Dourson, Andrea Wullenweber, and Kenneth Poirier, "Uncertainties in the Reference Dose for Methylmercury," *Neurotoxicology* 22, no. 5 (2001): 677–89.

10. Gary J. Myers, Philip W. Davidson, Christopher Cox, Conrad F. Shamlaye, Donna Palumbo, Elsa Cernichiari, Jean Sloane-Reeves, Gregory E. Wilding, James Kost, Li-Shan Huang, and Thomas W. Clarkson, "Prenatal Methylmercury Exposure from Ocean Fish Consumption in the Seychelles Child Development Study," *Lancet* 361, no. 9370 (2003): 1686–92.

11. Ibid.

ylmercury exposure resulting solely from ocean fish consumption."[12]

What perhaps makes the Seychelles study most relevant to Americans is that Seychelles residents eat the same fish varieties commonly eaten in the United States, and, unlike the Faroe Islands study, there are no other health, educational, environmental, or dietary differences that might make the results unreliable. The only important dietary difference is that typical Seychelles residents consume much more fish than do typical Americans—the exposure of both mothers and children ranged from about the same to 27 times greater than the typical American consumer. Furthermore, unlike the Faroe study, testing has remained double-blind—meaning neither the children nor the scientists administering and scoring the neurodevelopmental tests knew any one child's methylmercury level—which tends to make a study more accurate and less prone to researcher bias.[13] The Faroe Islands study, on the other hand, ceased being double-blind once the children were tested at age 7.

Finally, the Seychelles researchers tested their subjects at 6, 16, 29, 66, and 107 months of age. They evaluated the children on 57 different measurements of neurocognitive, language, memory, motor, perceptual, and behavioral functions, making this research the most comprehensive study ever done of mercury exposure. The ultimate finding, according to lead investigator Gary Myers, a professor of neurology and pediatrics at the University of Rochester Medical Center, is that "These children show no adverse effects through nine years of age, suggesting that eating ocean fish, when there is no local pollution, is safe."[14] And Constantine Lyketsos of Johns Hopkins Hospital and Health System concludes that "the existing evidence suggests that methylmercury exposure from fish consumption during pregnancy, of the level seen in most parts of the world, does not have measurable cognitive or behavioral effects in later childhood."[15]

New Zealand

A third major study was conducted in New Zealand[16] but has generally not been considered methodologically sufficient, on its own, to support conclusions about the effect of mercury on health.[17] The New Zealand researchers did find mixed evidence, with some tests indicating a negative effect from mercury exposure. But the study investigated only 38 mother–child pairs found to have high hair mercury levels, making the sample too small a source from which to estimate a safe exposure level. In addition, the principal source of dietary mercury exposure in New Zealand is through the consumption of shark meat, which tends to be much higher in mercury concentration than the typical fish species consumed in the United

12. Ibid.

13. Sandy Szwarc, *Fishy Advice: The Politics of Methylmercury in Fish and Mercury Emissions* (Washington, DC: Competitive Enterprise Institute, 2004).

14. Myers, "Statement of Dr. Gary Myers."

15. Constantine G. Lyketsos, "Should Pregnant Women Avoid Eating Fish? Lessons from the Seychelles," *Lancet* 361, no. 9370 (2003): 1668.

16. K. S. Crump, T. Kjellström, A. M. Shipp, A. Silvers, and A. Stewart, "Influence of Prenatal Mercury Exposure upon Scholastic and Psychological Test Performance: Benchmark Analysis of a New Zealand Cohort," *Risk Analysis* 18, no. 6 (1998): 701–13.

17. Gary J. Myers, Philip W. Davidson, and Conrad F. Shamlaye, "A Review of Methylmercury and Child Development," *Neurotoxicology* 19, no. 2 (1998): 313–28. See also National Research Council, *Toxicological Effects of Methylmercury* (Washington, DC: National Academies Press, 2000), 128–29.

States. Thus, the study subjects were exposed to much higher levels of methylmercury than are typical Americans.

EPA's Risk Assessment

Despite the relative merits of the Seychelles research, and the comparative shortcomings of the Faroe research, the EPA's "reference dose" (or estimated safe exposure level) for methylmercury is based solely on the Faroe Islands study. At the EPA's request, a National Research Council (NRC) committee was impaneled to advise the agency on developing the reference dose.

