JOINT CENTER
AEI-BROOKINGS JOINT CENTER FOR REGULATORY STUDIES

# Regulating Mercury Emissions: What Do We Know About Costs and Benefits?

**Randall Lutter, Elizabeth Mader, and Nathan Knuffman**

Regulatory Analysis 01-03

March 2001

Mr. Lutter is a fellow and Ms. Mader is an analyst with the AEI-Brookings Joint Center for Regulatory Studies. Mr. Knuffman contributed to this research while preparing a related master's project at the University of Maryland in the spring of 2000. Mr. Lutter's e-mail address is rlutter@aei.org. We thank Richard Belzer and Resources for the Future seminar participants for helpful comments. The views expressed in this paper are those of the authors and not necessarily the views of any institutions with which they are affiliated.

# JOINT CENTER

In response to growing concerns about understanding the impact of regulation on consumers, business, and government, the American Enterprise Institute and the Brookings Institution have established the AEI-Brookings Joint Center for Regulatory Studies. The primary purpose of the center is to hold lawmakers and regulators more accountable by providing thoughtful, objective analysis of existing regulatory programs and new regulatory proposals. The Joint Center builds on AEI's and Brookings's impressive body of work over the past three decades that has evaluated the economic impact of regulation and offered constructive suggestions for implementing reforms to enhance productivity and consumer welfare. The views in Joint Center publications are those of the authors and do not necessarily reflect the views of the staff, council of academic advisers, or fellows.




All Joint Center publications can be found at www.aei.brookings.org

## Executive Summary

United States policymakers are concerned with mercury emissions because mercury has potentially adverse effects on children whose mothers consumed contaminated fish while pregnant. Congress and the Environmental Protection Agency are considering different proposals to cut or even eliminate mercury emissions from oil and coal-fired power plants.

We compare the cost of cutting power plants' mercury emissions with the likely reductions in the number of cases of subtle neurological effects. Given current scientific understanding, the health and environmental improvements are very unlikely to provide an economic justification for the costs of stringent controls on mercury emissions. In addition, if Congress or EPA were to regulate mercury emissions from power plants, an approach that used prices would be more efficient than one that limited the quantity of mercury emissions.

# Regulating Mercury Emissions:
# What Do We Know About Costs and Benefits?

**Randall Lutter, Elizabeth Mader, and Nathan Knuffman**

## 1. Introduction

Mercury in the environment has provoked substantial concern among U.S. policymakers.[1] An organic form, methylmercury (MeHg), accumulates in higher concentrations as it moves up the food chain, and prenatal exposure to low doses from maternal consumption of fish has been associated with subtle neurological deficiencies in children.[2] To reduce human exposure, states have issued more than 1,900 fish consumption advisories covering nearly the entire East Coast, the Gulf of Mexico, and the Great Lakes.[3]

Further government action is likely. Several bills in Congress would require utilities to reduce their mercury emissions by 90 percent.[4] During the election campaign, then-Governor Bush expressed support for the ideas behind these bills.[5] The Environmental Protection Agency (EPA), which regulates mercury emissions from municipal waste combustors and medical waste incinerators, determined in December 2000 that regulating emissions from coal and oil burning utilities under the Clean Air Act (CAA) is "appropriate and necessary".[6] Its decision will lead to a regulation by December 2004, requiring plants to adopt the "maximum achievable control technology" (MACT), a standard likely to lead to stringent emissions reductions.[7]

Regulating mercury emissions from power plants entails a tradeoff. More stringent mercury emissions limits may reduce mercury contamination of fish, thereby

[1] See Renner (1999) for discussion of federal agencies' consideration of health effects of mercury exposure.
[2] See National Research Council (2000).
[3] Each advisory addresses specific species or size of fish from certain bodies of water. The list of states excludes Delaware, Maryland and Ohio. See U.S. Environmental Protection Agency (1999b).
[4] The Clean Power Plant and Modernization Act of 1999 (S 1949) sponsored by Senator Leahy would require the removal of 90% of the mercury otherwise present in the fuel. The Clean Smokestacks Act of 1999 (HR 2900) sponsored by Congressman Waxman would cut emissions to 10 percent of 1997 emissions. Senator Leahy and Congressman Waxman's staff inform us that these bills will be reintroduced. For a discussion of emissions reductions options, see U.S. Environmental Protection Agency (1999a).
[5] See Bush (2000).
[6] See U.S. Environmental Protection Agency (2000).
[7] See U.S. Environmental Protection Agency (2000) and the Clean Air Act, at 42 U.S.C. Section 7412.

lowering the risks of adverse health effects. On the other hand, controlling mercury emissions entails costs that utilities will pass on to customers.

While assessing this tradeoff is difficult because of limitations to scientific understanding, Lutter and Mader suggest that eliminating mercury emissions from U.S. power plants could reduce the numbers of U.S. children experiencing subtle neurological deficiencies by on the order of 10,000 per year.[8] We use this estimate as a point of departure and assess the costs and benefits of mercury emissions controls.

We show that the costs of reducing mercury emissions from power plants are likely to substantially outweigh the benefits. We also show that the quantity restrictions in Congressional proposals and in EPA's regulatory effort are unlikely to be as efficient as an alternative approach that reduces the risk of high compliance costs.

The next section deals with public health and environmental benefits of reducing mercury emissions from power plants. The subsequent sections address the cost and cost-effectiveness of emissions cuts, the general limitations of current understanding, policy design, and conclusions.

## 2. Public Health and Environmental Benefits of Controlling Environmental Mercury

We focus on human health effects associated with consumption of mercury-contaminated fish because benefits to wildlife appear to be quite small. Such benefits are concentrated in species whose diet is mostly fish because methylmercury tends to accumulate in fish tissue. [9] In its multi-volume report to Congress in 1997, EPA described environmental effects by noting only that environmental mercury may adversely affect reproduction of loons. But common loon populations have been rising for several decades. The annual growth rate of the common loon population was 2.6 percent between

[8] See Lutter and Mader (2001).

[9] See U. S. Environmental Protection Agency (1997, Vol. VII, Chapter 3). Although mercury is also a threat to the endangered Florida panthers, the State of Florida lists it as less important than the loss, fragmentation and degradation of habitat, inbreeding of panthers, lack of large prey, and disease. See Florida Fish and Wildlife Conservation Commission (2000). Panthers, because they are top of the food chain predators, suffer from contaminants other than mercury, such as polychlorinated biphenyls and pesticides; see U.S. Geological Survey (1999). Mercury in the Everglades comes from Europe and Asia as well as North America; see Florida Fish and Wildlife Conservation Commission (2000) and also U.S. Geological Survey (2000a and 2000b). Thus, reductions in U.S. mercury emissions may have very small effects on levels of mercury in South Florida, which is anyway low in the list of threats facing panthers.

1966 and 1999, with a 95 percent confidence interval from 1.6 to 3.7 percent.[10] Populations of other fish-eating birds have been growing at even faster rates.[11] These high growth rates and the fact there appears to be no correlation between areas of low population growth and areas of high mercury deposition suggest that the ecological benefits of reducing mercury emissions are likely to be negligible.[12]

Lutter and Mader recently estimated that as many as 180,000 U.S. children per year were likely to experience neurological deficiencies from exposure to mercury but that the vast majority of these deficiencies would be quite small compared to variations found within normal populations.[13] Their estimates are different from those recently reported in the *Mortality and Morbidity Weekly Review*, in that Lutter and Mader assessed both exposure and the likely severity of health effects (using available epidemiological relationships).[14] Lutter and Mader found that all of the effects are relatively small percentages of a standard deviation (see table). In addition, they found that, because other factors contribute to exposure, eliminating mercury emissions from U.S. power plants would avoid only about 5 percent of these cases per year.[15]

The Lutter and Mader assessment may overestimate public health improvements if recent government advisories reduce excessive fish consumption among people who are highly exposed to mercury. The Food and Drug Administration just released a new advisory recommending that, to avoid levels of mercury that could harm an unborn child, pregnant women should not eat any shark, swordfish, king mackerel or tilefish and should limit their consumption of cooked fish to twelve ounces per week on average.[16] EPA released a similar directive to reduce consumption of wild-caught freshwater fish. It

---

[10] See Sauer et al. (2000).

[11] For osprey populations the survey-wide trend is 6.7 percent (with a 95 percent confidence interval of 4.8 percent to 8.6 percent) while for double-crested cormorants the survey-wide trend is 7 percent per annum (and the 95 percent confidence interval is from 2.4 percent to 11.6 percent). See Sauer et al. (2000).

[12] See the trend maps in Sauer et al. (2000).

[13] Lutter and Mader (2001) also consider the possibility of cardiovascular effects of mercury-contaminated fish, as suggested by Salonen et al. (1995), but conclude that the lack of replication of those results and the contrary results of the Kinjo study (1996) make it inappropriate to include cardiovascular benefits of mercury reduction without further research into the existence of such an effect.

[14] See Center for Food Safety and Applied Nutrition (2001).

[15] This assessment of the benefits of reducing U.S. mercury emissions neglects effects on non-U.S. populations although cuts in U.S. mercury emissions may improve the health of children in other countries whose mothers consume large quantities of fish. Assessing the magnitude and significance of any health improvements in these populations is beyond the scope of this project.