> The committee conclude[d] that there do not appear to be any serious flaws in the design and conduct of the Seychelles, Faroe Islands, and New Zealand studies that would preclude their use in a risk assessment. However, because there is a large body of scientific evidence showing adverse neurodevelopmental effects, … the committee conclude[d] that [a reference dose] should not be derived from a study, such as the Seychelles study, that did not observe an association with [methylmercury].[18]

Thus, merely because the Seychelles study found that dietary exposure to methylmercury at levels as much as 10 times greater than seen in the United States appear to be safe, the NRC panel refused to consider it. But almost all of the "large body of scientific evidence," on which the committee based its decision, is evidence only of extremely high mercury exposures that bear no useful relationship to current dietary intake.

Once the NRC committee hand-selected the data it would use, it identified a *benchmark* dose, which is the lowest dose thought to cause zero harm over a lifetime of daily exposure in the most sensitive population of children. Using data from the Faroe Islands study, the NRC committee recommended setting the benchmark dose at 58 micrograms per liter in a person's blood, and the EPA agreed. Even this number is much lower than evidence from the Seychelles study and other recent research would indicate to be safe. Yet, to build in another large margin of safety, the NRC then set the *reference dose* used for establishing regulatory policy an order of magnitude lower: a daily intake of one-tenth of one microgram of mercury per kilogram of the consumer's body weight.[19]

This reference dose is the most restrictive safety threshold in the world, and most other scientific bodies—including the United Nation's Food and Agriculture Organization and World Health Organization, the governments of Canada and the United Kingdom, and even the Agency for Toxic Substances and Disease Registry of the U.S. Department of Health and Human Services—have established minimum recommended exposure levels that are several times higher than the EPA's reference dose.[20] Nevertheless, a U.S. Centers for Disease Control and Prevention (CDC) study of American children and women of childbearing age found that, in 1999 and 2000, a mere 8 percent of the studied population had blood mercury levels

18. National Research Council, *Toxicological Effects of Methylmercury*, 6.

19. Ibid., 21.

20. Harold M. Koenig, *Mercury in the Environment: The Problems, the Risks, and the Consequences* (Annapolis, MD: Annapolis Center for Science-Based Public Policy, 2003). See also Ken Ogilvie, *Mercury in the Environment: A Primer* (Toronto, ON: Pollution Probe, 2003).

above the extra safe reference dose.[21] A follow-up study in 2001 and 2002 found that only 4 percent were above the reference dose level.[22] None were even close to the very conservative benchmark dose that EPA estimates will cause zero harm over a lifetime of exposure. But by warning consumers—especially women of childbearing age—to be concerned about mercury exposure from eating seafood, the EPA and the FDA are actually putting American lives at risk.

Importance of Fish for Good Health

The most important problem with EPA's extraordinarily low reference dose for methylmercury exposure is that it has led the EPA and the FDA to jointly warn American consumers that eating too much of certain kinds of fish may be harmful to their health. Unfortunately, exactly the opposite is the case. A vast body of scientific research clearly indicates that, even if current dietary levels of mercury exposure were to pose some risk, the benefits obtained by consuming fish vastly outweighs that risk. According to Walter Willett, professor of nutrition at the Harvard School of Public Health, the benefits of eating seafood "are likely to be at least 100-fold greater than the estimates of harm, which may not exist at all."[23]

Instead of improving consumer health, EPA and FDA mercury advisories have needlessly frightened consumers away from eating a food that is actually very good for them. The agencies have issued increasingly complicated and extensive mercury advisory notices that appear to be confusing consumers about which fish species are safe and which are dangerous. A joint FDA–EPA advisory issued in March 2004 warns women of childbearing age to avoid swordfish, shark, king mackerel, and tilefish from the Gulf of Mexico (but not tilefish from the Atlantic Ocean).[24] It then suggests that women eat 12 ounces per week of a variety of fish species, and it lists several fish types that are especially low in methylmercury—including canned light tuna. However, the advisory distinguishes among canned tuna varieties, indicating that, if women eat six ounces of albacore tuna, they should then eat no more than six ounces of any other fish that week. It's no wonder that many consumers have become concerned about eating any fish at all. The health benefits of fish consumption are both very large and well established, however.

Fish, especially species such as tuna and salmon, are inexpensive sources of protein that are also rich in important minerals and beneficial omega-3 fatty acids.[25] Consumption of as little as one or two servings of fish each week is associated with a substantial reduction in the

21. Kathryn Mahaffey, Robert Clickner, and Catherine Bodurow, "Blood Organic Mercury and Dietary Mercury Intake: National Health and Nutrition Examination Survey, 1999 and 2000," *Environmental Health Perspectives* 112, no. 5 (2003): 562–70.