[16] See U.S. Food and Drug Administration (2001c).

says, “If you are pregnant or could become pregnant, are nursing a baby, or if you are feeding a young child, limit consumption of fish caught by family and friends to one meal per week. For adults one meal is six ounces of cooked fish or eight ounces uncooked fish; for a young child one meal is two ounces cooked fish or three ounces uncooked fish.”[17] These advisories will lower the benefits of reducing emissions to the extent that they lower the number of pregnant women whose diets expose them to high levels of mercury.

## 3. Costs of Controlling Mercury Emissions

According to EPA, the costs of stringent regulation of mercury emissions are likely to be between $1.1 billion per year and $1.7 billion per year.[18] The emissions reductions from mercury specific controls *and* pre-existing controls are between 60 to 95 percent for the lower cost estimate and between 80 to 95 percent for the upper cost estimate.[19] These estimates reflect use of a composite sorbent (lime and powdered activated carbon) that was tested in only a small number of pilot scale systems and are fairly uncertain. EPA predicts that costs would rise by about 40 percent if estimates were based on a technology supported by data from a larger number of trials of pilot scale systems.[20]

A key question in evaluating cost is the effectiveness of mercury emission controls in reducing other forms of pollution. In its recent determination, EPA reaches no conclusion about whether mercury emission controls reduce emissions of nitrogen oxides and sulfur dioxide.[21] EPA had previously found that mercury controls on utility emissions are likely to have “little effect” on sulfur dioxide and oxides of nitrogen,[22] and we adopt that view here.[23]

[17] See U.S. Environmental Protection Agency (2001).
[18] See Jayarman et al. (2000). These are 1999 dollars.
[19] See Jayarman et al. (2000, p. 7). EPA apparently gives no estimate of how much of these mercury emissions reductions result from adoption of the new mercury-specific control measures. One memo indicates, however, that in 1999 air pollution control devices currently installed on existing units captured 43 percent of the mercury in fuels. See Princiotta (2000, p.6).
[20] See Jayarman et al. (2000).
[21] See U.S. Environmental Protection Agency (2000).
[22] See U.S. Environmental Protection Agency (1999a, 4-2).
[23] The effect may depend in part on the stringency of controls for sulfur-dioxide and nitrogen oxides, something that may vary with ongoing court battles and future regulations.

The cost-effectiveness of controls on coal-fired utilities may be quite poor compared to controls to reduce mercury emissions from other sources. The best measure of cost-effectiveness—the incremental social cost for the last unit of environmental and public health damage from mercury—is not available. EPA's estimates suggest, however, that the cost per pound of mercury emissions removed at coal-fired power plants is more than 75 times the cost per pound of a recent regulation of emissions from municipal waste combustors[24] and about 17 times the cost per pound of regulating medical waste incinerator emissions.[25] These comparisons are imperfect because 1) they neglect reductions in other contaminants, likely to be smaller for power plant controls;[26] 2) they are based on average rather than incremental cost; and 3) the data on utility control costs may be slightly higher than more recent estimates. Nonetheless, the cost of mercury controls for utilities appears much greater than the cost of controls for other sources.

## 4. Comparison of Health Benefits and Costs

It is difficult to compare the reductions in risk described earlier with the costs of regulating mercury. Such comparisons typically require assessment of the value of health benefits using measures of willingness to pay to avert risks. Yet small changes in finger tapping skills, hand-eye coordination, and the ability to recall names—changes found in affected individuals—are such specific and relatively minor health effects that the economics literature has not developed estimates of willingness to pay. The McCarthy generalized cognitive index is a broad measure of neurological performance that may be more amenable to economic valuation, but it was not statistically significantly associated with mercury in one series of studies.[27] Moreover, this index is not equivalent to I.Q., a measure of neurological performance with clear and measurable economic implications.[28]

---

[24] See Table 5 for a full explanation.
[25] See U.S. Environmental Protection Agency (1997, Vol. VIII, p. ES-14). These cost-effectiveness estimates assume that the entire cost of control is attributed to mercury removal; see p. ES-13.
[26] See U.S. Environmental Protection Agency (1999a, 4-2).
[27] See Davidson et al. (1998). See also Myers et al. (2000).
[28] McCarthy reported correlation coefficients of only 0.71 between the McCarthy Scale's generalized cognitive index and the Wechsler Preschool and Primary Scale of Intelligence, a full-scale measure of IQ; See Massoth (1985, p.10) describing McCarthy. Nagle (1979, p. 319) reports that the McCarthy Scales' concurrent validity with conventional IQ tests suggests that the McCarthy generalized cognitive index and IQ are not compatible. In studies of learning disabled, mentally retarded, and gifted children, the McCarthy

While the health gains from *eliminating* mercury emissions from power plants are difficult to value in dollar terms, subjectively they appear much smaller than EPA's estimates of $1.1 billion to $1.7 billion per year for the costs of unspecified cuts in emissions. Regulatory costs of about $1.5 billion per year might result in improvements in the health of around 10,000 children, given Lutter and Mader's assumption that the elimination of mercury emissions from power plants would cut elevated exposure in the United States by only 5 percent.[29] In this case, whether the health benefits justify the costs amounts to whether a family would prefer a payment of $150,000 to receiving these health improvements.[30] The size of the health improvements in question suggests a clear answer. As shown in the table, the middle exposure group would experience gains in naming skills and reaction times of about 11 percent and 14 percent of a standard deviation, respectively. Improvements in other aspects of neurological performance would be smaller, except for the small group of children initially exposed to levels greater than 4 ppm. Yet all these changes in neurological performance are within the range of normal outcomes, which typically encompasses four standard deviations. As a result, the health improvements would be hard to discern without a formal evaluation. Therefore, we believe that the vast majority of all families would view such health effects as much less valuable than $150,000.

## 5. General Limitations

Before jumping to a discussion of policy, we briefly review general limitations of this analysis. First, we have ignored any behavioral response, although for nearly thirty years economists have recognized that people protect themselves from risks and that changes in such self-protection can alter the effectiveness of regulatory efforts to control risks.[31] In the case of mercury, if anglers decide to eat more fish after a program of

---

scale underestimated IQs by an average of 8 to 20 points. For further discussion of the correlation between the McCarthy Scales and IQ, see also Massoth (1985, pp. 10-11) and Davis (1975, pp. 102-104).

[29] Five percent of the sum of the population estimates in table 2 is 7,000 for the low estimate and 9,000 for the high estimate. This calculation understates the cost per case avoided because it uses cost estimates that reflect only a partial cut in emissions and health improvements consistent with a total elimination of emissions.

[30] In fact, this thought experiment is simplified. Families should more accurately be asked to choose between a modest payment and a very small reduction in risk of minor health effects.

[31] See Ehrlich and Becker (1972) and more recently Shogren and Crocker (1999).

emissions reductions is in place, their total exposure may not be reduced as much as estimated here and could even be unaffected by the emissions cuts.

Yet a recent EPA decision illustrates how government actions might change behavior so as to *increase* risks. In a decision based "solely on data and scientific judgments about the relationship between pollutant concentrations and environmental and human health effects", EPA set a stringent water quality criterion for methylmercury that can be interpreted to mean that much of the current fish supply is not safe.[32] EPA's criteria level "to protect consumers of fish and shellfish among the general population"[33] is 30 percent of the Food and Drug Administration's "action limit" of 1 ppm.[34] Approximately a third of all edible fish found in U.S. waters have methylmercury concentrations in excess of the criteria level set by EPA.[35] In addition, the *mean* concentrations of mercury for several species and the maximum concentrations for nearly all species exceed the criteria value.[36] Since EPA believes that ambient water quality criteria are "numeric values considered to be protective of public health for pollutant concentrations in aquatic media,"[37] its action suggests that mercury concentrations in a substantial portion of fish consumed by U.S. residents may not be safe. Consumers may well react to this news by reducing fish consumption even though this could increase their health risks, especially for groups such as women beyond child-bearing age.[38] While the net effect of EPA's action on risk is an empirical question, the net benefits of cutting mercury emissions will be lowered to the extent that the public reduces its fish consumption. We ignore such behavioral changes because they are hard to forecast.

Second, we ignore distributional effects. While these are hard to assess, controlling mercury emissions from power plants may redistribute resources away from the poor because they are thought to be disproportionately affected by increases in energy costs. No conclusions about the distribution of net benefits by income level are possible,

---

[32] See U.S. Environmental Protection Agency (2001b, p. 1345).
[33] See U.S. Environmental Protection Agency (2001b, p. 1344).
[34] See U.S. Food and Drug Administration (1998).
[35] See U.S. Environmental Protection Agency (1999, Table 4-2).
[36] EPA does not report other points in the distribution. Species with mean values above EPA's criteria value are porgy, shark, and swordfish. See U.S. Environmental Protection Agency (2001a, p. 5-28). For maximum reported concentrations, see U.S. Environmental Protection Agency (1997, p. 4-63, Vol. IV).
[37] See U.S. Environmental Protection Agency (2001b, p. 1345).
[38] See Egeland et al. (1997).

however, because virtually nothing is known about the socioeconomic status of women who are highly exposed to mercury.