22. R. L. Jones, T. Sinks, S. E. Schober, and M. Pickett, "Blood Mercury Levels in Young Children and Childbearing-Aged Women—United States, 1999–2002," *Morbidity and Mortality Weekly Report* 53, no. 43 (2004): 1018–1020.

23. Sally Squires, "Good Fish, Bad Fish: Sorting Seafood's Benefits from Risks Can Leave Consumers Floundering," *Washington Post*, August 8, 2006, F1, 5.

24. FDA and EPA, "What You Need to Know About Mercury in Fish and Shellfish: Advice for Women Who Might Become Pregnant, Women Who Are Pregnant, Nursing Mothers, Young Children," FDA and EPA, Washington, DC, March 2004, http://www.epa.gov/waterscience/fishadvice/advice.html.

25. British Nutrition Foundation, "n-3 Fatty Acids and Health," BNF Briefing Paper, British Nutrition Foundation, London, 2000.

risk of stroke and heart disease, lowering the probability of death from coronary disease by more than one-third and lowering total mortality by 17 percent.[26] And these benefits exist despite any potential health risk of methylmercury consumption. Yet, at the same time that the American Heart Association and American Dietetic Association have been recommending that consumers *increase* consumption of fish,[27] the public has been led to believe that they should instead reject most fish.

Despite beliefs to the contrary, pregnant women and their children also reap numerous benefits from fish consumption, because fish are a good source of the n-3 fatty acids docosahexaenoic acid and eicosapentaenoic acid. These two nutrients are known to contribute to healthy pregnancy outcomes and fetal growth and to reduce the risk of preeclampsia and premature labor. But a Harvard University study found that, after publication of the FDA's 2001 mercury advisory, pregnant women reduced their fish intake dramatically because of confusing advisories.[28]

Conclusion

The mercury advisory warnings issued in recent years have spawned an unhealthy trend toward lower fish consumption. However, a substantial body of evidence indicates that the amount of mercury in the American diet is so low that it has little or no health effect on even at-risk populations, such as pregnant women and children. The basis for these mercury advisories is a single, unreliable study chosen solely for the reason that it purportedly found negative health consequences of low-level mercury exposure. Even if that study was accurate, however, further research by the CDC indicates that no American women of childbearing age have dietary mercury exposure anywhere near those allegedly harmful levels.

The policy brief entitled "Mercury Pollution and Regulation" in this volume's "Clean Air" section further discusses the politicization of the mercury debate and the high cost of complying with new power plant emissions regulations, which could have their own substantial impact on humans.

Key Experts

Gregory Conko, Senior Fellow, Competitive Enterprise Institute, gconko@cei.org.

Iain Murray, Senior Fellow, Competitive Enterprise Institute, imurray@cei.org.

26. Dariush Mozaffarian and Eric B. Rimm, "Fish Intake, Contaminants, and Human Health: Evaluating the Risks and the Benefits," *Journal of the American Medical Association* 296, no. 15 (2006): 1885–99. See also Hiroyasu Iso, Kathryn M. Rexrose, Meir J. Stampfer, JoAnn E. Manson, Graham A. Colditz, Frank E. Speizer, Charles H. Hennekens, and Walter C. Willett, "Intake of Fish and Omega-3 Fatty Acids and Risk of Stroke in Women," *Journal of the American Medical Association* 285, no. 3 (2001): 304–12, and Penny Kris-Etherton, W.S. Harris, and Lawrence J. Appel, "Summary of the Scientific Conference on Dietary Fatty Acids and Cardiovascular Health, Nutrition Committee of the American Heart Association," *Circulation* 103, no. 7 (2001): 1034–39.

27. American Heart Association, "At-a-Glance: American Heart Association's Dietary Recommendations for Children and Adolescents," October 30, 2006, American Heart Association, Dallas, TX, http://www.americanheart.org/presenter.jhtml?identifier=3034000.

28. Emily Oken, Ken P. Kleinman, Wendy E. Berland, Steven R. Simon, Janet W. Rich-Edwards, and Matthew W. Gillman, "Decline in Fish Consumption among Pregnant Women after a National Mercury Advisory," *Journal of Obstetrics and Gynecology* 102, no. 2 (2003): 346–51.

Recommended Readings

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Updated 2008.