## 6. Policy Design

The legislative and regulatory initiatives issued to date are unlikely to lead to efficient mercury regulation for several general reasons. First, they all appear to be too stringent. Only very modest mercury controls would appear to make economic sense.

Second, the proposals would regulate the quantity of emissions, rather than the price, even though Weitzman's seminal insights suggest that quantity controls are inferior in this instance.[39] Weitzman assessed which class of policy instruments would generally provide higher expected social benefits when control costs are uncertain. He indicated that a price control (that is, an effluent charge) would have higher expected net social benefits if the marginal benefits curve were flatter than the marginal cost curve.

For mercury, the marginal benefits curve is likely to be very flat throughout the entire range of mercury emissions from utilities because such emissions contribute to only a small part of total exposure. Thus, even the elimination of mercury emissions from U.S. utilities would reduce human exposure by only 5 percent, as discussed above. Marginal control costs, on the other hand, are likely to rise very steeply over the interval of proposed emission reductions.[40] To limit the risk of unexpectedly high compliance costs, the efficient policy instrument would be a price-based one that limits cost increases and does not stipulate a specific, numerical emissions limit. Of course, hybrid policies are also possible.[41] Under a hybrid approach, the government would require that utilities have permits to emit mercury, allow utilities to trade permits, and also offer to supply unlimited permits at a given price that effectively caps economic costs. The legislative proposals, by focusing only on the quantity of emissions, do not control the risk of high compliance costs and so are less efficient than an alternative approach based on effluent charges.

Third, the recent legislative proposals are unlikely to ensure that mercury controls from all sources are cost-effective—that is, the marginal cost of avoiding environmental

[39] See Weitzman, M. L. (1974).
[40] This argument is very similar to one advanced by William Pizer in the context of climate change. See Pizer (1997).
[41] See Weitzman (1978) and Roberts and Spence (1976).

damages from mercury is equalized among different sources—because they cover only one of the several sources of mercury that are regulated. Lutter and Mader estimate that power plants in the United States will account for only 21 percent of mercury deposited in the United States by 2006.[42] This percentage is much less than the 70 percent of total emissions covered by EPA's sulfur dioxide permit trading program.[43] A cost-effective approach would entail equivalent emission limits or effluent charges in multiple sectors.

In addition to these general shortcomings, EPA's recent determination that regulation of mercury emissions from coal- and oil-fired electric utility steam generating units is "appropriate and necessary"[44] is unlikely to lead to efficient regulation for more specific reasons. First, EPA has invoked a section of the Clean Air Act that pays little attention to economics. Section 112(c) of the Clean Air Act directs EPA to establish emission standards equal to the maximum achievable control technology (MACT),[45] and the agency may not consider the benefits or the costs of more or less stringent standards when it develops its regulation. Second, EPA has applied the section in a manner that covers oil-fired plants as well as coal-fired plants, although oil-fired plants' mercury emissions will be approximately 0.2 percent of total power plant emissions.[46] Third, EPA will likely be unable to allow plants to trade emissions permits under the projected MACT standards; at least, no MACT regulation to date allows permit trading. Thus, EPA's regulation will not be economically sensible. Moreover, the ultimate status of EPA's regulation is in doubt because the Edison Electric Institute filed a petition with the court of appeals seeking a review of EPA's determination; in addition, the Utility Air Regulatory Group plans to file a petition with EPA asking the agency to reconsider its determination of December 2000.[47]

The legislative proposals and EPA's recent regulatory determination all seem to neglect established principles for economically sound regulation, although the Environmental Council of States has recently advocated scientifically sound, cost-

---

[42] See Lutter and Mader (2001, Appendix).
[43] See U.S. Environmental Protection Agency (1993, p. 3590).
[44] See U.S. Environmental Protection Agency (2000).
[45] Existing law defines MACT to be a technology capable of meeting emission levels achieved by the average of the best-performing 12 percent of sources. EPA may choose the pool of sources over which to define this average; See U.S. Environmental Protection Agency (2000).
[46] See U.S. Environmental Protection Agency (2000, p. 79,828).
[47] See Cook, 2001.

effective and flexible mercury reduction programs.[48] Instead of regulating so as to maximize net benefits—a principle articulated in executive orders on regulation signed by Presidents Reagan and Clinton[49]—these initiatives seem to adhere to a view that bioaccumulative, persistent toxics should be stringently regulated regardless of costs and benefits. Yet these labels merely point to pertinent analytic issues; they do not invalidate economic principles. The bioaccumulative nature of methylmercury means that its effects are most likely to appear at the top of the food chain. Persistence means that damages relate to the stock of past emissions or that ecological systems are slow to recover; yet because concentrations in various media are not rising and natural processes assimilate some mercury through burial in sediment and volatilization, the extent of persistence is best seen as an empirical question.[50] Finally, toxic health effects can be incorporated into a benefits analysis by considering these effects to be a risk that people strive to avoid. There is nothing about mercury that prevents an economically sound evaluation of alternative emission control policies.

Finally, international agreements to control mercury emissions may be appropriate because mercury pollution crosses international boundaries. Yet the effect of deep unilateral cuts in mercury emissions on the development of sensible international agreements on mercury emissions control policies is unclear. The United States and Canada agreed on a strategy for the virtual elimination of persistent toxic substances, including mercury, from the Great Lakes, without the United States having unilaterally adopted deep emissions cuts in advance.[51] The strategy is credited with spurring the development of a variety of control measures in the Great Lakes area. The United States may promote the development of economically sensible emission control measures in other countries as much by adopting relatively lax controls as by adopting stringent ones with costs disproportionately larger than expected benefits.

---

[48] See Environmental Council of States (2001).
[49] Presidential Executive Orders 12291 and 12866; see Reagan (1981) and Clinton (1993), respectively.
[50] EPA reports that mercury concentrations in mussels at a sample of 154 sites were unchanged in the period from 1986 to 1993. See EPA (2001a, p. 5-27). EPA notes "there are no clear temporal trends in tissue mercury concentrations in fish and shellfish over the past two decades." See EPA (2001a, p. 5-46). Poissant et al. (2000) reported that water-air exchanges contributed to atmospheric mercury buildup over water bodies.
[51] See U.S. Environmental Protection Agency (1999c).

## 7. Conclusions

Given current scientific understanding, the health and environmental benefits are very unlikely to provide an economic justification for the costs of stringent controls on mercury emissions. Available data suggest that cutting power plants' mercury emissions may reduce cases of subtle and mostly imperceptible neurological effects among children at a cost on the order of $150,000 per case avoided. Other health and environmental benefits appear negligible.

Current legislative and regulatory proposals also ignore the fact that effluent charges may be economically preferable to quantity restrictions for mercury reduction. A modest charge for mercury emissions or for coal combustion emitting mercury may make much more sense than the proposals issued to date.

Mercury-Related Declines as a Percent of the Standard Deviation
In Neurological Test Scores Among U.S. Children

| | Exposure Categories | | | | | |
|---|---|---|---|---|---|---|
| Level Of Exposure | 1 ppm to 2 ppm | | 2 ppm to 4 ppm | | > 4 ppm | |
| Average Exposure Within Exposure Category | 1.5 ppm | | 2.8 ppm | | 5.4 ppm | |
| Reductions in Children Exposed By Exposure Level | Low | High | Low | High | Low | High |
| | 5,000 | 6,000 | 1,200 | 1,500 | 300 | 1,500 |
| Finger Tapping | 3.9 | | 9.9 | | 16 | |
| Hand-Eye Coordination | 3.2 | | 8.1 | | 13 | |
| Reaction Time | 5.3 | | 14 | | 22 | |
| Boston Naming Test | 4.1 | | 11 | | 17 | |
| Long-Delay Recall of 12 Words | 3.2 | | 8.4 | | 14 | |
| McCarthy's Perceptual Performance Scale (when one child is excluded) | 1.6 | | 5.8 | | 14 | |

Note that the reductions in children exposed are based on Lutter and Mader's assumption that eliminating mercury emissions from U.S. power plants would reduce the number of highly exposed U.S. residents by 5 percent. See Lutter and Mader (2001).

## References


Bush, George W. September 29, 2000. “A Comprehensive National Energy Policy.” Speech given at Saginaw, Michigan.

Center for Food Safety and Applied Nutrition, Food and Drug Administration; the U.S. Environmental Protection Agency; National Energy Technology Laboratory, Department of Energy; National Marine Fisheries Laboratory, National Oceanic and Atmospheric Administration; National Center for Health Statistics, National Center for Environmental Health, Centers for Disease Control. 2001. “Blood and Hair Mercury Levels in Young Children and Women of Childbearing Age—United States, 1999”. *Mortality and Morbidity Weekly Report.* 50, no. 8. pp. 140-143.

Clinton, William. September 30, 1993. “Executive Order 12866: Regulatory Planning and Review.” *Public Papers of the Presidents.* Washington, D.C.: Government Printing Office.

Cook, Steve. 2001. “Electric Utilities Challenge Decision by EPA to Regulate Mercury Emissions.” Regulation, Law and Economics. Washington, DC: Bureau of National Affairs, Inc.

Davidson, Philip, Gary Myers, Christopher Cox, Catherine Axtell, Conrad Shamlaye, Jean Sloane-Reeves, Elsa Cernichiari, Larry Needham, Anna Choi, Yining Wang, Maths Berlin, Thomas Clarkson. 1998. “Effects of Prenatal and Postnatal MeHg Exposure From Fish Consumption on Neurodevelopment: Outcomes at 66 Months of Age in the Seychelles Child Development Study.” *Journal of the American Medical Association.* 280, pp. 701-707.

Davis, Everett. 1975. “Concurrent Validity of the McCarthy Scales of Children’s Abilities.” *Measurement and Evaluation in Guidance* 8, no. 2, pp. 101-104.

Egeland, Grace and John Middaugh. 1997. “Balancing Fish Consumption Benefits With Mercury Exposure.” *Science.* 278, No. 5345, pp1904-1905.

Ehrlich, Isaac, and Gary Becker. 1972. "Market Insurance, Self-Insurance, and Self-Protection." *Journal of Political Economy* 80, pp. 623-48.

Environmental Council of States. February 27, 2001. “Need for Articulation of a National Vision for Mercury.” Resolution Number 01-1.

Florida Fish and Wildlife Conservation Commission. 2000. “Florida Panther Net”. <http://www.panther.state.fl.us/panther/handbook/threats/index.html>.

ICF Consulting. 2000. "Mercury Control Cost Calculations: Assumptions, Approach, and Results, EPA Contract No. 68-D7-0081, Task 011, Subtask 02". September 30, 2000.

Kinjo, Y., S. Akiba, N. Yamaguchi, S. Mizuno, S. Watanabe, J. Wakamiya, M. Futatsuka, and H. Kato. 1996. "Cancer Mortality in Minamata Disease Patients Exposed to Methylmercury Through Fish Diet". *Journal of Epidemiology.* 6, No. 3, pp. 134-138.

Lutter, Randall, and Elizabeth Mader. 2001. *Health Risks From Mercury-Contaminated Fish: A Reassessment.* Washington, D.C.: AEI-Brookings Joint Center for Regulatory Studies. Manuscript.

Mason, Robert P., John R. Reinfelder, and Francois M. Morel. 1996. "Uptake, Toxicity, and Trophic Transfer of Mercury in a Coastal Diatom", *Environmental Science & Technology* 30, 6.

Massoth, N. 1985. "The McCarthy Scales of Children's Abilities as a Predictor of Achievement: A Five Year Follow-up." *Psychology in the Schools* 22, pp. 10-13.

Myers, G., P. Davidson, D. Palumbo, C. Shamlaye, C. Cox, E. Cernichiari, T. Clarkson. 2000. "Secondary Analysis From The Seychelles Child Development Study: The Child Behavior Checklist." *Environmental Research* 84, no. 1, pp. 12-19.

Nagle, Richard J. 1979. "The McCarthy Scales of Children's Abilities: Research Implications for the Assessment of Young Children." *School Psychology Digest* 8, no. 3, pp. 319-326.

National Research Council. 2000. *Toxicological Effects of MeHg.* Committee on the Toxicological Effects of MeHg, Board on Environmental Studies and Toxicology, Commission on Life Sciences, National Research Council. National Academy Press. Washington D.C.

Pizer, William. 1997. "Prices and Quantities Revisited: The Case of Climate Change". Resources for the Future. Working Paper 98-02. At www.rff.org.

Poissant, Laurier, Marc Amyot, Martin Pilote, and David Lean. 2000. "Mercury Water-Air Exchange Over The Upper St. Lawrence River And Lake Ontario". *Environmental Science &Technology.* 34, no. 15, p. 3069.

Princiotta, Frank. 2000. "Control of Mercury Emissions from Coal-fired Utility Boilers". Memo from Director of Air Pollution Prevention and Control Division, to John Seitz, Director, Office of Air Quality Planning and Standards (MD-10), EPA, October 25, 2000.

Reagan, Ronald. February 17, 1981. "Executive Order 12291: Federal Regulation." *Public Papers of the Presidents.* Washington, D.C.: Government Printing Office.

Renner, Rebecca. 1999. "Consensus On Health Risks From Mercury Exposure Eludes Federal Agencies." *Environmental Science & Technology* 33, no. 13, p. 269A.

Roberts, M. J. and M. Spence. 1976. "Effluent Charges and Licenses Under Uncertainty". *Journal of Environmental Economics and Management* 5, pp. 193–208.

Salonen, Jukka, K. Seppanen, K. Nyyssonen, H. Korpela, J. Kauhanen, M. Kantola, J. Tuomilehto, H. Esterbauer, F. Tatzber, R. Salonen. 1995. "Intake of Mercury from Fish, Lipid Peroxidation, and the Risk of Myocardial Infarction and Coronary, Cardiovascular and Any Death in Eastern Finnish Men. *Circulation.* Vol 91, No. 3, 645-655.

Sauer, J. R., J. E. Hines, I. Thomas, J. Fallon, and G. Gough. 2000. *The North American Breeding Bird Survey, Results and Analysis 1966 - 1999. Version 98.1, USGS Patuxent Wildlife Research Center,* Laurel, MD, at http://159.189.24.4/bbs/bbs.html

Shogren, Jason, and Thomas D. Crocker. 1999. "Risk and its Consequences." *Journal of Environmental Economics and Management* 37, no. 1, pp.44-51.

U.S. Environmental Protection Agency. 1993. "Acid Rain Program: General Provisions and Permits, Allowances System, Continuous Emissions Monitoring, Excess Emissions and Administrative Appeals." *Federal Register* 58, no. 6, p. 3590.

U.S. Environmental Protection Agency. 1997. *Mercury Study Report to Congress, Volumes I to VIII*. EPA-452/R-97-003. Washington, D.C.: U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency. 1999a. *Analysis of Emissions Reduction Options for the Electric Power Industry*. Washington, D.C.: U.S. Environmental Protection Agency, Office of Air and Radiation.

U.S. Environmental Protection Agency. 1999b. *Mercury Update: Impact on Fish Advisories*. Washington, D.C.: U.S. Environmental Protection Agency. EPA-823-F-99-016.

U.S. Environmental Protection Agency. 1999c. *United States Response to Recommendations in the International Joint Commission's Ninth Biennial Report on Great Lakes Water Quality.* U.S. Department of State and U.S. Environmental Protection Agency Great Lakes National Program Office - Chicago, Illinois.

U.S. Environmental Protection Agency. 2000. “Regulatory Finding on the Emissions of Hazardous Air Pollutants from Electric Utility Steam Generating Units”. *Federal Register*, Vol. 65, No. 245, pp. 79825-79831.

U.S. Environmental Protection Agency. 2001a. *Water Quality Criteria for Methylmercury: Criteria Document.* EPA Office of Water, Water Quality Criteria and Standards. Taken from http://www.epa.gov/waterscience/criteria/methylmercury/document.html on January 11, 2001. Document dated January 3, 2001.

U.S. Environmental Protection Agency. 2001b. “Water Quality Criteria: Notice of Availability of Water Quality Criterion for the Protection of Human Health: Methylmercury”. *Federal Register.* Vol. 66, No. 5, January 8, 2001. pp 1344-1359.

U.S. Environmental Protection Agency. 2001c. “EPA National Advice on Mercury in Freshwater Fish for Women Who Are or May Become Pregnant, Nursing Mothers, and Young Children”. EPA Office of Water. Taken from http://www.epa.gov/ost/fishadvice/advice.html on January 16, 2001. Document dated January 12 2001.

U.S. Food and Drug Administration. 1998. Industry Activities Staff Booklet: Action Levels For Poisonous Or Deleterious Substances In Human Food And Animal Feed. Taken from http://vm.cfsan.fda.gov/~lrd/fdaact.html on January 12, 2001. Document dated March 1998.

U.S. Food and Drug Administration. January 16, 2001. ”An Important Message For Pregnant Women And Women Of Childbearing Age Who May Become Pregnant About The Risks Of Mercury In Fish”. Center for Food Safety and Applied Nutrition, U.S. Food and Drug Administration, Consumer Advisory.

U.S. Geological Survey. 1999. *Mercury in the Geochemical Cycle and Food Chain of the Everglades*. Taken from http://sofia.usgs.gov/publications/fs/166-96/printfood.html on March 19, 2000. Last updated: November 12, 1999.

U.S. Geological Survey. 2000a. “*Can Control of Local Sources Reduce the Risks?”* Taken from http://sflwww.er.usgs.gov/sfrsf/rooms/mercury/control/ on September 18, 2000. South Florida Information Access. South Florida Restoration Science Forum. Last updated July 5, 2000.

U.S. Geological Survey. 2000b. *Interactions of Mercury with Dissolved Organic Carbon in the Florida Everglades*. Taken from http://sofia.usgs.gov/projects/merc_carbon/index.html on March 19, 2000. Last updated: March 3, 2000.

Weitzman, M. L. 1974. “Prices Vs. Quantities.” *Review of Economic Studies* 41, no. 4, pp. 477–491.

Weitzman, M. L. 1978. “Optimal Rewards For Economic Regulation.” *American Economic Review* 68, no. 4, pp. 683–691.